PhD Diary

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Part I

2023

Chapter 1

November

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1.1.1 AOSP

Zygote

Zygote initializes by pre-loading the entire Android framework. Unlike desktop Java, it does not load the libraries lazily; it loads all of them as part of system start up. After completely initializing, it enters a tight loop, waiting for connections to a socket. When the system needs to create a new application, it connects to the Zygote socket and sends a small packet describing the application to be started. Zygote clones itself, creating a new kernel-level process.

Memory is organized into uniformly sized **pages**. When the application refers to memory at a particular address, the device hardware reinterprets the address as an index into a **page table**. Newly cloned Zygote processes for newly started applications are simply clone of Zygote's page table, pointing to the exact same pages of physical memory. Only the pages the new application uses for its own purposes are not shared:

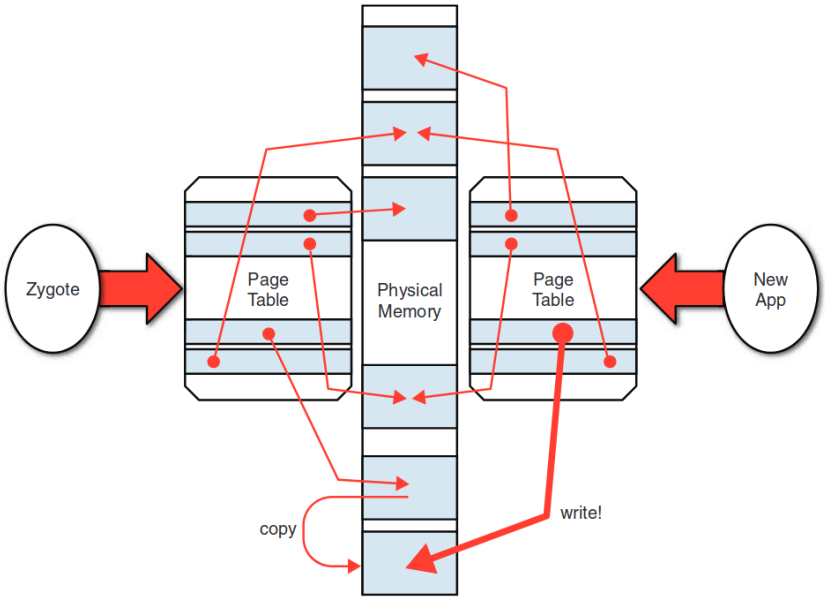


Figure 1.1: Zygote Copy-on Write

Zygote Initialization

Zygote is started by `init`. `ro.zygote` system variable set at platform build time decides which of four types of Zygotes are started and which one is "primary". Both the `init` and Zygote scripts are stored inside `$AOSP/system/core/rootdir`. In the following `init.zygote64_32.rc`, 2 Zygote processes, primary and secondary, are started at 2 different sockets:

```
1  service zygote /system/bin/app_process64 -Xzygote \
2          /system/bin --zygote --start-system-server --socket-name=zygote
3      class main
4      priority -20
5      user root
6      group root readproc reserved_disk
7      socket zygote stream 660 root system
8      socket usap_pool_primary stream 660 root system
9      onrestart exec_background - system system -- /system/bin/vdc volume abort_fuse
10     onrestart write /sys/power/state on
11     onrestart restart audioserver
12     onrestart restart cameraserver
13     onrestart restart media
14     onrestart restart media.tuner
15     onrestart restart netd
16     onrestart restart wificond
17     task_profiles ProcessCapacityHigh MaxPerformance
18     critical window=${zygote.critical_window.minute:-off} target=zygote-fatal
19
20 service zygote_secondary /system/bin/app_process32 -Xzygote \
21         /system/bin --zygote --socket-name=zygote_secondary --enable-lazy-preload
22     class main
```

```
23      priority -20
24      user root
25      group root readproc reserved_disk
26      socket zygote_secondary stream 660 root system
27      socket usap_pool_secondary stream 660 root system
28      onrestart restart zygote
29      task_profiles ProcessCapacityHigh MaxPerformance
30      disabled
```

The actual application that is started as user root at the very highest priority by `init` is `/system/bin/app_process64`. The script requests that `init` create a stream socket for the process and catalog it as `/dev/socket/zygote_secondary` which will be used by the system to start new Android applications.

Zygote is only started once during the system startup, by `app_process64` and `app_process32`, and is simply cloned to start subsequent applications. Zygote initialization sequence is described below:

Method	Description	Source
`init.rc`	Imports the `init.zygote64_32.rc` that contains the script that starts Zygote service.	`$AOSP/system/core/rootdir`
`init.zygote64_32.rc`	Runs `app_process64` and `app_process32` which will initialize the starting of Zygote service.	`$AOSP/system/core/rootdir`
`app_process`	Creates `AppRuntime`, a subclass of `AndroidRuntime`, that does bookkeeping, naming the process, setting up parameter, and the name of the class to run when not running Zygote, and then calls `AndroidRuntime.start()` to invoke the runtime.	`$AOSP/frameworks/base/cmds/app_process`
`AppRuntime::start`	Invokes `startVM` which invokes `JNI_CreateJavaVM`.	`AOSP/frameworks/base/core/jni/AndroidRuntime.cpp`
`JNI_CreateJavaVM`	Calls `Runtime::Create`.	`$AOSP/art/runtime/jni/java_vm_ext.cc`
`Runtime::Create`	Initializes the ART runtime, loading the system OAT files and the libraries they contain.	`$AOSP/art/runtime/runtime.cc`

Table 1.1: Zygote Initialization Sequence

The argument that `app_process` passed to `start` is `com.android.internal.os.Zygote.Init`, the source for which is in `$AOSP/frameworks/base/core/java/com/android/inter-`

nal/os/ZygoteInit.java. app_process is the launcher for all Java programs (not apps!) in the Android system, and Zygote is one example of the programs (system service) to be launched.

Zygote System Service

Zygote has 3 major tasks, on startup:

1. Register the socket to which the system will connect to start new application. Handled by registerServerSocket method which creates socket using the named passed as parameter for init script.
2. Preload Android resources (classes, libraries, resources and even WebViews) with a call to preload method. After preload is finished, Zygote is fully initialized and ready to clone to new applications very quickly.
3. Start Android System Server. Thus, SystemServer is the first application to be cloned by Zygote.

After it has completed these three tasks, it enters a loop, waiting for connections to the socket.

1.1.2 C++ Primer

Primitive Built-in Types

Includes **arithmetic types** and a special type named **void** which has no associated values and can be used in only a few circumstances, most commonly as the return type for functions that do not return a value.

The arithmetic types are divided into two categories: **integral types** (which include character and boolean types) and floating-point types.

Type	Meaning	Minimum Size
bool	boolean (true or false)	NA
char	character	8 bits
w_char_t	wide character	16 bits
char16_t	Unicode character	16 bits
char32_t	Unicode character	32 bits
short	short integer	16 bits
int	integer	16 bits
long	long integer	32 bits
long long	long integer	64 bits
float	single-precision floating-point	6 significant digits

`double`	double-precision floating-point	10 significant digits
`long double`	extended-precision floating-point	10 significant digits

Table 1.2: Zygote Initialization Sequence

Except for `bool` and extended character types, the integral types may be **signed** (can represent negative or positive numbers) or **unsigned**. By default, `int`, `short`, `long`, `long long` are all signed. To declare unsigned type, prepend `unsigned` to the type. `char` is signed on some machine and `unsigned` on others, and `unsigned int` is abbreviated as `unsigned`.

Conversions happen automatically when we use an object of one type where an object of another type is expected.

```
1 unsigned u = 10;
2 int i = -42;
3 std::cout << i + i << std::endl; // prints -84
4 std::cout << u + i << std::endl; // if 32-bit ints, prints 4294967264
```

In the above snippet, converting a negative number to `unsigned` will cause the value to "wrap around" because `unsigned` values can never be less than 0. Thus, extra care should be taken if we want to write loops with `unsigned` values and stopping conditions at negative values like the snippet below:

```
1 // WRONG: u can never be less than 0; the condition will always succeed
2 for (unsigned u = 10; u >= 0; --u)
3     std::cout << u << std::endl;
```

As such it is always advisable to not mix `signed` and `unsigned` types. By default, integer literals (`42`) are signed, while octal (`024`) and hexadecimal (`0x14`) may be signed or unsigned.

Escape sequences are used as if they were single characters:

```
1 std::cout << '\n'; // prints a newline
2 std::cout << "\tHi!\n"; // prints a tab followd by "Hi!" and a newline
```

Variables

Initialization is not assignment. Initialization happens when a variable is given a value when it is created. Assignment obliterates an object's current value and replaces that value with a new one.

Four different ways to initialize:

```
1 int units_sold = 0;
2 int units_sold = {0}; // list initialization; does not work for built-in types if
      data loss is likely
3 int units_sold{0};
4 int units_sold(0);
```

Variables defined outside any function body are initialized to zero by default. Variables of built-in type defined inside a function are **uninitialized** and therefore undefined. Objects of class type that we do not explicitly initialize have a value that is defined by the class.

A **declaration** makes a name known to the program. A file that wants to use a name defined elsewhere includes a declaration for that name. A **definition** creates the associated entity. A definition involves declaration, allocates storage and may provide the variable with an initial value.

```
1 extern int i;   // declares but not define j
2 int j;          // declares and defines j
3 int k = 12;     // declares, defines and initializes j
4 extern double pi = 3.14;     // definition
```

Variables must be defined only once but can be declared several times. To use a variable in more than one file requires declarations that are separate from the variable's definition. To use the same variable in multiple files, we must define that in one - and only one - file. Other files that use that variable must declara - but not define - that variable.

1.2 November 15, 2023

1.2.1 C++ Primer

Scopes of Names

Most scopes in C++ are delimited by curly braces.

```
1  #include <iostream>
2  int main() {
3      int sum = 0;
4      // sum values from 1 through 10 inclusive
5      for (int val = 1; val <= 10; ++val)
6          sum += val; // equivalent to sum=sum+val
7      std::cout << "Sum␣of␣1␣to␣10␣inclusive␣is␣"
8          << sum << std::endl;
9      return 0;
10 }
```

In above program, `main` - like most names defined outside a function - has **global scope** and thus, is accessible throughout the program. `sum` has **block scope** and is accessible from its point of declaration throughout the rest of the `main` function. `val` is defined in the scope of the `for` statement and can be used in that statement but not elsewhere in `main`.

Names declared in the outer scope can also be redefined in an inner scope although it is always a bad idea:

```
1 #include <iostream>
2 // Program for illustration purposes only: It is bad style for a function
```

```
// to use a global variable and also define a local variable with the same name
int reused = 42; // reused has global scope
int main() {
    int unique = 0; // unique has block scope

    // output #1: uses global reused;prints 42 0
    std::cout << reused << " " << unique << std::endl;

    int reused = 0; // new, local object named reused hides global reused
    // output #2: uses local reused; prints 0 0
    std::cout << reused << " " << unique << std::endl;

    // output #3: explicitly requests the global reused; prints 42 0
    std::cout << ::reused << " " << unique << std::endl;

    return 0;
}
```

When the scope operator (`::` **operator**) has an empty LHS, it is a request to fetch the name on the RHS from the global scope.

References

A **reference** defines an alternative name for an object. A reference type can be defined by writing a declarator of the form `&d` where `d` is the name being declared:

```
int ival = 1024;
int &refVal = ival; // refVal refers to (is another name for) ival
int &refVal2; // error: a reference must be initialized
```

When we define a reference, instead of copying the initializer's value, we bind the reference to its initializer. Once initialized, a reference remains bound to its initial object. There is no way to rebind a reference to refer to a different object. Because there is no way to rebind a reference, references must be initialized.

A reference is not an object. Instead, a reference is just another name for an already existing object. Thus, *all* operation on that reference are actually operations on the object to which the reference is bound:

```
refVal = 2; // assigns 2 to the object to which refVal refers, i.e., to ival
int ii = refVal; // same as ii=ival
```

Becuase references are not objects, we may not define a reference to a reference. We can define references in a single definition with each identifier that is a reference being preceded by the `&` symbol:

```
int i = 1024, i2 = 2048; // i and i2 are both ints
int &r = i, r2 = i2; // r is a reference bound to i; r2is an int
int i3 = 1024, &ri = i3; // i3 is an int; riis a reference bound to i3
int &r3 = i3, &r4 = i2; // both r3and r4are references
```

Pointers

Like references, pointers are used for indirect access to other objects. Unlike a reference, a pointer is an object in its own right. Pointers can be assigned and copied; a single pointer can point to several different objects over its lifetime. Unlike a reference, a pointer need not be initialized at the time it is defined. Like other built-in types, pointers defined at block scope have undefined value if they are not initialized.

We define a pointer type by writing a declarator of the form *d,whered is the name being defined. The * must be repeated for each pointer variable:

```
int *ip1, *ip2; // both ip1 and ip2 are pointers to int
double dp, *dp2; // dp2 is a pointer to double; dp is a double
```

A pointer holds the address of another object. We get the address of an object by using the address-of operator (& **operator**):

```
int ival = 42;
int *p = &ival; // p holds the address of ival; p is a pointer to ival

double dval;
double *pd = &dval; // ok: initializer is the address of a double
double *pd2 = pd; // ok: initializer is a pointer to double
int *pi = pd; // error: types of pi and pd differ
pi = &dval; // error: assigning the address of a doubletoapointertoint
```

We can use the dereference operator (* **operator**) to access that object:

```
int ival = 42;
int *p = &ival; // p holds the address of ival; p is a pointer to ival
cout << *p; // * yields the object to which p points; prints 42

*p = 0; // * yields the object; we assign a new value to ival through p
cout << *p; // prints 0
```

When we assign to *p, we are assigning to the object to which p points. We may dereference only a valid pointer that points to an object.

void* is a special pointer type that can hold the address of any object. Its useful for when the type of the object at that address is unknown:

```
double obj = 3.14, *pd = &obj; // ok: void*can hold the address value of any data
    pointer type
void *pv = &obj; // objcan be an object of any type
pv = pd; // pvcan hold a pointer to any type
```

The modifiers * and & do not apply to all variables defined in a single statement:

```
int* p1, p2; // p1 is a pointer to int; p2is an int
int *p1, *p2; // both p1and p2are pointers to int
```

As pointers are objects in memory, they also have addresses of their own. Therefore, we can store the address of a pointer in another pointer:

```
int ival = 1024;
int *pi = &ival; // pi points to an int
int **ppi = &pi; // ppi points to a pointer to an int
```

We indicate each pointer level by its own *. Dereferencing a pointer to a pointer yields the pointer. So in this case, you must dereference twice to access the underlying object.

1.2.2 AOSP

Starting Android System Server and Other Apps using Zygote

During its initialization, Zygote will check for `start-system-server` flag, and if set, will bring up `SystemServer` in the following sequence:

Method	Description	Source
`ZygoteInit.forkSystemServer`	Runs after the Zygote process has been initialized. It is hardcoded with System Server classpath[1] as one of the arguments to call `Zygote.forkSystemServer` to spawn `SystemServer` process.	`AOSP/framework/base/core/java/com/android/internal/os/ZygoteInit.java`
`Zygote.forkSystemServer`	`Zygote` class wraps native methods that communicate with Android Runtime, one of whom is `com_android_internal_os_nativeForkSystemServer`.	`AOSP/framework/base/core/java/com/android/internal/os/Zygote.java`
`com_android_internal_os_native_ForkSystemServer`	Calls `zygote::ForkCommon` and `SpecializeCommon` which does the actual forking.	`AOSP/frameworks/base/core/jni/com_android_internal_os_Zygote.cpp`
`SpecializeCommon`	Looks at the flags and Process ID for setting up sandboxing, configuring the correct SE Linux context, and process capabilities. Afterwards, it will call `Zygote` methods for post-fork procedures.	`AOSP/frameworks/base/core/jni/com_android_internal_os_Zygote.cpp`
`Zygote.callPostForkSystemServerHooks`	Calls `ZygoteHooks.java` at the end of specialization procedures. Only applicable for `SystemSever`.	`AOSP/framework/base/core/java/com/android/internal/os/Zygote.java`

[1] `com.android.server.SystemServer`, the source for which is stored in `AOSP/frameworks/base/services/java/com/android/server/SystemServer.java`.

Method	Description	Source
`Zygote.callPostForkChildHooks`	Calls `ZygoteHooks.java` at the end of specialization procedures. Applicable to all applications and services including `SystemServer`	`AOSP/framework/base/core/java/com/android/internal/os/Zygote.java`
`ZygoteHooks.postForkSystemServer` and `ZygoteHooks.postForkSystemServer`	Wrappers for `ZygoteHooks` inside the Android Runtime. They call their respective native code inside the ART via Java Native Interface.	`AOSP/libcore/dalvik/src/main/java/dalvik/system/ZygoteHooks.java`
`ZygoteHooks_nativePostForkSystemServer`	Loads the specialized class libraries to start the the System Server.	`AOSP/art/runtime/native/dalvik_system_ZygoteHooks.cc`
`ZygoteHooks_nativePostForkChild`	Loads the specialized class libraries to start the service/application.	`AOSP/art/runtime/native/dalvik_system_ZygoteHooks.cc`
`handleSystemServerProcess`	The control returns to `ZygoteInit`, and finish remaining work for the newly forked system server process, and calls `ZygoteInit.zygoteInit`.	`AOSP/framework/base/core/java/com/android/internal/os/ZygoteInit.java`
`ZygoteInit.zygoteInit`	The main function called when started through the zygote process, which calls `RuntimeInit.applicationInit`	`AOSP/framework/base/core/java/com/android/internal/os/ZygoteInit.java`
`RuntimeInit.applicationInit`	Calls the `public static void main` method of the application	`AOSP/framework/base/core/java/com/android/internal/os/RuntimeInit.java`
`ZygoteServer.runSelectLoop`	After forking has finished, the control enters `ZygoteServer` which starts an endless loop that handles incoming connections with `ZygoteConnection.processCommand`.	`AOSP/framework/base/core/java/com/android/internal/os/ZygoteServer.java`
`ZygoteConnection.processCommand`	Calls `Zygote.forkAndSpecialize` which is a version of `ZygoteInit.forkSystemServer` for the masses.	`AOSP/framework/base/core/java/com/android/internal/os/ZygoteConnection.java`
`Zygote.forkAndSpecialize`	A version of `Zygote.forkSystemServer` for the masses.	`AOSP/frameworks/base/core/jni/com_android_internal_os_Zygote.cpp`

Method	Description	Source
`com_android_internal_os_native_ForkAndSpecialize`	Calls `zygote::ForkCommon` and `SpecializeCommon` which does the actual forking, and returns to `ZygoteInit` and immediately enters `ZygoteServer`.	`AOSP/frameworks/base/core/jni/com_android_internal_os_Zygote.cpp`

Table 1.3: System Server and Applications Initialization Sequence

1.3 November 17, 2023

1.3.1 AOSP Hardware Abstraction Layer

The interface to the hardware is a device drivers which are usually device specific and sometimes proprietary. A single set of C header files describes the functionality that a HAL provides to the Android system. HAL Code for a particular device is the implementation of the API defined by those header files, so that no code above the HAL needs to be changed to port Android to use the new device.

HAL Code Structure

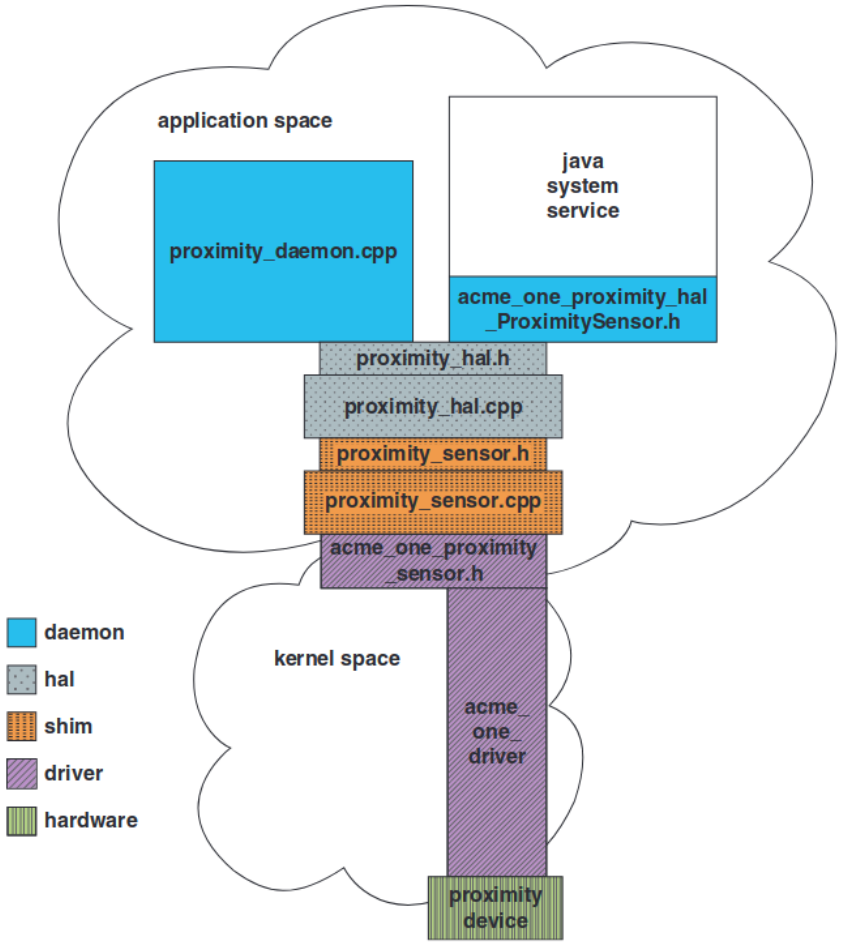


Figure 1.2: HAL Layer Structure

The code consists of four functional components as show in Figure 1.2:

1. **HAL code (dotted boxes):** Abstraction that separates the capabilities of hardware from its specific implementations. The `.h` file defines the HAL interface, and the implementation (`.cpp` file) specializes the Android HAL API for the target hardware.

2. **Shim code (dashed boxes):** Glue code that connects the HAL to a specific device hardware/driver. This code adapts the Android HAL API to the device driver for the hardware.

3. **Daemon (blue):** Stand-alone application that interacts with the hardware through the HAL.

4. **Java System Service (white):** System Service that Android applications will use to access the custom hardware.

The source for those components are structured like in the directory tree below:

```
one
├── app
├── native_daemon
│   └── ...
├── java_daemon
│   └── ...
└── proximity
    ├── include
    │   ├── dev
    │   │   └── ...
    │   └── ...
    ├── dev
    │   └── ...
    ├── hal
    │   └── ...
    └── jni
        └── ...
```

where `one` is the device folder of the AOSP project. All the code implementing the HAL for the proximity sensors goes into a new subdirectory `proximity`.[2]

1.4 November 18, 2023

1.4.1 Configuring AOSP for Acme Device on Ubuntu 23

Repo Manifest

Top-level subdirectory named `.repo` contains the `manifests` repository inside `manifests` subdirectory. The `manifests` repo contain one or more manifest files named as the argument of the `-m` command line option. `.repo/manifest` file controls the structure of the rest of the repository, and includes `.repo/manifests/default.xml`[3] which is a list of git repositories. `repo` program parses `manifest.xml`, and thus `default.xml`, and clone each repository into a location specfied inside `default.xml`.

[2] To be a "real" HAL, the interface `proxmity/include/proximity_hal.h` would have to be promoted from its current directory specifically for the One device, up into the Android source tree to a location that would make it visible to other code that needed to use it. Here, it is only shared by Acme devices, so it is put under the subdirectory of the Acme device directory. If it's visible across device from multiple vendors, it might be promoted into the `device` directory itself.

[3] `https://gerrit.googlesource.com/git-repo/+/master/docs/manifest-format.md`

Each `project` element in the XML identifies a git repository by its `name`, relative to some base URL, its `remote`; and where that repository should be placed in the local workspace, its `path`. If the full URL for the repository is not specified, repo will use the default remote specified in the `default` element near the top of the manifest:

```
<default revision="refs/tags/android-13.0.0_r11"
    remote="aosp"
    sync-j="4" />
```

where the remote, `aosp`, is defined likewise in the top of of the `default.xml`:

```
<remote  name="aosp"
    fetch=".."
    review="https://android-review.googlesource.com/" />
```

Instead of including a URL as its attribute, it includes the `fetch` attribute which indicatese the URL for this remote should be derived from the URL used to initialize the workspace (the argument to the `-u` option).

```
git ls-remote -h https://android.googlesource.com/platform/manifest.git
repo init -u https://android.googlesource.com/platform/manifest -b android-10.0.0
    _r33
git config --global user.email "mg.weiminn@gmail.com"
git config --global user.name "weiminn"
repo init -u https://android.googlesource.com/platform/manifest -b android-10.0.0
    _r33
repo sync -j31
source build/envsetup.sh
lunch sdk_phone_x86_64-userdebug
make -j31
```

Ubuntu 23 does not have the repository for `libncurses5` because they already have `libncurses6`, so you have to add old `focal` repository to your `/etc/apt/sources.list`:

```
deb http://security.ubuntu.com/ubuntu focal-security main universe
```

After including the old repo, update the repository index and install `libncurses5`:

```
sudo apt update
sudo apt install libncurses5
```

1.5 November 19, 2023

1.5.1 Building AOSP HAL

Implementing the HAL

Device driver and its API are usually provided by a third-party hardware provider. Shim code include `.h` files for one or more device drivers.

New devices can communicate with the processor via USB which is popular. Even without driver, the device can be accessed with generic USB commands. *libusb*[4] is

[4] `https://libusb.info`

a portable, user-mode, and USB-version agnostic library for using USB devices, and supports Android. If the device has a driver, it is likely to be a specialization of the USB command.

```
#ifndef PROXIMITY_HAL_H
#define PROXIMITY_HAL_H

#include <hardware/hardware.h>

#define ACME_PROXIMITY_SENSOR_MODULE "libproximityhal"

typedef struct proximity_sensor_device proximity_sensor_device_t;

struct value_range {
    int min; int range;
};

typedef struct proximity_params {
    struct value_range precision;
    struct value_range proximity;
}

proximity_params_t;

struct proximity_sensor_device { hw_device_t common;
    int fd;
    proximity_params_t params;
    int (*poll_sensor)(proximity_sensor_device_t *dev, int precision);
}; #endif // PROXIMITY_HAL_H
```

1.6 November 20, 2023

1.6.1 `const` Qualifier

When we have variables whose value we know cannot be changed, and We want to prevent code from inadvertently giving a new value to the variable, we define the variable's type as `const`:

```
const int bufSize = 512; // input buffer size
bufSize = 512; // error: attempt to write to const object
```

Because we can't change the value of a const object after we create it, it must be initialized:

```
const int i = get_size(); // ok: initialized at run time
const int j = 42; // ok: initialized at compile time
const int k; // error: k is uninitialized const
```

`const` is Local to the File

When a `const` object is initialized from a compile-time constant as in:

```
const int bufSize = 512;
```

the compiler will usually replace uses of the variable with its corresponding value during compilation. Thus, when we split a program to multiple files, every file that uses that `const` must have a access to its initializer. In order to see the initializer, the variable must be defined in every file that wants to use the variable's value. To support this, we define the `const` in one file, and declare it in other files that use that object.

```
1 // file_1.cc defines and initializes a const that is accessible to other files
2 extern const int bufSize = fcn();
3
4 // file_1.h
5 extern const int bufSize; // same bufSize as defined in file_1.cc
```

Because `bufSize` is `const`, we must specify `extern` in order for `bufSize` to be used in other files. `extern` signifies that `bufSize` is not local to this file and that its definition will occur elsewhere.

References to `const`

Unlike an ordinary reference, a reference to `const` cannot be used to change the object to which the reference is bound:

```
1 const int ci = 1024;
2 const int &r1 = ci; // ok: both reference and underlying object are const
3 r1 = 42; // error: r1is a reference to const int &r2 =
4 ci; // error: nonconstreference to a constobject
```

We can bind a reference to a `const` to a nonconst object, literals, or a more general expression:

```
1 int i = 42;
2 const int &r1 = i; // we can bind a const int& to a plain int object
3 const int &r2 = 42; // ok: r1 is a reference to const
4 const int &r3 = r1 * 2; // ok: r3 is a reference to
5 const int &r4 = r * 2; // error: r4is a plain, nonconst reference
```

It is important to realize that a reference to `const` restricts only what we can do through that reference. Binding a reference to `const` to an object says nothing about whether the underlying object itself is `const`.

Pointers and `const`

Like a reference to `const`, a pointer to `const` may not be used to change the object to which the pointer points. We may store the address of a `const` object only in a pointer to `const`, where we can modify the pointer itself (change the reference stored inside) but not the object (value) pointed to:

```
1 const double pi = 3.14; // pi is const; its value may not be changed
2 double *ptr = &pi; // error: ptr is a plain pointer
3 const double *cptr = &pi; // ok: cptr may point to a double that is const
4 *cptr = 42; // error: cannot assign to *cptr
```

Like a reference to const, a pointer to const says nothing about whether the object to which the pointer points is const, that there is no guarantee that an object pointed to by a pointer to const won't change.

We can have a pointer that is itself const, and the address it holds cannot by changed. We indicate that the pointer is const by putting the const by the const:

```
int errNumb = 0;
int *const curErr = &errNumb; // curErr will always point to errNumb
const double pi = 3.14159;
const double *const pip = &pi; // pip is a constpointer to a const object

*pip = 2.72; // error: pip is a pointer to const  and cannot be changed as the
    pointer is const
// if the object to which curErrpoints (i.e., errNumb) is nonzero
if (*curErr) {
    errorHandler();
    *curErr = 0; // ok: reset the value of the object to which curErr is bound
        because errNumb is not const
}
```

Constant Expressions

A constant expression is an expression whose value cannot change and that can be evaluated at compile time. A literal is a constant expression. A const object that is initialized from a constant expression is also a constant expression:

```
const int max_files = 20; // max_files is a constant expression
const int limit = max_files + 1; // limit is a constant expression
int staff_size = 27; // staff_size is not a constant expression
const int sz = get_size(); // sz is not a constant expression
```

Although staff_size is initialized from a literal, it is not a constant expression because it is a plain int, not a constint. Even though sz is a const, the value of its initializer is not known until run time, and thus, sz is not a constant expression.

We can ask the compiler to verify that a variable is a constant expression by declaring the variable in a constexpr declaration. Variables declared as constexpr are implicitly const and must be initiated by constant expressions:

```
constexpr int mf = 20; // 20 is a constant expression
constexpr int limit = mf + 1; // mf+1 is a constant expression
constexpr int sz = size(); // ok only if size is a constexpr function
```

Because a constant expression is one that can be evaluated at compile time, only literal types (arithmetic, reference, and pointer) types can be defined as constant expressions. Custom classes, library IO and string types are not literal types. We can point (or bind) to an object that remains at a fixed address.

constexpr declaration applies to the pointer, not the type to which the pointer points:

```
const int *p = nullptr; // pis a pointer to a constint
constexpr int *q = nullptr; // qis a constpointer to int
```

p is a pointer to const (low-level), whereas q is a constant pointer (top-level).

1.6.2 Rudimentary AOSP HAL Application

Create Rudimentary Service source file, `rudi.cpp`, in `AOSP/device/generic/goldfish/app/wei_daemon`

```
#include <unistd.h>
#include <stdio.h>
#include <android/log.h>

#define DELAY_SECS 2
#define ALOG(msg) __android_log_write(ANDROID_LOG_DEBUG, "WEIMINN␣PROJ", msg)

int main(int argc, char *argv[]) {
    ALOG("STARTING␣WEIMINN␣PROJECT");

    int n = 0;
    while (true) {
        sleep(DELAY_SECS);
        n++;

        ALOG("TESTING");
    }
}
```

And create Soong build file, `Android.bp` in the same folder:

```
cc_binary {
    name: "weiminn_daemon",
    relative_install_path: "hw",
    init_rc: ["init.weiminn.rc"],
    header_libs: [
        "liblog_headers",
    ],
    srcs: [
        "weiminn.cpp"
    ],
    shared_libs: [
        "liblog",
        "libcutils",
    ],
    static_libs: [
    ],
    vendor: true,
    proprietary: true,
}
```

Add `wei_rudi_daemon` to the `PRODUCT_PACKAGES+=\` attribute of `AOSP/device/generic/goldfish/vendor.mk`

Add the startup script below to the end of the `init.rc` file:

```
service wei_rudi_daemon /vendor/bin/hw/wei_rudi_daemon
    class main
    user system
    group system
    oneshot
```

But the service cannot start due to SE Policy not being implemented for the service yet:

```
11-21 02:13:54.242  1862  1862 W cp : type=1400 audit(0.0:231): avc: denied {
    getattr } for path="/vendor/bin/hw/wei_rudi_daemon" dev="dm-3" ino=110
    scontext=u:r:shell:s0 tcontext=u:object_r:vendor_file:s0 tclass=file
    permissive=0
```

1.7 November 21, 2023

1.7.1 Fixing SELinux Policy to Start System Service

Add `seclabel` to the startup script:

```
service weiminn_daemon /vendor/bin/hw/weiminn_daemon
    class main
    user system
    group system
    seclabel u:r:ueventd:s0
```

Add `start weiminn_daemon` under `on early-init` right after `start ueventd`.

Got a new permission denied error this time:

```
11-21 09:45:47.732 0 0 E init : cannot execv('/vendor/bin/hw/weiminn_daemon'). See
     the 'Debugging init' section of init's README.md for tips: Permission denied
11-21 09:45:47.733 0 0 I init : Service 'weiminn_daemon' (pid 1402) exited with
    status 127
11-21 09:45:47.733 0 0 I init : Sending signal 9 to service 'weiminn_daemon' (pid
    1402) process group...
```

Adding `device/generic/goldfish/sepolicy/x86/weiminn.te` with following contents:

```
type weiminn, domain;
permissive weiminn;
type weiminn_exec, vendor_file_type, exec_type, file_type;

init_daemon_domain(weiminn)
```

and changed `seclabel` of the startup script to `seclabel u:r:weiminn_exec:s0`. And it reverts to the previous error:

```
11-21 10:19:43.865 0 0 I init : starting service 'weiminn_daemon'...
11-21 10:19:43.866 0 0 F init : cannot setexeccon('u:r:weiminn_exec:s0') for
    weiminn_daemon: Invalid argument
11-21 10:19:43.867 0 0 I init : Service 'weiminn_daemon' (pid 1827) exited with
    status 6
11-21 10:19:43.868 0 0 I init : Sending signal 9 to service 'weiminn_daemon' (pid
    1827) process group...
11-21 10:19:43.868 0 0 I libprocessgroup : Successfully killed process cgroup uid
    1000 pid 1827 in 0ms
```

1.7.2 Memory Dump

Try on Android Emulator

Set up emulator environment by appending the following inside `~/.bashrc`:

```
export ANDROID_SDK_ROOT=~/Android/Sdk
export ANDROID_HOME=~/Android/Sdk
export ANDROID_AVD_HOME=~/.android/avd

PATH=$PATH:$ANDROID_SDK_ROOT/emulator
```

Register the path:

```
source ~/.bashrc
```

Create new AVD, Pixel 7 Pro with Tramisu (Android 13 with Google APIs, not Google Play), via Android Studio.

Run emulator using command:

```
emulator -avd Pixel_7_Pro_API_33
```

Load APK into emulator:

```
adb devices # to get id of running instance
adb root
adb install -r de.drmaxnix.birthdaycountdown.apk
```

Clone Fridump[5]:

```
git clone https://github.com/Nightbringer21/fridump
code fridump
pip install frida frida-tools
```

Download and Run Fridump dependencies:

```
git clone https://github.com/Nightbringer21/fridump
code fridump
adb push frida-server /data/local/tmp
sudo sysctl kernel.yama.ptrace_scope=0 && frida-ps -D emulator-5554
frida-ps -D emulator-5554 | grep Birth # to get process ID of the Birthday app

# inside emulator shell
./data/local/tmp/frida-server
```

Found out that Fridump doesn't support the latest Android 13 and API 34, so download Android 10 with API 29 with Pixel 3a.

Run Fridump:

```
python fridump.py -U -s Birthday\ Countdown
```

and it works now!

1.8 November 22, 2023

1.8.1 C++ Data Structure

`Sales_item` Struct

The data structure does not support any operations[6] any requires the user to implement the operations themselves:

[5] `https://pentestcorner.com/introduction-to-fridump`

[6] Basically, class with only attributes, and no methods.

```
struct Sales_data {
    std::string bookNo;
    unsigned units_sold = 0;
    double revenue = 0.0;
};
```

The names defined inside the class must be unique within the class but can reuse names defined outside the class. We define data members the same way that we define normal variables: We specify a base type followed by a list of one or more declarators.

The close curly that ends the class body must be followed by a semicolon. The semicolon is needed because we can define variables after the class body:

```
struct Sales_data { /* ... */ } accum, trans, *salesptr;
// equivalent, but better way to define these objects
struct Sales_data { /* ... */}; Sales_data accum, trans, *salesptr;
```

The semicolon marks the end of the (usually empty) list of declarators. Ordinarily, it is a bad idea to define an object as part of a class definition. Doing so obscures the code by combining the definitions of two different entities—the class and a variable—in a single statement.

We use the dot operator (`.`) to read into the member attributes of the object:

```
Sales_data data1, data2;
double price = 0; // price per book, used to calculate total revenue

// read the first transactions: ISBN, number of books sold, price per book
std::cin >> data1.bookNo >> data1.units_sold >> price;

// calculate total revenue from price and units_sold
data1.revenue = data1.units_sold * price;

// read the second transaction
std::cin >> data2.bookNo >> data2.units_sold >> price;
data2.revenue = data2.units_sold * price;
```

Preprocessor

In order to ensure that the class definition is the same in each file, classes are usually defined in header files. Typically, classes are stored in headers whose name derives from the name of the class. Thus, we will define our `Sales_data` class in a header file named `Sales_data.h`.

Headers often need to use facilities from other headers. For example, because our `Sales_data` class has a string member, `Sales_data.h` must `#include` the `string` header. As we've seen, programs that use `Sales_data` also need to include the `string` header in order to use the `bookNo` member. As a result, programs that use `Sales_data` will include the `string` header twice: once directly and once as a side effect of including `Sales_data.h`. Because a header might be included more than once, we need to write our headers in a way that is safe even if the header is included multiple times.

The **preprocessor** is a program that runs before the compiler and changes the source text of our programs. Our programs already rely on one preprocessor facility, `#include`. When the preprocessor sees a `#include`, it replaces the `#include` with the contents of the specified header.

Header guards can be defined using the preprocessor. Preprocessor variables have one of two states: defined and not defined. `#define` directive takes a name as a preprocessor variable. `#ifdef` is true if the variable has been defined, and `#ifndef` is true if the variable has not been defined. If the test is true, then everything following the `#ifdef` or `#ifndef` is processed up to the matching `#endif`:

```
#ifndef SALES_DATA_H

#define SALES_DATA_H
#include <string>

struct Sales_data {
    std::string bookNo;
    unsigned units_sold = 0;
    double revenue = 0.0;
};

#endif
```

The first time `Sales_data.h` is included, the `#ifndef` test will succeed. The preprocessor will process the lines following `#ifndef` up to the `#endif`. As a result, the preprocessor variable `SALES_DATA_H` will be defined and the contents of `Sales_data.h` will be copied into our program. If we include `Sales_data.h` later on in the same file, the `#ifndef` directive will be false. The lines between it and the `#endif` directive will be ignored.

Preprocessor variables, including names of header guards, must be unique throughout the program. Typically we ensure uniqueness by basing the guard's name on the name of a class in the header. To avoid name clashes with other entities in our programs, preprocessor variables usually are written in all uppercase.

1.9 November 23, 2023

1.9.1 C++ Types and Data Structures

Aliases

Traditionally, we use `typedef` for synonym for another type:

```
typedef double wages; // wages is a synonym for double
typedef wages base, *p; // base is a synonym for double, p for double*
```

The new standard introduced a second way to define **alias declaration** type alias:

```
using SI = Sales_item; // SI is a synonym for Sales_item
```

It is also possible to declare "pointer to" alias:

```
typedef char *pstring;
const pstring cstr = 0; // equivalent to char *const cstr = 0;
const pstring *ps; // equivalent to const char *ps;
```

`auto` Type Specifier

We can let the compiler deduce the type from the initializer for us by using the `auto` type specifier:

```
// the type of item is deduced from the type of the result of adding val1 and val2
auto item = val1 + val2; // item initialized to the result of val1+val2
```

The initializaer for all the variables muxt have types that are consistent with each other:

```
auto i = 0, *p = &i; // ok: i is int and p is a pointer to int
auto sz = 0, pi = 3.14; // error: inconsistent types for sz and pi
```

`auto` ignores top-level `const`s, and only low-level initializer are usually kept:

```
auto i = 0, *p = &i; // ok: i is int and p is a pointer to int
auto sz = 0, pi = 3.14; // error: inconsistent types for sz and pi
```

1.10 November 25, 2023

1.10.1 Android Memory Dump

Heap Dump

```
adb shell am dumpheap <PID> <HEAP-DUMP-FILE-PATH>
adb shell cat <HEAP-DUMP-FILE-PATH> > <LOCAL-FILE-PATH>
strings <LOCAL-FILE-PATH> <LOCAL-FILE-PATH-FOR-STRINGS>

pip install objection
frida-ps -Uai
# objection -g de.drmaxnix.birthdaycountdown explore
objection -g bloodpressure.bpdiary explore

android hooking list classes #List all loaded classes, As the target application gets usedmore, this command will return more classes.

android hooking search classes bloodpressure.bpdiary
android hooking search methods bloodpressure.bpdiary recordDbActivity

android hooking watch class bloodpressure.bpdiary.recordDbActivity --dump-args --dump-return

android hooking watch class_method bloodpressure.bpdiary.recordDbActivity.showWeight --dump-args --dump-backtrace --dump-return
```

1.11 November 27, 2023

1.11.1 Android Profile Guided Compilation

7 8

Baseline Profiles

```
adb shell cmd package dump-profiles bloodpressure.bpdiary
adb shell cat /data/misc/profman/bloodpressure.bpdiary-primary.prof.txt >
    bpdiary_profile.txt
```

Perfetto

Simpleperf

9

```
git clone https://android.googlesource.com/platform/system/extras
cd extras/simpleperf/demo/scripts/
python3 app_profiler.py -p simpleperf.example.java
python3 report_html.py --add_source_code --source_dirs ../demo --add_disassembly
sudo apt-get install python3-tk
./report.py
```

```
python3 app_profiler.py -p bloodpressure.bpdiary
adb shell /data/local/tmp/simpleperf record -o /data/local/tmp/perf.data -e task-
    clock:u -f 1000 -g --duration 10 --log info --app bloodpressure.bpdiary
```

Profcollect

10

This is only supported by Coresight ETM-enabled ARM devices, so emulator doesn't work.

Inside ADB shell:

```
device_config put profcollect_native_boot enabled true
setprop persist.device_config.profcollect_native_boot.collection_interval 60
setprop persist.device_config.profcollect_native_boot.sampling_period 1000
setprop persist.device_config.profcollect_native_boot.max_trace_limit 53687091200
setprop persist.device_config.profcollect_native_boot.enabled true
setprop ctl.stop profcollectd
setprop ctl.start profcollectd
ps -e | grep profcollectd
```

[7] https://developer.android.com/games/agde/pgo-overview

[8] https://newandroidbook.com/files/ArtOfDalvik.pdf

[9] https://android.googlesource.com/platform/system/extras/+/main/simpleperf/demo/README.md

[10] https://android.googlesource.com/platform/system/extras/+/master/profcollectd/

1.12 November 29, 2023

1.12.1 Android OAT Dump Parser

The format for OAT files is described in `AOSP/art/dex2oat/linker/oat_writer.h`.

`.bss`[11] is the portion of an ojbect file, executable, or assembly language code that contains statically allocated variables that are declared but not have been assigned a value yet.

```
import argparse

# helper function
def findLineWith(arr, s):
    for i in range(len(arr)):
        if s in arr[i]:
            return i

def parse_method(method_arr):
    method_sig_raw = method_arr.pop(0)
    method_sig_raw_ = method_sig_raw[0: method_sig_raw.index(')')+1]
    method_sig_raw__ = method_sig_raw_.split(':')[1:]
    method_sig = method_sig_raw__[0].strip()

    method_arr.pop(0) # discard "DEX CODE:"
    endOfDex = findLineWith(method_arr, "OatMethodOffsets")
    dexCode = method_arr[0: endOfDex]

    startOfOat = findLineWith(method_arr, "CODE:")
    nativeCode = method_arr[startOfOat+1:] # Exclude "CODE: "

    parsed_method = {'method_sig': method_sig, 'dex': dexCode, 'native':
        nativeCode}

    # print("Parsed", method_sig)

    return parsed_method

def parse_type(type_arr):
    method_indexes = [i for i in range(len(type_arr)) if 'method_idx' in type_arr[
        i]]
    if len(method_indexes) > 0:
        method_indexes.append(len(type_arr))
    methods_raw = [type_arr[method_indexes[i]:method_indexes[i+1]] for i in range
        (0, len(method_indexes)-1)]

    methods = []
    for mraw in methods_raw:
        methods.append(parse_method(mraw))

    return {'type_name': type_arr[0].split()[1], 'methods': methods}

def load_oat_dump(p):
    f = open(p)
    lines = f.readlines()

```

[11] https://en.wikipedia.org/wiki/.bss

```
44      # determine the start and end of DEX code
45      startOfOatDex = lines.index('OatDexFile:\n')
46      endOfOatDex = lines.index('OAT␣FILE␣STATS:\n')
47      OatDex = lines[startOfOatDex:endOfOatDex]
48
49      # extract the classes and types
50      type_indexes = [i for i in range(len(OatDex)) if 'type_idx' in OatDex[i]]
51      type_indexes.append(len(OatDex))
52      all_types = [OatDex[type_indexes[i]:type_indexes[i+1]] for i in range(0, len(
            type_indexes)-1)]
53
54      all_methods = []
55      all_methods_dict = {}
56
57      for t in all_types:
58          parsed = parse_type(t)
59          all_methods += parsed['methods']
60
61          for m in parsed['methods']:
62              all_methods_dict[m['method_sig']] = {}
63              all_methods_dict[m['method_sig']]['dex'] = m['dex']
64              all_methods_dict[m['method_sig']]['native'] = m['native']
65
66      # return all_methods
67      return all_methods_dict
68
69  def load_schema(p):
70      f = open(p)
71      lines = f.readlines()
72
73      schema = []
74      for l in lines:
75          split = l.split('|||')
76          schema.append(split[1][:-1]) # -1 to remove \n character
77          # print("Added schema", schema[-1])
78      return schema
79
80  parser = argparse.ArgumentParser(description='OAT␣Debloation␣Checker')
81  parser.add_argument('--oat', type=str, help='OAT␣Dump␣TXT␣file')
82  parser.add_argument('--schema', type=str, help='Debloating␣schema␣file')
83
84  try:
85      args = parser.parse_args()
86      # print("Options:", args.OAT, args.schema)
87
88      # Load Debloated OAT Dump
89      print("Debloated␣OAT␣Dump:", args.oat)
90      normal_methods = load_oat_dump(args.oat)
91      # normal_methods = load_oat_dump('prelim_results/com.storiestime/10
            min_normal_com.storiestime_oat_dump.txt')
92
93      # Load Schema
94      print("Schema␣File:", args.schema)
95      schema = load_schema(args.schema)
96      # schema = load_schema('Money_script/success_schema/169_com.
            storiestime_removed_methods.txt')
97
98      # Check if debloated
99      for m in schema:
```

```
100         retrieve = normal_methods[m]
101         if 'NO CODE!' in retrieve['native'][0]:
102             print(m, ' is debloated!')
103         else:
104             print(m, ' is not debloated!')
105 
106     # print('test')
107 except Exception as e:
108     print("Exception!", str(e))
```

Chapter 2

December

2.1 December 01, 2023

2.1.1 C++ Strings and Vectors

Namespace `using` Declarations

The scope operator (`::`) says that the compiler should look in the scope of the left-hand operand for the name of the right-hand operand. `using` declaration lets us use a name from a namespace without qualifying the name with `namespace::` prefix as below:

```
1  #include <iostream>
2
3  // when we use the name cin, we get the one from the namespace std
4  using namespace::name;
5
6  int main(){
7      int i;
8      cin >> i;
9      cout << i;
10     std::cout << i;
11     return 0;
12 }
```

Headers should NOT include `using` declarations, as the contents of a header are copied into the including program's text. As a result, a program that didn't intend to use the specified library name might encounter unexpected name conflicts.

`string` Type

If you include a header that includes `<string>` you may not have to do so explicitly. However, it is bad practice to count on this, and well-written headers include guards against multiple inclusion, so assuming you're using well-written header files, there is

no harm in including a header that was included via a previous include.[1]:

```
#include <string> // You need to include the <string> header to use std::string.
using std:string;
```

Most common ways to initialize strings:

```
// direct initialization
string s1; // default initialization; s1 is the empty string
string s4(10, 'c'); // s4 is ccccccccc
string s6("hiya");

// copy initialization
string s2 = s1; // s2 is a copy of s1
string s3 = "hiya"; // equivalent to string s3("hiya");
string s8 = string(10, 'c') // copying initialization; s8 is ccccccccc
```

When we initialize a variable using =, we are asking the compiler to copy initialize the object by copying the initializer on the right-hand size into the object being created. When we omit the =, we use direct initialization.

string Operations:

Statement	Description
os<<s	Writes s onto output stream os. Return os.
is>>s	Reads whitespaced-separated string from is to s. Return is.
getline(is,s)	Reads a line of input from is into s. Returns is.
s.empty()	Returns true if s is empty; otherwise return false.
s.size()	Returns the number of characters in s.
s[n]	Returns a reference to the char at position n in s.
s1 + s2	Returns a string that is the concatenation of s1 and s2.
s1 += s2	Equivalent to s1 = s1 + s2.
s1 = s2	Replaces characters in s1 with a copy of s2.
s1 == s2 and s1 != s2	The strings in s1 and s2 are equal if they contain the same characters. The equality is case-sensitive.
<, <=, >, >=	Comparisons are case-sensitive and use dictionary ordering.

Table 2.1: string Operations

To check individual character:

Function	Description
isalnum(c)	true if c is a letter or a digit.
isalpha(c)	true if c is a letter.
iscntrl(c)	true if c is a control character.

[1] https://stackoverflow.com/a/73640984

Function	Description
`digit(c)`	`true` if `c` is a digit.
`isgraph(c)`	`true` if `c` is not a space but is printable.
`islower(c)`	`true` if `c` is a lowercase letter.
`isprint(c)`	`true` if `c` is a printable character (i.e., a space or a character that has a visible representation).
`ispunct(c)`	`true` if `c` is a punctuation character.
`isspace(c)`	`true` if `c` is whitespace (i.e., a space, tab, vertical tab, return, newline, or formfeed).
`isupper(c)`	`true` if `c` is an uppercase letter.
`isxdigit(c)`	`true` if `c` is a hexadecimal digit.
`tolower(c)`	If `c` is an uppercase letter, returns its lowercase equivalent; otherwise returns `c` unchanged.
`toupper(c)`	If `c` is an lower letter, returns its uppercase equivalent; otherwise returns `c` unchanged.

Table 2.2: `cctype` Functions

Reading an Unknown Number of `string`s

If the stream is valid - it hasn't hit end-of-file or encountered an invalid input - then the body of `while` is executed:

```
1  int main() {
2      string word;
3      while (cin >> word) // read until end-of-file
4          cout << word << endl; // write each word followed by a new line
5
6      // Reads the given stream up to and including the first newline
7      string line; // read input a line at a time until end-of-file
8      while (getline(cin, line))
9          // The newline that causes getline to return is discarded; the newline is
               not stored in the string.
10         cout << line << endl;
11
12     while (getline(cin, line))
13         // Only print lines that are not empty
14         if (!line.empty())
15             cout << line << endl;
16
17     return 0;
18 }
```

Library `string`s and String Literals

When we mix `string`s and string or character literals, at least one operand to each + operator must be of `string` type:

```
string s4 = s1 + ", "; // ok: adding a string and a literal
string s5 = "hello" + ", "; // error: no string operand
string s6 = s1 + ", " + "world"; // ok: each + has a string operand
string s7 = "hello" + ", " + s2; // error: can't add string literals
```

For compatibility reasons with C, string literals are NOT standard library `strings`. It is important to remember that these types differ when you use string literals and library `strings`.

Characters in `strings`

`string` expression represent a sequence of characters, and to traverse every character, we can use a range `for` that follows the syntax:

```
for (declaration: expression)
    statement
```

A simple example:

```
string str("some string");
// print the characters in str one character to a line
for (auto c : str) // for every char in str
    cout << c << endl; // print the current character followed by a newline
```

We use auto to let compiler deduce the type of `c`, which in this case will be `char`.

If we want to change the value of the character in a `string`, we must define the loop variable as a reference type:

```
string str("some string");
// convert s to uppercase
for (auto &c : str) // for every char ref in str
    c = toupper(s); // c is a reference, so the assignment changes the char in s
```

The subscript operator (the `[]` operator) takes a `string::size_type` value that denotes the position of the character we want to access. The operator returns a reference to the character at the given position:

```
string str("some string");
if (!s. empty())            // make sure there's a character to print
    cout << s[0] << endl;   // print the first character in s
```

To iterate using subscript:

```
// process characters in s until we run out of characters or we hit a whitespace
for (
    decltype(s.size()) index = 0;
    index != s.size() && !isspace(s[index]); // the operator yields true if both
        operands are true
    ++index)
        s[index] = toupper(s[index]); // capitalize the current character
```

`vector` Type

A `vector` is a collection[2] of objects, all of which have the same type, and each of which has an associated index that gives access to that object. Below is the headers to use a `vector`:

```
#include <vector>
user std::vector;
```

`vector` is not a class/type but a class template, which is a set of instructions for the compiler for generating classes/types, a process called instantiation. To specify what kind of class (what type of object we want the `vector` to hold) we want to instantiate, we supply additional information inside a pair of angle brackets following the template's name:

```
vector<int> ivec; // ivec holds objects of type
int vector<Sales_item> Sales_vec; // holds Sales_items
vector<vector<string>> file; // vector whose elements are vectors
```

Here, `vector<int>`, `vector<Sales_item>`, and `vector<vector<string>>` are the types generated types by the compiler.

Because references are not objects, we cannot have a vector of references.

Defining and Initializing `vectors`

The most common way of Initializing a vector is to initialize an empty `vector`. We can also perform direct and copy initialization, but the objects must be the same type:

```
vector<string> svec; // default initialization; svechas no elements

// direct and copy initialization
vector<int> ivec2(ivec); // copy elements of ivec into ivec2
vector<int> ivec3 = ivec; // copy elements of ivec into ivec3
vector<string> svec(ivec2); // error: svec holds strings, not ints

// list initialization
vector<string> articles = {"a", "an", "the"};
vector<string> articles2{"a", "an", "the"};
vector<string> articles3("a", "an", "the"); // error

vector<int> ivec(10, -1); // ten int elements, each initialized to -1
vector<string> svec(10, "hi!"); // ten strings; each element is "hi!"

vector<int> ivec(10); // ten elements, each initialized to 0
vector<string> svec(10); // ten elements, each an empty string
```

Some classes require that we always supply an explicit initializer, and cannot be default initialized, in which case, we must supply the initial value/

[2]Often referred to as container because it "contains" other objects.

`vector` Operations

Two `vectors` are equal if they have the same numnber of elements, and if the corresponding elements all have the same value. If the vectors have differing sizes, but the elements that are in common are equal, then the vector with fewer elements is less than the one with more elements. If the elements have differing values, then the relationship between the `vectors` is determined by the relationship between the first elements that differ. We can compare two `vectors` only if we can compare the element in those `vectors`.

Methods	Description
`v.empty()`	Returns `true` if `v` is empty; otherwise returns `false`.
`v.size()`	Returns the number of elements in `v`.
`v.push_back(t)`	Adds an element with value `t` to the end of `v`.
`v[n]`	Returns a reference to the element at position `n` in `v`.
`v1 = v2`	Replaces the elements in `v1` with a copy of the elements in `v2`.
`v1 = {a, b, c, ...}`	Replaces the elements in `v1` with a copy of the elements in the comma-separated list.
`v1 == v2` and `v1 != v2`	`v1` and `v2` are equal if they have the same number of elements and each element in `v1` is equal to corresponding element in `v2`.
`<, <=, >, >=`	Have their normal meanings using dictionary ordering.

Table 2.3: `vector` Methods

As with `strings`, subscript for `vector` start at 0; the type of a subscript is the corresponding `size_type`; and we can write to the element returned by the subscript operator.

Subscripting a `vector` does NOT add elements:

```
1 vector<int> ivec; // empty vector
2 for (decltype(ivec.size()) ix = 0; ix != 10; ++ix)
3     ivec[ix] = ix; // disaster: ivec has no elements
```

It is an error to subscript an element that doesn't exist, but it is an error that the compiler is unlikely to detect. Instead, the value we get at run time is undefined[3]. A good way to ensure that subscripts are in range is to avoid subscripting altogether by using a range `for` whenever possible.

[3] *Buffer overflow* errors are the result of subscripting elements that don't exist. Such bugs are the most common cause of security problems in PC and other applications.

2.2 December 03, 2023

2.2.1 C++ Iterator, and Arrays

Iterators

Iterators are more general mechanism than subscript operators. All of the library containers have iterators, but only a few of them support the subscript operator. Like pointers, iterators give us indirect acess to an object.

```
// the compiler determines the type of b and e;
// b denotes the first element and e denotes one past the last element in v
auto b = v.begin(), e = v.end(); // b and e have the same type
```

The `begin` member returns an iterator that denotes the first element (if there is one). The `end` member returns an iterator positioned "one past the end" of the associated container (or `string`), also referred to as the off-the-end iterator. If the container is empty, `begin` returns the same iterator as the one returned by `end`.

We do not know (or need to care about) the precise type that an iterator has, so we use `auto` to define `b` and `e`.

We compare two valid iterators using == or `!=`. Iterators are equal if they denote the same element of if they are both off-the-end iterators for the same container. Otherwise, they are unequal.

Like pointers, we can dereference a valid iterator to obtain the elemnt denoted by an iterator. Dereferencing an invalid iterator or an off-the-end iterator has undefined behavior:

```
string s("some␣string");
if (s.begin() != s.end()) { // make sure s is not empty
    auto it = s.begin(); // it denotes the first character in s
    *it = toupper(*it); // make that character uppercase
}
```

Iterators also support a few other operations:

Methods	Description
`*iter`	Returns a reference to the element denoted by the iterator `iter`.
`iter->mem`	Dereferences `iter` and fetches the member named `mem` from the underlying element. Equivalent to `(*iter).mem`.
`++iter`	Increments `iter` to refer to the next element in the container.
`-iter`	Decrements `iter` to refer to the previous element in the container.
`iter1 == iter2` and `iter1 != iter2`	Compares two iterators for equality. Two iterators are equal if they denote the same element or if they are off-the-end iterator for the same container.

Table 2.4: Iterator operations

The increment (++) operator to move from one element to the next:

```
string s("some string");
for (auto it = s.begin(); it != s.end() && !isspace(*it); ++it) {
    *it = toupper(*it); // make that character uppercase
}
```

Because the iterator returned by `end` does not denote an element, it may not be incremented or dereferenced.

When we need to read but not write to an object, we ask specifically for `const_iterator` type:

```
vector<int> v;
auto b = v.cbegin(); // b has type vector<int>::const_iterator
auto e = v.cend(); // e has type vector<int>::const_iterator
```

Regardless of whether the container is `const`, they return a `const_iterator`.

Iterators for `string` and `vector` support additional operations that can move an iterator multiple elements at a time, often referred to as iterator arithmetic:

Iter. Arithmetic	Description
`iter + n` and `iter - n`	Adding (subtracting) an integral value `n` to (from) an iterator yields an iterator that many elements forward (or backward) within the container. The resulting iterator must denote elements in, or one past the end of, the same container.
`iter += n` and `iter -= n`	Compound-assignment for iterator addition and subtraction. Assigns to `iter1` the value of adding `n` to, or subtracting `n` from, `iter1`.
`iter1 - iter2`	Subtracting two iterators yields the number that when added to the right-hand iterator yields the left-hand iterator. The iterators must denote elements in, or one past the end of, the same container.
>,>=,<,<=	Relational operators on iterators. One iterator is less than another if it refers to an element that appears in the container before the one referred to by the other iterator. The iterators must denote elements in, or one past the end of, the same container.

Table 2.5: Iterator Arithmetics

A classic algorithm that uses iterator arithmetic is binary search:

```
vector<int> v;
// text must be sorted
// begand end will denote the range we're searching
auto beg = text.begin(), end = text.end();
```

```
auto mid = text.begin() + (end - beg)/2; // original midpoint

// while there are still elements to look at and we haven't yet found sought
while (mid != end && *mid != sought) {
    if (sought < *mid) // is the element we want in the first half?
        end = mid; // if so, adjust the range to ignore the second half
    else // the element we want is in the second half
        beg = mid + 1; // start looking with the element just after mid
    mid = beg + (end - beg)/2; // new midpoint
}
```

Arrays

Similar to library `vector` type, an `array` is a container of unnamed objectis of a single type that we access by position. Unlike a `vector`, arrays have fixed size; we cannot add elements to an array, in order to attain better runtime performance for specialize applications at the cost of flexibility.

An array declarator has the form `a[d]`, where `a` is the name being defined and `d` is the dimension of the array which specifies the number of elements and must be greater than zero. The dimension must be known at compile time, which means that the dimension must be a `constexpr`:

```
unsigned cnt = 42; // not a constant expression
constexpr unsigned sz = 42; // constant expression
int arr[10]; // array of ten ints
int *parr[sz]; // array of 42 pointers to int
string bad[cnt]; // error: cnt is not a constant expression
string strs[get_size()]; // ok if get_size is constexpr, error otherwise
```

By default, the elements in an array are default initialized. As with `vector`, arrays hold objects. Thus, there are no arrays of references.

We can list initialize an array which allow us to omit the dimension as the compiler infers it from the number of initializers. If we specify, the number of initializers must not exceed the specified size:

```
const unsigned sz = 3;
int ia1[sz] = {0,1,2}; // array of three ints with values 0, 1, 2
int a2[] = {0, 1, 2}; // an array of dimension 3
int a3[5] = {0, 1, 2}; // equivalent to a3[] = {0, 1, 2, 0, 0}
string a4[3] = {"hi", "bye"}; // same as a4[] = {"hi", "bye", ""}
int a5[2] = {0,1,2}; // error: too many initializers
```

Character arrays can also be initialized from a string literals. It's important to remember that string literals end with a null character:

```
char a1[] = {'C', '+', '+'}; // list initialization, no null
char a2[] = {'C', '+', '+', '\0'}; // list initialization, explicit null
char a3[] = "C++"; // null terminator added automatically
const char a4[6] = "Daniel"; // error: no space for the null!
```

We cannot initialization an array as a copy of another array, nor is it legal to assign one array to another[4]:

```
int a[] = {0, 1, 2}; // array of three ints
int a2[] = a; // error: cannot initialize one array with another
a2 = a; // error: cannot assign one array to another
```

Defining arrays that hold pointers is fairly straightforward, defining a pointer or reference to an array is a bit more complicated:

```
int *ptrs[10]; // ptrs is an array of ten pointers to int
int &refs[10] = /* ? */; // error: no arrays of references
int (*Parray)[10] = &arr; // Parray points to an array of ten ints
int (&arrRef)[10] = arr; // arrRef refers to an array of ten ints
```

The parentheses around `*Parray` means that `Parray` is a pointer. Looking right, we see that `Parray` points to an array of size 10. Looking left, we see taht the elements in the array are `ints`.. Thus, `Parray` is a pointer to an array of ten `ints`. Similarly, `&arrRef` says that `arrRef` is a reference.

We can use range `for` or the subscript operator to access elements of an array:

```
// count the number of grades by clusters of ten: 0--9, 10--19, . . . 90--99, 100
unsigned scores[11] = {}; // 11 buckets, all value initialized to 0
unsigned grade;
while (cin >> grade) {
    if (grade <= 100)
        ++scores[grade/10]; // increment the counter for the current cluster
}

for (auto i : scores) // for each counter in scores
    cout << i << "␣"; // print the value of that counter
cout << endl;
```

We have to use a variable to have type `size_t` (defined in `cstddef` header) which is a machine-specific unsigned type that is guaranteed to be large enough to hold the size of any object in memory.

The most common source of security problems are buffer overflow bugs. Such bugs occur when a program fails to check a subscript and mistakenly uses memory outside the range of an array or similar data structure. Nothing stops a program from stepping across an array boundary except careful attention to detail and thorough testing of the code.

We obtain a pointer to an array element by taking the address of that element:

```
string nums[] = {"one", "two", "three"}; // array of strings
string *p = &nums[0]; // p points to the first element in nums
string *p2 = nums; // equivalent to p2=&nums[0]
```

When we use an object of array type, we are really using a pointer to the first element in that array, as the compiler automatically substitutes a pointer to the first element.

When we use an array as an initializer for a variable defined using `auto`, the deduced type is a pointer, not an array:

[4]Some compilers allow array assignment as a compiler extension.Itis usually a good idea to avoid using nonstandard features. Programs that use such features, will not work with a different compiler.

```
int ia[] = {0,1,2,3,4,5,6,7,8,9}; // ia is an array of ten ints
auto ia2(ia); // ia2 is an int* that points to the first element in ia
ia2 = 42; // error: ia2 is a pointer, and we can't assign an int to a pointer
```

Although `ia` is an array of ten `int`s, when we use `ia` as an initializer, the compiler treats that initialization as if we had written:

```
auto ia2(&ia[0]); // now it's clear that ia2 has type int*
```

This converstion does not happen when we use `decltype`:

```
// ia3 is an array of ten ints
decltype(ia) ia3 = {0,1,2,3,4,5,6,7,8,9};
ia3 = p; // error: can't assign an int* to an array
ia3[4] = i; // ok: assigns the value of ito an element in ia3
```

Pointers to array elements support the same operations as iterators on `vector`s or `string`s:

```
// ia3 is an array of ten ints
int arr[] = {0,1,2,3,4,5,6,7,8,9};
int *p = arr; // p points to the first element in arr
++p; // ppoints to arr[1]
int *e = &arr[10]; // pointer just past the last element in arr
```

`arr` has 10 elements, so the last element in `arr` is at index 9. Like the off-the-end iterator, off-the-end pointer does not point to an element. As a result, we may not dereference or increment an off-the-end pointer.

To be safer and less error-prone, we can use `begin` and `end` functions that act like similarly named container members. However, as arrays are not class types, these are not member functions, so they take an argument that is an array:

```
int ia[] = {0,1,2,3,4,5,6,7,8,9}; // ia is an array of ten ints
int *beg = begin(ia); // pointer to the first element in ia
int *last = end(ia); // pointer one past the last element in ia
```

Pointers that address array elements can use all iterator operations in Table 2.4 and Table 2.5. When we add an itegral value to or from a pointer, the result is a new pointer. That new pointer points to the element the given number ahead of the original pointer:

```
constexpr size_t sz = 5;
int arr[sz] = {1,2,3,4,5};
int *ip = arr; // equivalent to int*ip=&arr[0]
int *ip2 = ip + 4; // ip2points to arr[4], the last element in arr

// ok: arris converted to a pointer to its first element; ppoints one past the end
     of arr int *p = arr + sz; // use caution -- do not dereference! int *p2 = arr
     + 10; // error: arrhas only 5 elements; p2has undefined value
```

When we add `sz` to `arr`, the compiler converts `arr` to a pointer to the first element in `arr`. As a result, we can dereference the resulting pointer:

```
int ia[] = {0,2,4,6,8}; // array with 5 elements of type int
int last = *(ia + 4); // ok: initializes last to 8, the value of ia[4]
last = *ia + 4; // ok: last=4,equivalenttoi
```

As with iterators, subtracting two pointers gives us the distance between those pointers. The pointers must point to elements in the same array:

```
auto n = end(arr) - begin(arr); // n is 5, the number of elements in arr
```

The result of subtracting two pointers is a library type named `ptrdiff_t` which is a machine-specific type and is defined in the `cstddef` header.

When we subscript an array, we are subscripting a pointer to an element in that array:

```
int i = ia[2];  // ia is converted to a pointer to the first element in ia
                // ia[2]fetches the element to which (ia+2)points
int *p = ia; // p points to the first element in ia
i=*(p + 2); // equivalent to i=ia[2]
int k = p[-2]; // p[-2] is the same element as ia[0]
```

Unlike subscripts for `vector` and `string`, the index of the built-in subscript operator is not an unsigned type.

Modern C++ programs should use vectors and iterators instead of built-in arrays and pointers, and use strings rather than C-style array-based character strings. Pointers are used for low-level manipulations and it is easy to make bookkeeping mistakes. Other problems arise because of the syntax, particularly the declaration syntax used with pointers.

Multidimensional Arrays

Multidimensional arrays in C++ are actually arrays of arrays:

```
int ia[3][4]; // array of size 3; each element is an array of ints of size 4
// array of size 10; each element is a 20-element array whose elements are arrays
    of 30 ints
int arr[10][20][30] = {0}; // initialize all elements to 0

int ia[3][4] = { // three elements; each element is an array of size 4
    {0, 1, 2, 3}, // initializers for the row indexed by 0
    {4, 5, 6, 7}, // initializers for the row indexed by 1
    {8, 9, 10, 11} // initializers for the row indexed by 2
};

// equivalent initialization without the optional nested braces for each row
int ia[3][4] = {0,1,2,3,4,5,6,7,8,9,10,11};

// explicitly initialize only element 0 in each row
int ia[3][4] = {{ 0 }, { 4 }, { 8 }};

// explicitly initialize row 0; the remaining elements are value initialized
int ix[3][4] = {0, 3, 6, 9};

// assigns the first element of arr to the last element in the last row of ia
ia[2][3] = arr[0][0][0];

int (&row)[4] = ia[1]; // binds row to the second four-element array in ia
```

2.3 December 04, 2023

2.3.1 C++ Expressions I

lvalues and rvalues

Every expression is either an rvalue or an lvalue. lvalues could stand on the left-hand side of an assignment where as rvalue could not. Roughly speaking, when we use an object as an rvalue, we use the object's value (its contents). When we use an object as an lvalue, we use the object's identity (its location in memory). We can use an lvalue when an rvalue is required, but we cannot use an rvalue when an lvalue (i.e., a location) is required. When we use an lvalue in place of an rvalue, the object's contents (its value) are used:

- Assignement requires a (non `const`) lvalue as its left-hand operand and yields its left-hand operand as an lvalue.
- The address-of operator requires an lvalue operand and returns a pointer to its operand as an rvalue.
- The built-in dereference and subscript operators and the iterator dereference and `string` and `vector` subscript operator all yield lvalues.
- The buit-in and iterator increment and decrement operators require lvalue operands and the prefix versions also yield lvalues.

Lvalues and rvalues also differ when used with `decltype`. When we apply `decltype` to an expression, the result is a reference type if the expression yields an lvalue.

Arithmetic Operators

Division between integers returns an integer. If the quotient contains a fractional part, it is truncated toward zero:

```
1 int ival1 = 21/6; // ival1 is 3; result is truncated; remainder is discarded int
2 ival2 = 21/7; // ival2 is 3; no remainder; result is an integral value
```

For most operators, operands of type bool are promoted to int. In this case, the value of b is true, which promotes to the int value 1. That (promoted) value is negated, yielding -1. The value-1 is converted back to bool and used to initialize b2. This initializer is a nonzero value, which when converted to bool is true.Thus,the value of b2 is true!

The operands to % must have integral type:

```
int ival = 42;
double dval = 3.14;

ival % 12; // ok: result is 6
ival % dval; // error: floating-point operand
```

2.4 December 05, 2023

2.4.1 C++ Expressions II

Logical and Relational Operators

The relational operators take operands of arithmetic or pointer type; the logical operators take operands of any type that can be converted to `bool`. The operands to those operators are rvalues and the result is an rvalue.

Associativity	Operator	Function	Use
Right	`!`	logical `NOT`	`!expr`
Left	`<`	less than	`expr < expr`
Left	`<=`	less than or equal	`expr <= expr`
Left	`>`	greater than	`expr > expr`
Left	`>=`	greater than or equal	`expr >= expr`
Left	`==`	equality	`expr == expr`
Left	`!=`	inequality	`expr != expr`
Left	`&&`	logical `AND`	`expr && expr`
Left	`||`	logical `OR`	`expr || expr`

Table 2.6: Logical and Relational Operators

Because relational operators return `bools`, the result of chaining these operators together is likely to be surprising:

```
// oops! this condition compares k to the bool result of i<j
if(i<j<k) // true if k is greater than 1!
```

The compiler converts `val` to `bool`:

```
if (val) { /* ... */} // true if val is any nonzero value
if (!val) { /* ... */}// true if val is zero
if (val == true) { /* ... */}// trueonly if valis equal to 1!
if (val == 1) { /* ... */}
```

If `val` is not `bool`, then `true` is converted to the type of `val` before the == operator is applied.

Assignment Operators

The left-hand operand of an assignment operator must be a modifiable lvalue. For example, given:

```
int i = 0, j = 0, k = 0;     // initializations, not assignment
const int ci = i;            // initialization, not assignment
1024 = k;                    // error: literals are rvalues
i + j = k;                       // error: arithmetic expressions are rvalues
ci = k;                      // error: ci is a const(nonmodifiable) lvalue
k = 0;                       // result: type int, value 0
k = 3.14159;                 // result: type int, value 3
k = {3.14};                  // error: narrowing conversion
vector<int> vi;              // initially empty
vi = {0,1,2,3,4,5,6,7,8,9}; // vi now has ten elements, values 0 through 9
```

Unlike the other binary operators, assignment is right associative. The right-most assignment, `jval = 0`, is the right-hand operand of the left-most assignment operator:

```
int ival, jval;
ival = jval = 0; // ok: each assigned 0
int ival, *pval; // ival is an int; pval is a pointer to int
ival = pval = 0; // error: cannot assign the value of a pointer to an int
string s1, s2;
s1 = s2 = "OK"; // string literal "OK"converted to string
```

Each object in a multiple assignment must have the same type as its right-hand neighbor or a type to which that neighbor can be converted.

Assignment often occur in conditions. Because assignment has relatively low precedence, we usually must parenthesize the assignment for the condition to work properly:

```
// a verbose and therefore more error-prone way to write this loop
int i = get_value(); // get the first value
while (i != 42) {
    // do something . . .
    i = get_value();
    // get remaining values

}

int i;
// a better way to write our loop---what the condition does is now clearer
while ((i = get_value()) != 42) {
    // do something . . .
}
```

Assignment Operators

The dot and arrow operators provide for member access. The dot operator fetches a member from an object from an object of class type; arrow is defined so that *ptr->mem* is a synonym for *(*ptr).mem)*:

```
string s1 = "a␣string", *p = &s1;
auto n = s1.size(); // run the sizemember of the strings1
```

```
3 n = p->size();       // equivalent to (*p).size()
4 n=(*p).size();       // run size on the object to which p points
5
6 // run the size member of p, then dereference the result!
7 *p.size(); // error: p is a pointer and has no member named size
```

Because dereference has a lower precedence than dot, we must parenthesize the dereference subexpression.

Conditional Operator

The conditional (the `?:` operator) lets us embed simple if-else logic inside an expression:

```
1 // cond ? expr1: expr2;
2 string final grade = (grade < 60) ? "fail": "pass";
```

where `expr1` and `expr2` are expressions of the same type.

An incompletely parenthesized conditional operator in an output expression can have surprising results:

```
1 cout << ((grade < 60) ? "fail" : "pass"); // prints pass or fail
2 cout << (grade < 60) ? "fail" : "pass"; // prints 1 or 0!
3 cout << grade < 60 ? "fail" : "pass"; // error: compares cout to 60
```

The second expression uses the comparison between `grade` and `60` as the operand to the « operator.

Bitwise Operator

Because there are no guarantees for how the sign bit is handled, it is strongly recommended to use `unsigned` types with the bitwise operators.

Operator	Function	Use
	bitwise NOT	expr
«	left shift	expr1 « expr2
»	right shift	expr1 » expr2
&	bitwise AND	expr1 & expr2
^	bitwise XOR	expr1 êxpr2
|	bitwise OR	expr1 | expr2

Table 2.7: Bitwise Operators

The built-in menaing of the shift operators is to perform a bitwise shift on their operands. They yield a value that is a copy of the left-hand operand with the bits

shifted as directed by the right-hand operand. The right-hand operand must not be negative and must be a value that is strictly less than the number of bits in the result. Otherwise, the operation is undefined. The bits are shifted left («) or right (»). Bits that are shifted off the end are discarded:

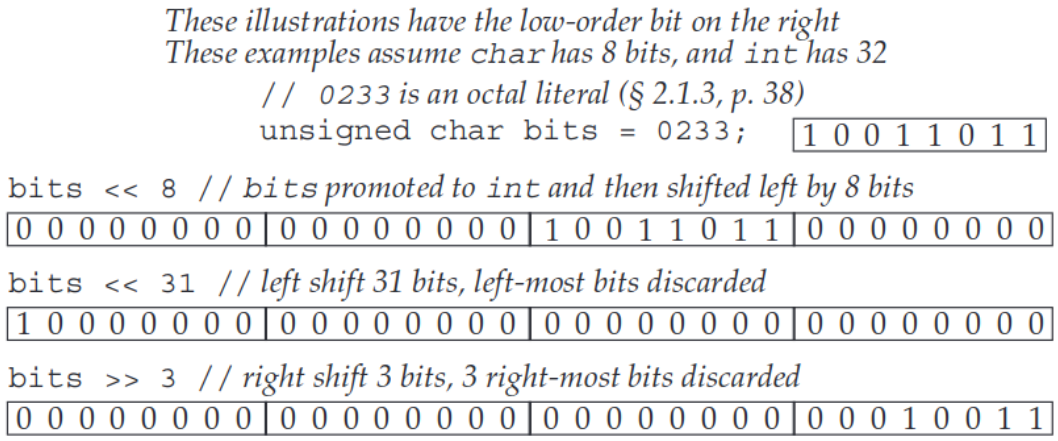


Figure 2.1: Bitwise Shift Operation

Shift operators have midlevel precedence (lower than the arithmetic operators but higher than the relational, assignment, and conditional operators):

```
1 cout << 42 + 10; // ok: + has higher precedence, so the sum is printed
2 cout << (10 < 42); // ok: parentheses force intended grouping; prints 1
3 cout << 10 < 42; // error: attempt to compare cout to 42!
```

The bitwise NOT operator generates a new value with the bits of its operand inverted:

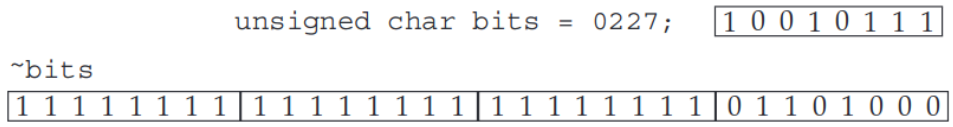


Figure 2.2: Bitwise NOT Operation

The AND, OR, and XOR operators generate new values with the bit pattern composed from its two operands:

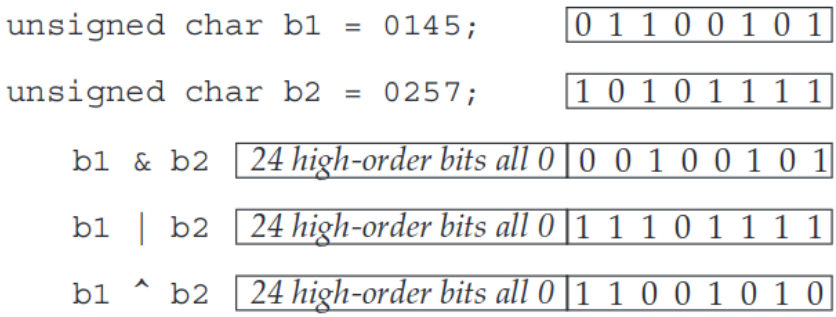


Figure 2.3: Bitwise AND, OR, and XOR Operation

`sizeof` Operator

The `sizeof` operator returns the size, in bytes, of an expression or a type name. The operator is right associative. The result of `sizeof` is a constant expression of type `size_t`. The operator takes one of two forms:

```
1 sizeof(type)
2 sizeof expr
```

The `sizeof` operator is unusual in that it does not evaluate its operand:

```
1 Sales_data data, *p;
2 sizeof(Sales_data); // size required to hold an object of type Sales_data
3 sizeof data; // size of data's type, i.e., sizeof(Sales_data)
4 sizeof p; // size of a pointer
5 sizeof *p; // size of the type to which p points, i.e., sizeof(Sales_data)
6 sizeof data.revenue; // size of the type of Sales_data's revenue member
7 sizeof Sales_data::revenue; // alternative way to get the size of revenue
```

Dereferencing an invalid pointer as the operand to `sizeof` is safe because the pointer is not actually used, because `sizeof` does not need to dereference the pointer to know what type it will return.

The result of applying `sizeof` depends in part on the type involved:

- `sizeof char` or an expression of type `char` is guaranteed to be 1.
- `sizeof` a reference type returns the size of an object of the referenced type.
- `sizeof` a pointer returns the size needed to hold a pointer.
- `sizeof` a dereferenced pointer returns the size of an object of the type to which the pointer points; the pointer need not be valid.
- `sizeof` an array is the size of the entire array. It is equivalent to taking the `sizeof` the element type times the number of elements in the array. Note that `sizeof` does not convert the array to a pointer.
- `sizeof` a `string` or a `vector` returns only the size of the fixed part of these types; it does not return the size used by the object's elements.

Because `sizeof` returns the size of the entire array, we can determine the number of elements in an array by dividing the array size by the element size.

Comma Operator

The comma operator takes two operands, which it evaluates from left to right. Like the logical AND and logical OR and the conditional operator guarantees the order in which its operands are evaulated. Most common use for the comma operator is in a `for` loop:

```
vector<int>::size_type cnt = ivec.size();
// assign values from size...1 to the elements in ivec
for(vector<int>::size_type ix = 0;
        ix != ivec.size(); ++ix, --cnt)
    ivec[ix] = cnt;
```

The left-hand expression is evaluated and its result is discarded. The result of a comma expression is the value of its right-hand expression. The result is an lvalue if the right-hand operand is an lvalue.

Type Conversions

Implicit conversions are carried out automatically without programmer intervention, and are defined to preserve precision, if possible.

- In most expressions, values of integral types smaller than `int` are first promoted to an appropriate larger integral type.
- In conditions, non`bool` expressions are converted to `bool`.
- In initializations, the initializer is converted to the type of the variable; in assignments, the right-hand operand is converted to the type of the left-hand.
- In arithmetic and relational expressions with operands of mixed types, the types are converted to a common type.

Conversions also happen during function calls.

Arithmetic conversions:

```
bool flag;      char cval;
short sval;     unsigned short usval;
int ival;       unsigned int uival;
long lval;      unsigned long ulval;
float fval;     double dval;

3.14159L + 'a'; // 'a' promoted to int, then that intconverted to long double
dval + ival; // ival converted to double
dval + fval; // fval converted to double
ival = dval; // dval converted (by truncation) to int
flag = dval; // if dval is 0,then flag is false, otherwise true
cval + fval; // cval promoted to int, then that int converted to float
```

```
13 sval + cval; // sval and cval promoted to int
14 cval + lval; // cval converted to long
15 ival + ulval; // ival converted to unsigned long
16 usval + ival; // promotion depends on the size of unsigned short and int
17 uival + lval; // conversion depends on the size of unsigned int and long
```

Array to pointer conversion:

```
1 int ia[10]; // array of ten ints
2 int* ip = ia; // convert ia to a pointer to the first element
```

This conversion is not performed when an array is used with `decltype` or as the operand of the address-of(`&`), `sizeof`, or `typeid` operators. The conversion is also omitted when we initialize a reference to an array. A similar pointer conversion happens when we use a function type in an expression.

A constant integral value of `0` and the literal `nullptr` can be converted to any pointer type; a pointer to any `nonconst` type can be converted to `void*`, and a pointer to any type can be converted to a `const void*`

There is an automatic conversion from arithmetic or pointer types to `bool`. If the pointer or arithmetic value is zero, the conversion yields `false`; any other yields `true`:

```
1 char *cp = get_string();
2 if (cp) /* ... */// trueif the pointer cp is not zero
3 while (*cp) /* ... */// trueif *cpis not the null character
```

We can convert a pointer to a `nonconst` type to a pointer to the corresponding `const` type, and similarly for references. That is, if `T` is a type, we can convert a pointer or a reference to `T` into a pointer or a reference to `const T`:

```
1 int i;
2 const int &j = i; // convert a non const to a reference to const int
3 const int *p = &i; // convert address of a non const to the address of a const
4 int &r = j, *q = p; // error: conversion from const to nonconst not allowed
```

The reverse conversion - removing a low-level `const` - does not exist.

2.5 December 06, 2023

2.5.1 C++ Statements

An expression becomes an expression statement when it is followed by a semicolon. Expression statements cause the expression to be evaluated and its result discarded:

```
1 ival + 5;       // rather useless expression statement
2 cout << ival;   // useful expression statement
```

Null statement is a single semicolon, and is legal anywhere a statement is expected:

```
1 ;                   // null statement
2 ival = v1 + v2;;    // ok: second semicolon is a superfluous null statement
3
4 // disaster: extra semicolon: loop body is this null statement
5 while (iter != svec.end()) ; // the while body is the empty statement
6     ++iter; // increment is not part of the loop
```

A compound statement, usually referred to as a block, is a sequence of statements and declarations surrounded by a pair of curly braces. Names introduced inside a block are accessible only in that block and in blocks nested inside that block.

Conditional Statements

An `if` statement conditionally executes another statement based on whether a specified condition is true:

```
if (condition)
    statement
else
    statement2
```

We use a block to enclose multiple statements:

```
// if failing grade, no need to check for a plus or minus
if (grade < 60)
    lettergrade = scores[0];
else {
    lettergrade = scores[(grade - 50)/10]; // fetch the letter grade
    if (grade != 100) // add plus or minus only if not already an A++
        if (grade % 10 > 7) lettergrade += '+'; // grades ending in 8 or 9 get a +
            else if (grade % 10 < 3)
            lettergrade += '-'; // grades ending in 0, 1,or 2 get a
}
```

It is a common mistake to forget the curly braces when multiple statements must be executed as a block.

Danglging `else` is resolved by specifying that each `else` matched with the closest preceding unmatched `if`:

```
// WRONG: execution does NOT match indentation; the else goes with the inner if
if (grade % 10 >= 3)
    if (grade % 10 > 7)
        lettergrade += '+'; // grades ending in 8 or 9 get a +
else
    lettergrade += '-'; // grades ending in 3, 4, 5, 6, or 7 get a minus!

// add a plus for grades that end in 8 or 9 and a minus for those ending in 0, 1,
    or 2
if (grade % 10 >= 3) {
    if (grade % 10 > 7)
        lettergrade += '+'; // grades ending in 8 or 9 get a +
} else // curlies force the elseto go with the outer if
    lettergrade += '-'; // grades ending in 0, 1, or 2 will get a minus
```

We can make the else part of the outer if by enclosing the inner if in a block.

Iterative Statements

The syntactic form of the `for` statement is:

```
// for (initializer; condition; expression)
//     statement
```

```
3
4  // process characters in s until we run out of characters or we hit a whitespace
5  for (decltype(s.size()) index = 0;
6          index != s.size() && !isspace(s[index]); ++index)
7      s[index] = toupper(s[index]); // capitalize the current character
```

The order of evaluation of `for` loop:

1. *init-statement* is executed once at the start of the loop.
2. Next, *condition* is evaluated.
3. If the condition is `true`, the `for` body executes.
4. Finally, *expression* is evaluated.

init-statement can define several objects in a single declaration statement:

```
1  // remember the size of v and stop when we get to the original last element
2  for (decltype(v.size()) i = 0, sz = v.size(); i != sz; ++i)
3      v.push_back(v[i]);
```

A `for` header can omit any (or all) of *init-statement*, *condition*, or *expression*, by replacing them with null statements:

```
1  auto beg = v.begin();
2  for ( /* null */; beg != v.end() && *beg >= 0; ++beg)
3      ;// no work to do
4
5  // Omitting condition is equivalent to writing true as the condition
6  for (int i = 0; /* no condition */ ; ++i) {
7      // process i; code inside the loop must stop the iteration!
8  }
9
10 // If we omit expression for the for header, either the condition or the body must
       do something to advance the iteration
11 vector<int> v;
12 for (int i; cin >> i; /* no expression */)
13     v.push_back(i);
```

The syntactic form of range `for` statement to iterate through elements of a container or other sequence:

```
1  // for (declaration: expression)
2  //     statement
```

expression must represent a sequence such as braced initializer list, array or object of type such as `vector` or `string` that has `begin` and `end` members that return iterators. *declaration* defines a variable. It must be possible to convert each element of the sequence to the variable's type. The easiest way to make sure the types match is to use the `auto` type specifier.

2.6 December 10, 2023

2.6.1 Learn about SELinux

SELinux Architecture

SELinux consists of four main components: object managers (OM), access vector cache (AVC), security server, and security policy as show below:

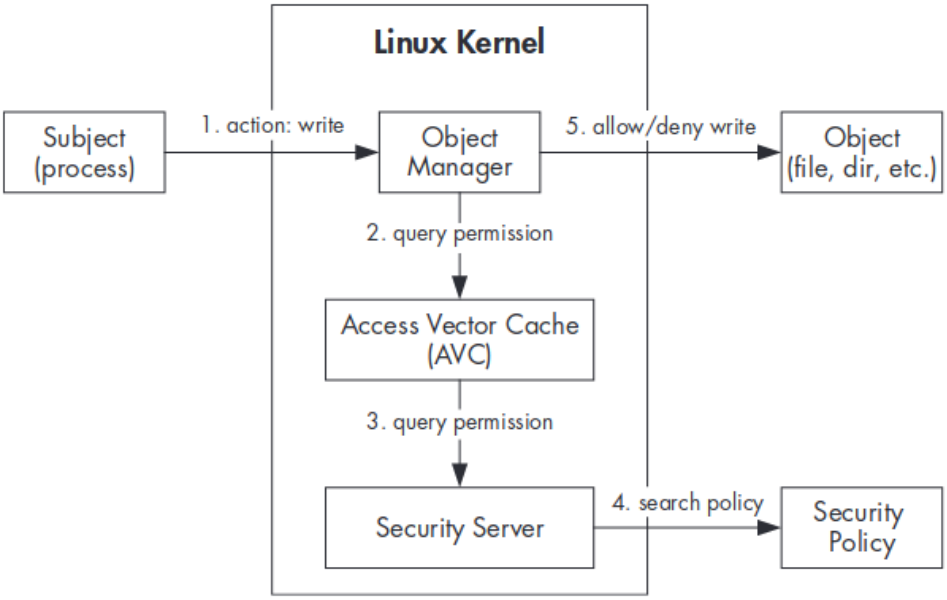


Figure 2.4: SELinux Components

When a subject asks to perform an action on an SELinux object, the associated object manager queries the AVC to see if the attempted action is allowed. If the AVC contains a cached security decision for the request, the AVC returns it to the OM which enforces the decision by allowing or denying the action. If the cache does not contain a matching security decision based on the currently loaded policy and returns it to the AVC, which caches it. The AVC in turn returns it to the OM which ultimately enforces the decision. The security server is part of the kernel, while the policy is loaded from userspace via a series of functions contained in the supporting userspace library.

SELinux Modes

SELinux has 3 modes:

- **Disabled.** No policy is loaded and only the default DAC security is enforced.
- **Permissive.** The policy is loaded and object access is checked, but access denial is only logged - not enforced.

- **Enforcing.** The security policy is both loaded and enforced, with violations logged.

SELinux mode can be checked and changed with the `getenforce` and `setenforce` commands:

```
1 # getenforce
2 Enforcing
3 # setenforce 0
4 # getenforce
5 Permissive
```

The mode set with `setenforce` is not persistent and will be reset to the default mode when the device reboots.

Mandatory Access Control

- **Subjects** are usually running processes that perform actions on objects,
- **Objects** are OS-level resources managed by the kernel (processes can also be objects), and
- **Actions** are carried out only if the security policy allows it.

Both subjects and objects have a set of security attributes (collectively known as the security context) which the OS queries in order to decide whether the requested action should be allowed or not. When SELinux is enabled, subjects cannot bypass or influence policy rules; therefore, the policy is mandatory. The MAC policy is only consulted if the DAC allows access to the resource. If the DAC denies access, the denial is taken as the final security decision.

SELinux support two forms of MAC: *type enforcement (TE)* and *multi-level security (MLS)*. MLS is used to enforce different levels of access to restricted information and is not used in Android. TE implemented in SELinux requires that all subjects and objects have an associated type and SELinux uses this type to enforce the rules of its security policy. A *type* is simply a string that's defined in the policy and assoicated with objects or subjects. Subject types references processes or groups of processes and are also referred to as *domains*. Types referring to objects usually specify the role an object plays within a policy, such as system file, application data file, and so on. The type (or domain) is an integral part of the security context.

Security Contexts

A *security context* (also referred to as a *security label*, or just *label*) is a string with four fileds delimited with colons: username, role, type, and an optional MLS security range.

An SELinux username is typically asosciated with a group of class of users; for example `user_u` for unprivileged users and `admin_u` for administrators. Users can be associated with one or more domain type. The type is used to group processes in a domain or to specify an object logical type. In Android context, the user is fixed to `u`.

The security range (or level) is used to implement ML and specifies the security levels a subject is allowed to access. In Android context, the security range is fixed to `s0`.

By specifying the option `-Z`, we can see the security context of the processes running:

```
# ps -Z
u:r:su:s0   root    1847    1834    10842820    3384    sigsuspe+
u:r:su:s0   root    1878    1847    10800932    3572    0
```

Subjects inherit the security context of their parent process, or they can change their context via *domain transition* which can be made automatic. For example, all system daemons are started by the *init* process, which has *u:r:init:s0* secuirty context, they would normally inherit this context, but Android's SELinux poly uses automatic domain transitions to set a dedicated domain to each daemon as need.

Similarly the context of files can be revealed using the `-Z` option:

```
# ls -Z
lrwxr-xr-x 1 root shell u:object_r:system_file:s0 6 2023-11-19 00:50 uuidgen ->
    toybox
-rwxr-xr-x 1 root shell u:object_r:vdc_exec:s0 101920 2023-11-19 00:50 vdc
-rwxr-xr-x 1 root shell u:object_r:viewcompiler_exec:s0 277472 2023-11-19 00:50
    viewcompiler
lrwxr-xr-x 1 root shell u:object_r:system_file:s0 6 2023-11-19 00:50 vmstat ->
    toybox
-rwxr-xr-x 1 root shell u:object_r:vold_exec:s0 994368 2023-11-19 00:50 vold
-rwxr-xr-x 1 root shell u:object_r:vold_prepare_subdirs_exec:s0 38576 2023-11-19
    00:50 vold_prepare_subdirs
-rwxr-xr-x 1 root shell u:object_r:system_file:s0 169 2023-11-19 01:02 vr
lrwxr-xr-x 1 root shell u:object_r:system_file:s0 6 2023-11-19 00:50 watch ->
    toybox
-rwxr-xr-x 1 root shell u:object_r:watchdogd_exec:s0 10760 2023-11-19 00:50
    watchdogd
lrwxr-xr-x 1 root shell u:object_r:system_file:s0 6 2023-11-19 00:50 wc -> toybox
lrwxr-xr-x 1 root shell u:object_r:system_file:s0 6 2023-11-19 00:50 which ->
    toybox
lrwxr-xr-x 1 root shell u:object_r:system_file:s0 6 2023-11-19 00:50 whoami ->
    toybox
-rwxr-xr-x 1 root shell u:object_r:wificond_exec:s0 393248 2023-11-19 00:50
    wificond
```

For objects, the security context is persistent and is usually stored as an extended attribute in the file's metadata. Objects typically inherit the type label of their parent (their directory), and can change to a different label via *type transition*.

Security Policy

Security policies are used by the security server in the kernel to allow or disallow access to kernel objects at runtime. For performance reasons, the policy is typically in binary form generated by compiling a number of policy source files. *Statements* define policy entities such as types, users, and roles. *Rules* allow or deny access to objects (access vector rules); and designate how default users, roles, and types are assigned (default rules). [5]

The listing below declares `file_type` and `domain` attributes, declares `system_data_file` type and associates it with `file_type` and `data_file_type` attributes, declares `untrusted_app` type and associate it with `domain` attribute:

```
1 attribute file_type;
2 attribute domain;
3
4 type system_data_file, file_type, data_file_type;
5 type untrusted_app, domain;
```

`user` statement declares an SELinux user identifier, associates it with its role(s), and optionally specifies its default security level and the range of security levels that user can access:

```
1 user u roles { r } level s0 range s0 - mls_systemhigh;
```

The *u* user is associated with the *r* role (inside the braces), which in turn is declared using the `role` statement as show below:

```
1 role r;
2 role r types domain;
```

The second statement associates the *r* role with the `domain` attribute, which marks it as a role assigned to processes (domains).

`permissive` statement allows a named domain to run in permissive mode[6]:

```
1 type adbd, domain;
2 permissive adbd;
3 --snip--
```

The `class` statement defines an SELinux object class. Object classes and their associated permissions are determined by the respected object manager implementations in Linux kernel, and are static within a policy. Object classes are usually defined in the *security_classes* policy source file:

```
1 --snip-
2 # file-related classes
3 class filesystem
4 class file
5 class dir
6 class fd
7 class lnk_file
```

[5] Type, attribute and permission statements make up the bulk of a security policy.

[6] Most domains in Android's current base policy are permissive.

```
class chr_file
class blk_file
class sock_file
class fifo_file
--snip--
```

Access vectors are usually defined and associated with object classes in a policy source file called *access_vectors*. Permissions can be either class-specific or inheritable by one or more object classes, in which case they're defined with the `common` keyword. Below is the definition of the set of permissions common to all file objects, and the association of the `dir` class (which represents directories), and a set of directory-specific permissions (*add_name*, *remove_name*, and so on):

```
--snip--
common file
{
    ioctl
    read
    write
    create
    getattr
    setattr
    lock
    --snip--
}
--snip--
class dir
inherits file
{
    add_name
    remove_name
    reparent
    search
    rmdir
    --snip--
}
--snip--
```

Type Transition Rules

Type enforcement rules and access vector rules typically make the bulk of an SELinux policy. The most commonly used type of enforcement rule is the `type_transition` rule, which specifies when domain and type transitions are allowed:

```
# from wpa_supplicant.te

# wpa - wpa supplicant or equivalent
type wpa, domain;
permissive wpa;
type wpa_exec, exec_type, file_type;

init_daemon_domain(wpa)
unconfined_domain(wpa)

```

```
11 # wpa_supplicant daemon uses the type transition rule to associate the control
       sockets it creates in /data/misc/wifi directory with wpa_socket type
12 type_transition wpa             wifi_data_file: sock_file   wpa_socket;
13 #               source type     target type     class       type of object after
       the transition
```

Domain Transition Rules

Most daemons are associated with a dedicated and use domain transitions to switch their domain when started. This is typically accomplished using the `init_daemon_domain()` macro, which under the hood is implemented using the `type_transition` keyword. The `init_daemon_domain()` macro takes one parameter and is defined in the *te_macros* file using two other macros: `domain_trans()` and `domain_auto_trans()` which are used to allow transition to a new domain and to execute the transition automatically, respectively:

```
1  # Domain transition macros definition int the te_macros file
2
3  # domain_trans(olddomain, type, newdomain)
4  define(‘domain_trans’, ‘
5  allow $1 $2:file { getattr open read execute };
6  allow $1 $3:process transition;
7  allow $3 $2:file { entrypoint read execute };
8  allow $3 $1:process sigchld;
9  dontaudit $1 $3:process noatsecure;
10 allow $1 $3:process { siginh rlimitinh }; ’)
11 # domain_auto_trans(olddomain, type, newdomain)
12 define(‘domain_auto_trans’, ‘
13 domain_trans($1,$2,$3)
14 type_transition $1 $2:process $3; ’)
15 # init_daemon_domain(domain)
16 define(‘init_daemon_domain’, ‘
17 domain_auto_trans(init, $1_exec, $1)
18 tmpfs_domain($1) ’)
19 --snip--
```

The lines beginning with the `allow` keyword are access vector (AV) rules.

Access Vector Rules

AV rules define what privileges processes have at runtime by specifying the set of permissions they have over their target objects:

```
1 # Format of AV rules
2 rule_name source_type target_type : class perm_set;
```

The `rule_name` can be `allow`, `dontallow`, `auditallow`, `neverallow`. `allow` specifies the operations that a subject (process) of the specified source type is allowed to perform on an object of the target type and class specified in the rule. `auditallow` rule is used with `allow` to record audit events when an operation is allowed. `dontaudit` rule is used to suppress the auditing of denial messages when a specified event is known

to be safe. `neverallow` rule says that the declared operation should never be allowed even if an explicit `allow` rule that allows it exists.

To form a rule, `source_type` and `target_type` elements are replaced with one or more previously defined `type` or `attribute` identifiers, where `source_type` is the identifier of a subject (process), and `target_type` is the identifer of an object the process is trying to access. The `class` element is replaced with the object class of the target, and `perm_set` specifies the set of permissions that the source process has over the target object. You can specify multiple types, classes, and permissions by enclosing them in braces ({}). In addition, so rules support use of the wildcard (*) and complement(~) operators, which allow you to specify that all types should be included or that all types except those explicityly listed should be included, respectively:

```
type vold, domain;
type vold_exec, exec_type, file_type;
init_daemon_domain(vold)

# allows daemons running in vold domain to mount, unmount, and remount filesystems
     of sdcard_type
allow vold sdcard_type:filesystem { mount remount unmount };

# allows daemons running in vold domain to use the CAP_SYS_PTRACE and CAP_KILL
    Linux capabilities
# self means that target domain is same as source (vold in this case)
allow vold self:capability { sys_ptrace kill };

type installd, domain;

# no audit log will be created if the installd daemon is denied the CAP_SYS_ADMIN
    capability
dontaudit installd self:capability sys_admin;

# forbids all domains but the init domain to load the SELinux policy
neverallow { domain -init } kernel:security load_policy;
```

2.7 December 13, 2023

2.7.1 Android Testing

Meeting with Mariano and Biniam

Yan Nai is encountering exceptions in DeepGUI[7]'s final step: MonkeyTest.

DeepGUI has 3 steps:

1. Data Collection of interations and events
2. Training
3. Monkey Test

[7] `https://github.com/Feri73/deep-gui`

2.8 December 19, 2023

2.8.1 SELinux Syntax

SELinux Tutorials from [8].

The security context of a process

The security context, together with the run-time user that the process is in, would define what the process is allowed to do.

```
ps -ef # -e gives all processes, -f gives more info, -Z gives security context

ls -ld dir # shows the permissions related to this directory
ls -ldZ dir # shows the permissions and also SELinux context
```

- **Domain.** The context of the process that is acting upon something.
- **Type.** The context of the resource on which the process is acting.
- **Class.** The object class of the resource (e.g. *file* or *socket*).
- **Permissions.** The permissions that are allowed given the *domain*, *type* and *class*.

SELinux rule syntax:

```
allow <domain> <type>:<class> { <permissions> };
```

Decoding Permission Denial Message

Message:

```
type=AVC msg=audit(1363289005.532:184): avc:  denied  { read } for  pid=29199 comm
    ="Trace"
name="online" dev="sysfs" ino=30 scontext=staff_u:staff_r:googletalk_plugin_t
tcontext=system_u:object_r:sysfs_t tclass=file
```

Log part	Name	Description
`type=AVC`	Log type	Only in the `audit.log` file; it informs the user what kind of audit log type this is.
`msg=audit(1363289005.532:184)`	Timestamp	Timestamp in seconds since epoch, meaning the number of seconds since January 1st, 1970. You can convert this to a more human readable format using date -d @ followed by the number, like so: `date -d @1363292159.532`.

[8] `https://wiki.gentoo.org/wiki/SELinux/Tutorials`

Log part	Name	Description
`avc:`	Log type (again)	
`denied`	State (if enforced)	What SELinux did, which can be either `denied` or `granted`. Note that, if SELinux is in premissive mode, then it will still log as `denied` even though it was enforced.
`{ read }`	Permission	Ther permission that was requested or executed. In this case, it is a read operation. Sometimes the permission contains a set like `{ read write }` but in most cases, it is a single permission request.
`for pid=29199`	Process PID	Ther process identifier of the process that took the action.
`comm="Trace"`	Process CMD	The process command (without arguments, and limited to 15 characters), which helps users identify what the process was in case the process is already gone (a PID is only useful if the process is still running)
`name="online"`	Target name	The name of the target (in this case, file name). This field depends heavily on the target itself; it can also be `path=`, `capability=`, `src=` and more. But in those cases, its purposes should be clear from the rest of the log.
`dev="sysfs"`	Device	Device on which the target (in case of a file or file system). In this case, the device is `sysfs` so we have the hint immediately that this is for something inside `/sys`. Other valid example are `dev=md-0`, `dev=sda1`, or `dev=tmpfs`.
`ino=30`	inode number	The inode number of the target file. In this case, since we know it is on the `sysfs` file system, we can look for this file using: `find /sys -xdev -inum 30`
`scontent=staff_u:staff_r:googletalk_plugin_t`	Source context	The security context of the process (the domain)
`tcontext=system_u:object_r:sysfs_t`	Target context	The security context of the target resource (in this case the file)
`tclass=file`	Target class	The class of the target.

Table 2.8: Permission Denied Syntax

2.9 December 22, 2023

2.9.1 SELinux Practical

File Contexts

Objects are mapped to classes[9] (e.g., a file, a directory, a symbolic link, a socket) and the different kinds of access for each class are represented by permissions. While types and attributes are regularly updated as part of Android SELinux policy, permissions and classes are statically defined and rarely updated as part of a new Linux release.

Attributes

Attributes allow the grouping of access control rules[10]. A domain or a type can be assigned an attribute, and access control rules can be defined on attributes. Through attribute, a rule can be valid for all types that are assigned a particular attfibute.

2.10 December 24, 2023

2.10.1 Run Daemon

Configure SELinux

Focus on allowing the shell process to execute the

Remove the following from `aosp13/device/generic/goldfish/app/wei_daemon/Android.bp`:

```
1 init_rc: ["init.weiminn.rc"],
```

Remove the following from `AOSP/device/generic/goldfish/sepolicy/x86/weiminn.te`:

```
1 type weiminn, domain;
2 #permissive weiminn;
3 type weiminn_exec, vendor_file_type, exec_type, file_type;
4
5 init_daemon_domain(weiminn)
```

Remove the following from `AOSP/device/generic/goldfish/app/init.weiminn.rc`:

```
1 service weiminn_daemon /vendor/bin/hw/weiminn_daemon
2 class main
3 user system
4 group system
5 oneshot
```

[9] https://android.googlesource.com/platform/system/sepolicy/+/refs/heads/main/private/security_classes

[10] https://wiki.gentoo.org/wiki/SELinux/Type_enforcement

Change the file contexts at aosp13/device/generic/goldfish/sepolicy/x86/file_contexts.te:

```
/vendor/bin/hw/weiminn_daemon u:object_r:weiminn_bin:s0
```

Making the project returns the following error message:

```
[  1% 9/786] //system/sepolicy:vendor_sepolicy.cil.raw Building cil for vendor_sepolicy.cil.raw [common]
FAILED: out/soong/.intermediates/system/sepolicy/vendor_sepolicy.cil.raw/android_common/vendor_sepolicy.cil.raw
out/host/linux-x86/bin/checkpolicy -C -M -c 30 -o out/soong/.intermediates/system/sepolicy/vendor_sepolicy.cil.raw/android_common/vendor_sepolicy.cil.raw out/soong/.intermediates/system/sepolicy/vendor_sepolicy.conf/android_common/vendor_sepolicy.conf && out/host/linux-x86/bin/build_sepolicy filter_out -f out/soong/.intermediates/system/sepolicy/reqd_policy_mask_for_vendor.cil/android_common/reqd_policy_mask_for_vendor.cil -t out/soong/.intermediates/system/sepolicy/vendor_sepolicy.cil.raw/android_common/vendor_sepolicy.cil.raw # hash of input list: 67f02b7bf3aa8ceaff84d183690cbc5581d11fc109b32ddce0ba702ff27c6223
device/generic/goldfish/sepolicy/x86/file_contexts.te:2:ERROR 'syntax error' at token '/vendor/bin/hw/weiminn_daemon' on line 4329
8:
/vendor/bin/hw/weiminn_daemon u:object_r:weiminn_bin:s0allow init tmpfs:lnk_file { create rename setattr unlink { { getattr open read ioctl lock map watch watch_reads } { open append write lock map } } };
#line 1 "device/generic/goldfish/sepolicy/x86/file_contexts.te"
checkpolicy:  error(s) encountered while parsing configuration
[  1% 10/786] //system/sepolicy:sepolicy_neverallows_vendor Neverallow check: sepolicy_neverallows_vendor
FAILED: out/soong/.intermediates/system/sepolicy/sepolicy_neverallows_vendor/policy
out/host/linux-x86/bin/checkpolicy -M -c 30 -o out/soong/.intermediates/system/sepolicy/sepolicy_neverallows_vendor/policy out/soong/.intermediates/system/sepolicy/sepolicy_neverallows_vendor.checkpolicy.conf/android_common/sepolicy_neverallows_vendor.checkpolicy.conf # hash of input list: 15871fa7f1904c26cfc726ea362c19ede7f225bff09f1871b1f7d5657882753a
device/generic/goldfish/sepolicy/x86/file_contexts.te:2:ERROR 'syntax error' at token '/vendor/bin/hw/weiminn_daemon' on line 7825
8:
/vendor/bin/hw/weiminn_daemon u:object_r:weiminn_bin:s0allow init tmpfs:lnk_file { create rename setattr unlink { { getattr open read ioctl lock map watch watch_reads } { open append write lock map } } };
#line 1 "device/generic/goldfish/sepolicy/x86/file_contexts.te"
checkpolicy:  error(s) encountered while parsing configuration
16:56:04 ninja failed with: exit status 1
```

Remove the content of aosp13/device/generic/goldfish/sepolicy/x86/file_contexts.te:

```
/vendor/bin/hw/weiminn_daemon u:object_r:weiminn_bin:s0
```

Change the service startup script at aosp13/system/core/rootdir/init.rc:

```
service weiminn_daemon /vendor/bin/hw/weiminn_daemon
class core
user shell
group shell log readproc
```

```
5 seclabel u:r:shell:s0
```

Now the error message changed to:

```
1 [  171.154645] init: starting service 'weiminn_daemon'...
2 [  171.155794] init: cannot execv('/vendor/bin/hw/weiminn_daemon'). See the '
      Debugging init' section of init's README.md for tips: Permission denied
3 [  171.155852] type=1400 audit(1703410052.492:42): avc: denied { execute } for
      comm="init" name="weiminn_daemon" dev="dm-3" ino=110 scontext=u:r:init:s0
      tcontext=u:object_r:vendor_file:s0 tclass=file permissive=0
4 [  171.156593] init: Service 'weiminn_daemon' (pid 1868) exited with status 127
5 [  171.157512] init: Sending signal 9 to service 'weiminn_daemon' (pid 1868)
      process group...
6 [  171.157946] libprocessgroup: Successfully killed process cgroup uid 2000 pid
      1868 in 0ms
```

inside `dmesg`, and

```
1 12-24 17:28:50.303     0     0 I init    : starting service 'weiminn_daemon'...
2 12-24 17:28:50.304     0     0 E init    : cannot execv('/vendor/bin/hw/
      weiminn_daemon'). See the 'Debugging init' section of init's README.md for
      tips: Permission denied
3 12-24 17:28:50.305     0     0 I init    : Service 'weiminn_daemon' (pid 1884)
      exited with status 127
4 12-24 17:28:50.306     0     0 I init    : Sending signal 9 to service '
      weiminn_daemon' (pid 1884) process group...
5 12-24 17:28:50.306     0     0 I libprocessgroup: Successfully killed process
      cgroup uid 2000 pid 1884 in 0ms
```

inside `adb logcat`.

It seems like the daemon is being started by the `init` process and the binary file inherit its file context `vendor_file` from its parent folder.

2.11 December 25, 2023

2.11.1 Run Daemon

Configure SELinux

Change the `seclabel` of the service inside `AOSP/device/generic/goldfish/app/init.weiminn.rc` to:

```
1 seclabel u:r:shell:s0
```

from

```
1 seclabel u:r:weiminn_daemon:s0
```

and the error message changed to

```
1 [61133.720482] init: starting service 'weiminn_daemon'...
2 [61133.721480] init: cannot setexeccon('u:r:weiminn_daemon:s0') for weiminn_daemon
      : Invalid argument
3 [61133.722452] init: Service 'weiminn_daemon' (pid 14423) exited with status 6
4 [61133.722745] init: Sending signal 9 to service 'weiminn_daemon' (pid 14423)
      process group...
5 [61133.723107] libprocessgroup: Successfully killed process cgroup uid 0 pid 14423
       in 0ms
```

in `dmesg`, and

```
12-25 10:57:23.010     0     0 I init    : starting service 'weiminn_daemon'...
12-25 10:57:23.011     0     0 F init    : cannot setexeccon('u:r:weiminn_daemon:
    s0') for weiminn_daemon: Invalid argument
12-25 10:57:23.011     0     0 I init    : Service 'weiminn_daemon' (pid 14441)
    exited with status 6
12-25 10:57:23.012     0     0 I init    : Sending signal 9 to service '
    weiminn_daemon' (pid 14441) process group...
12-25 10:57:23.012     0     0 I libprocessgroup: Successfully killed process
    cgroup uid 0 pid 14441 in 0ms
```

inside `adb logcat`.

The error seems to be come from the SELinux type `weiminn_daemon` inside the `init.rc`. So, I'm gonna change back to `seclabel u:r:shell:s0`, and inspect the `avc: denied` message, which tells us that the process is `init` type, and the binary is `vendor_file` type.

Add Access Vector rule to allow execute on `vendor_file` type. Alternatively, I put `setenforce 0` inside `adb shell`, and voila!

Log to `logcat` every time ART executes a Java method[11]. But it requires to be NOT on emulator, so scrap that plan.

[11] `https://stackoverflow.com/questions/33478647/android-app-java-jni-call-hooking-strategies`, `https://www.youtube.com/watch?v=mFq0vNvUgj8`

Part II

2024

Chapter 3

January

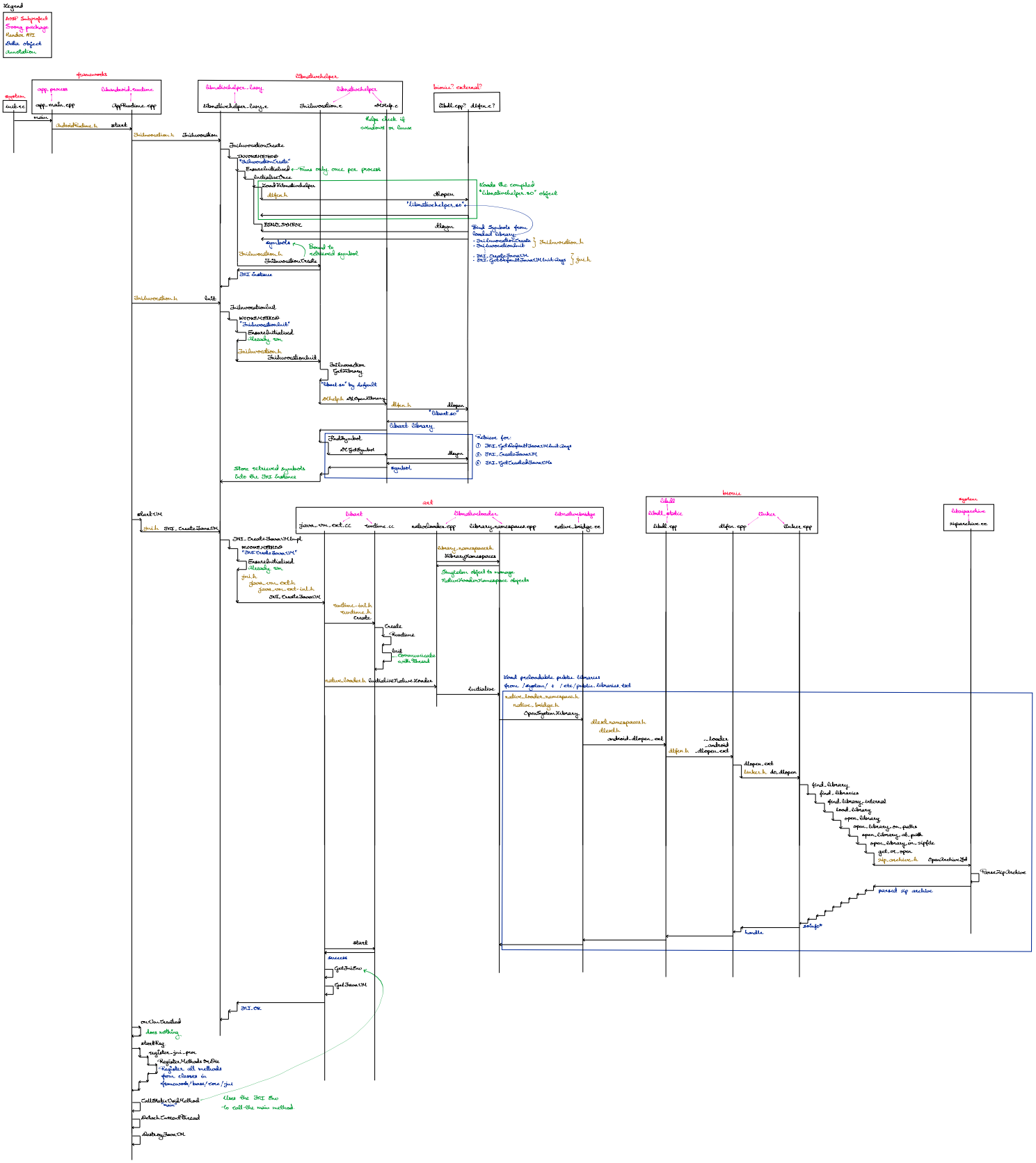
3.1 January 1, 2024

3.1.1 Connect Daemon to ART

References: Deep dive into ART(Android Runtime) for dynamic binary analysis[1], Android Shared Object loading process [2], Android Dynamic Library loading [3]

Took me 5 days to properly dissect the ART and Bionic loading process of Android OS.

[1] https://www.youtube.com/watch?v=mFq0vNvUgj8
[2] https://blog.csdn.net/qq_37661242/article/details/130448221
[3] https://juejin.cn/post/7274991134362124327


Legend
AOSP Subproject
Soong package
Runtime API
Public object
Invocation
frameworks
app_process
libandroid_runtime
system
cmds
app_main.cpp
AppRuntime.cpp
main
AndroidRuntime.h
start
libnativehelper
libnativehelper_lazy
libjnihelper
libnativehelper_lazy.c
JniInvocation.c
JNIHelp.c
Helper check if
invoked on Linux
bionic? external?
libdl.cpp
dlfcn.c
JniInvocation.h
JniInvocation
JniInvocationCreate
UNINITIALIZED
"libnativehelper.so"
EnsureInitialized - Runs only once per process
InitializeOnce
LoadNativeHelper
dlfcn.h
dlopen
Loads the compiled
"libnativehelper.so" object
RTLD_NOW|RTLD
dlsym
Find Symbols from
loaded library:
- JniInvocationCreate
- JniInvocationInit
- JNI_CreateJavaVM
- JNI_GetDefaultJavaVMInitArgs
JniInvocation.h
symbols
Bound to
retrieved symbol
JniInvocationCreate
JNI instance
JniInvocation.h
Init
JniInvocationInit
WINDOWS|HOST
"JniInvocationInit"
EnsureInitialized
Already ran
JniInvocation.h
JniInvocationInit
JniInvocation
GetLibrary
"libart.so" by default
dlfcn.h dlOpenLibrary
dlfcn.h
dlopen
"libart.so"
libart library
FindSymbol
dlGetSymbol
dlsym
"Retrieve for:
① JNI_GetDefaultJavaVMInitArgs
② JNI_CreateJavaVM
③ JNI_GetCreatedJavaVMs
symbol
Store retrieved symbols
into the JNI instance
art
libart
java_vm_ext.cc
runtime.cc
libnativeloader
native_loader.cpp
libnativebridge
native_bridge.cc
bionic
libdl
libdl_static
libdl.cpp
linker
dlfcn.cpp
linker.cpp
system
libziparchive
ziparchive.cc
BlockVM
jni.h JNI_CreateJavaVM
JNI_CreateJavaVM
JNI_CreateJavaVM_impl
WINDOWS|HOST
"JNI_CreateJavaVM"
EnsureInitialized
Already ran
jni.h
java_vm_ext.h
java_vm_ext_init.h
JNI_CreateJavaVM
runtime_init.h
runtime.h
Create
Create
Runtime
Init
Communicate
with Thread
native_loader.h InitializeNativeLoader
Initialize
library_namespaces
LibraryNamespaces
Singleton object to manage
NativeLoaderNamespace objects
Load predictable public libraries
from /system/ + /etc/public.libraries.txt
native_loader_namespace.h
native_bridge.h
OpenSystemLibrary
dlext_namespaces.h
dlfcn.h
android_dlopen_ext
dlfcn.h
__loader
_android
_dlopen_ext
dlopen_ext
linker.h do_dlopen
find_library
find_libraries
find_library_internal
load_library
open_library
open_library_on_paths
open_library_at_path
open_library_in_zipfile
get_cd_open
zip_archive.h
OpenArchiveFd
PineZipArchive
parsed zip archive
soinfo*
Loader
start
success
GetJniEnv
GetJavaVM
JNI_OK
onVmCreated
does nothing
startReg
register_jni_proc
RegisterMethodsOrDie
Registers all methods
from classes in
"com.android.internal.os"
CallStaticVoidMethod
"main"
Uses the JNI Env
to call the main method
AttachCurrentThread
startThreadLoop

Have to always sync the changes between aosp13/libnativehelper/include_jni/jni.h and aosp13/system/extras/module_ndk_libs/libnativehelper/include_jni/jni.h, so insert the following function definition after the definition of VM Initialization functions:

```
/*
* VM initialization functions.
*
* Note these are the only symbols exported for JNI by the VM.
*/
jint JNI_GetDefaultJavaVMInitArgs(void*);
jint JNI_CreateJavaVM(JavaVM**, JNIEnv**, void*);
jint JNI_GetCreatedJavaVMs(JavaVM**, jsize, jsize*);

// ADDED BY WEI MINN
string WEI_TestFunc();
```

Add k_WEI_TestFunc into MethodIndex enum of aosp13/libnativehelper/libnativehelper_lazy.c.

Add following statement inside the InitializeOnce of aosp13/libnativehelper/libnativehelper_lazy.c after the definition of BIND_SYMBOL:

```
// ADDED BY WEI MINN
BIND_SYMBOL(WEI_TestFunc);
```

Add following statement at the bottom of aosp13/libnativehelper/libnativehelper_lazy.c:

```
// ADDED BY WEI MINN
jstring WEI_TestFunc(){
    return "WEI␣TEST␣libnativehelper";
}
```

Here is the source code of the daemon in aosp13/device/generic/goldfish/app/wei_daemon/weiminn.cpp:

```
#include <unistd.h>
#include <stdio.h>

#include <android/log.h>
#include <nativehelper/JniInvocation.h>
#include <jni.h>

#define DELAY_SECS 2
#define ALOG(msg) __android_log_write(ANDROID_LOG_DEBUG, "WEIMINN␣PROJ", msg)

int main(int argc, char *argv[]) {
    ALOG("STARTING␣WEIMINN␣PROJECT");

    int n = 0;
    while (true) {
        sleep(DELAY_SECS);
        n++;

        struct _JNIEnv env;
        const char *res = env.GetStringUTFChars(WEI_TestFunc(), NULL);
        ALOG(res);
```

```
22
23          // ALOG("Test");
24      }
25  }
```

But the daemon keeps crashing!

Change the return types from `jstring` to `void*`, and print out `ALOG(WEI_TestFunc())` directly instead of converting from `jstring` to `char` and voila!

Add following statement at the bottom of `art` namespace inside `aosp13/art/runtime/jni/java_vm_ext.cc`:

```
1  // ADDED BY WEI MINN
2  extern "C" const void* WEI_TestFunc() {
3    char const *toReturn = "hello from runtime";
4    return toReturn;
5  }
```

Add following statement in `JniInvocationInit` function inside `aosp13/libnativehelper/JniInvocation.c`:

```
1  // ORIGINAL
2  DlSymbol JNI_GetDefaultJavaVMInitArgs_ = FindSymbol(library, "
       JNI_GetDefaultJavaVMInitArgs");
3  if (JNI_GetDefaultJavaVMInitArgs_ == NULL) {
4      return false;
5  }
6
7  DlSymbol JNI_CreateJavaVM_ = FindSymbol(library, "JNI_CreateJavaVM");
8  if (JNI_CreateJavaVM_ == NULL) {
9      return false;
10 }
11
12 DlSymbol JNI_GetCreatedJavaVMs_ = FindSymbol(library, "JNI_GetCreatedJavaVMs");
13 if (JNI_GetCreatedJavaVMs_ == NULL) {
14     return false;
15 }
16
17 // ADDED BY WEI MINN
18 DlSymbol WEI_TestFunc_ = FindSymbol(library, "WEI_TestFunc");
19 if (WEI_TestFunc_ == NULL) {
20     return false;
21 }
22
23 // ORIGINAL
24 instance->jni_provider_library_name = library_name;
25 instance->jni_provider_library = library;
26 instance->JNI_GetDefaultJavaVMInitArgs = (jint (*)(void *))
       JNI_GetDefaultJavaVMInitArgs_;
27 instance->JNI_CreateJavaVM = (jint (*)(JavaVM**, JNIEnv**, void*))
       JNI_CreateJavaVM_;
28 instance->JNI_GetCreatedJavaVMs = (jint (*)(JavaVM**, jsize, jsize*))
       JNI_GetCreatedJavaVMs_;
29
30 // ADDED BY WEI MINN
31 instance->WEI_TestFunc = (char* (*)()) WEI_TestFunc_;
```

Add following statement at the bottom of `JniInvocationImpl` struct in `aosp13/libnativehelper/JniInvocation.c`:

```
// Function pointers to methods in JNI provider.
jint (*JNI_GetDefaultJavaVMInitArgs)(void*);
jint (*JNI_CreateJavaVM)(JavaVM**, JNIEnv**, void*);
jint (*JNI_GetCreatedJavaVMs)(JavaVM**, jsize, jsize*);

// ADDED BY WEI MINN
void* (*WEI_TestFunc)();
```

Change all the function return signatures to `const void*`, because of `extern "C"` in `java_vm_ext.cc`.

Trying to call from `libnativehelper_lazy` to `art` by calling bound method stored inside `INVOKE_METHOD`:

```
// ADDED BY WEI MINN
const void* WEI_TestFunc(){
    typedef const void* (*M)();
    INVOKE_METHOD(WEI_TestFunc, M, library, buffer);
}
```

Getting compile time error!

3.2 January 2-3, 2024

3.2.1 Connect ART to Bionic

Need to solve the connection between `libnativehelper_lazy` and `art` first.

Change the parameters of `WEI_TestFunc` inside `libnativehelper_lazy`:

```
// ADDED BY WEI MINN
const void* WEI_TestFunc(){
    typedef const void* (*M)();
    EnsureInitialized();
    void* method = g_Methods[k_WEI_TestFunc];
    return ((M) method)();
}
```

Got this error message when trying to compile:

```
libnativehelper/libnativehelper_lazy.c:287:20: error: array index 16 is past the
    end of the array (which contains 15 elements) [-Werror,-Warray-bounds]
    void* method = g_Methods[k_WEI_TestFunc];
                   ^         ~~~~~~~~~~~~~~
```

Swap the position of `WEI_TestFunc` with `k_MethodCount` inside `MethodIndex enum` of `libnativehelper_lazy.c`:

```
// ADDED BY WEI MINN
k_WEI_TestFunc,

// Marker for count of methods
k_MethodCount
```

Android Emulator boot at startup screen and this is message from `adb logcat`:

```
01-02 13:12:46.793  3799  3799 F zygote  : Failed to find symbol 'WEI_TestFunc' in
    libnativehelper.so: undefined symbol: WEI_TestFunc
```

Because I forgot to put the following implementation inside `aosp13/libnativehelper/JniInvoca`

```
jint WEI_TestFunc(void* res) {
    ALOG_ALWAYS_FATAL_IF(NULL == g_impl.WEI_TestFunc, "Runtime library not loaded.
        ");
    return g_impl.WEI_TestFunc(res);
}
```

Daemon cannot load `libnativehelper.so`:

```
01-02 13:22:47.648     0     0 I init    : starting service 'weiminn_daemon'...
01-02 13:22:48.263  1867  1867 D WEIMINN PROJ: STARTING WEIMINN PROJECT
01-02 13:22:50.264  1867  1867 F weiminn_daemon: Failed to load libnativehelper.so
    : dlopen failed: library "libnativehelper.so" not found
```

Tombstone file at `adb shell cat /data/tombstones/tombstone_37 > tb.txt`:

```
*** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
Build fingerprint: 'Android/sdk_phone_x86_64/emulator_x86_64:13/TD1A.220804.031/
    eng.weimin.20231119.002237:userdebug/test-keys'
Revision: '0'
ABI: 'x86_64'
Timestamp: 2024-01-02 13:42:01.100413406+0800
Process uptime: 3s
Cmdline: /vendor/bin/hw/weiminn_daemon
pid: 3002, tid: 3002, name: weiminn_daemon  >>> /vendor/bin/hw/weiminn_daemon <<<
uid: 2000
signal 6 (SIGABRT), code -1 (SI_QUEUE), fault addr --------
Abort message: 'Failed to load libnativehelper.so: dlopen failed: library "
    libnativehelper.so" not found'
    rax 0000000000000000  rbx 0000000000000bba  rcx 00007b83e618d68f  rdx
        0000000000000006
    r8  c7632a7a8fbc8b50  r9  c7632a7a8fbc8b50  r10 00007fff3fde6d30  r11
        0000000000000217
    r12 00007fff3fde73b8  r13 0000000000000000  r14 00007fff3fde6d28  r15
        0000000000000bba
    rdi 0000000000000bba  rsi 0000000000000bba
    rbp 0000000000000001  rsp 00007fff3fde6d20  rip 00007b83e618d68f

backtrace:
        #00 pc 000000000005f68f  /apex/com.android.runtime/lib64/bionic/libc.so (
            abort+191) (BuildId: 57def992cb1772e13608c8efcafd893b)
        #01 pc 0000000000006a1a  /system/lib64/liblog.so (
            __android_log_default_aborter+10) (BuildId:
            acde2d0ef136fd6d1eb2a30987f39d55)
        #02 pc 00000000000075d2  /system/lib64/liblog.so (__android_log_assert
            +370) (BuildId: acde2d0ef136fd6d1eb2a30987f39d55)
        #03 pc 0000000000001cee  /vendor/bin/hw/weiminn_daemon (InitializeOnce
            +782) (BuildId: 64dca3fe723864a1e2dd2e698986fb43)
        #04 pc 00000000000ce2c3  /apex/com.android.runtime/lib64/bionic/libc.so (
            pthread_once+67) (BuildId: 57def992cb1772e13608c8efcafd893b)
        #05 pc 00000000000019c6  /vendor/bin/hw/weiminn_daemon (WEI_TestFunc+22) (
            BuildId: 64dca3fe723864a1e2dd2e698986fb43)
        #06 pc 0000000000001991  /vendor/bin/hw/weiminn_daemon (main+65) (BuildId:
             64dca3fe723864a1e2dd2e698986fb43)
        #07 pc 0000000000050c49  /apex/com.android.runtime/lib64/bionic/libc.so (
            __libc_init+89) (BuildId: 57def992cb1772e13608c8efcafd893b)

memory near rcx (/apex/com.android.runtime/lib64/bionic/libc.so):
    00007b83e618d660 45e820245c89ffff 4824244489000757  ...\$ .EW...D$$H
```

```
    00007b83e618d670 00000000282444c7 8d4cf76349fb6348  .D$(....Hc.Ic.L.
    00007b83e618d680 00000006ba102454 0f050f00000129b8  T$.......).......
    00007b83e618d690 290ffffc2ad20510 100f000000a02484  ...*...).$......
    00007b83e618d6a0 84290ffffc2ab305 b48d480000009024  ..*...).$....H..
    00007b83e618d6b0 0006bf0000009024 075bcfe8d2310000  $.........1...[.
    00007b83e618d6c0 894c00000002bf00 00075bb0e8d231f6  ......L..1...[..
    00007b83e618d6d0 e8c03100000027bf bfc3894800075754  .'...1..TW..H...
    00007b83e618d6e0 45e8c031000000ba 570fc68949000757  ....1..EW..I...W
    00007b83e618d6f0 290f102444290fc0 802484290f202444  ..)D$..)D$ .).$.
    00007b83e618d700 702444290f000000 44290f602444290f  ....)D$p.)D$‘.)D
    00007b83e618d710 0f402444290f5024 182444c730244429  $P.)D$@.)D$0.D$.
    00007b83e618d720 20245c89ffffffff 244489000756 83e8  .....\$ ..V...D$
    00007b83e618d730 0000282444c74824 f66349fb63480000  $H.D$(....Hc.Ic.
    00007b83e618d740 0006ba1024548d4c 0f00000129b80000  L.T$.......)....
    00007b83e618d750 45e80000007fbf05 ccccccccc00075b   .......E[.......

memory near r10 ([stack]):
    00007fff3fde6d10 0000000000000001 00007b83e618d66b  ........k....{..
    00007fff3fde6d20 c7632a7a8fbc8b50 ffffffffffffffdf  P...z*c.........
    00007fff3fde6d30 0000000000000000 00000000ffffffff  ................
    00007fff3fde6d40 000007d000000bba 0000000000000000  ................
    00007fff3fde6d50 0000000000000000 0000000000000000  ................
    00007fff3fde6d60 0000000000000000 0000000000000000  ................
    00007fff3fde6d70 0000000000000000 0000000000000000  ................
    00007fff3fde6d80 0000000000000000 0000000000000000  ................
    00007fff3fde6d90 0000000000000000 0000000000000000  ................
    00007fff3fde6da0 0000000000000000 0000000000000000  ................
    00007fff3fde6db0 0000000000000000 00007b83e6180998  ............{..
    00007fff3fde6dc0 00007fff3fde6ed0 00007fff3fde73b8  .n.?.....s.?....
    00007fff3fde6dd0 00007fff3fde6ed0 0000000000000000  .n.?............
    00007fff3fde6de0 00007fff3fde73a8 00007b83e67d9a1b  .s.?......}..{..
    00007fff3fde6df0 0000000000000001 00007b83e67da5d3  ..........}..{..
    00007fff3fde6e00 0000003000000020 00007fff3fde72f0   ...0.... r.?....

memory near r12 ([stack]):
    00007fff3fde7390 000061461a181010 000061461a17f90e  ....Fa......Fa..
    00007fff3fde73a0 0000000000000001 00007fff3fde827a  ........z..?....
    00007fff3fde73b0 0000000000000000 00007fff3fde8298  ............?....
    00007fff3fde73c0 00007fff3fde832d 00007fff3fde8340  -..?....@..?....
    00007fff3fde73d0 00007fff3fde8355 00007fff3fde8370  U..?....p..?....
    00007fff3fde73e0 00007fff3fde8383 00007fff3fde839c  ...?.......?....
    00007fff3fde73f0 00007fff3fde83c3 00007fff3fde83ec  ...?.......?....
    00007fff3fde7400 00007fff3fde8419 00007fff3fde8432  ...?....2..?....
    00007fff3fde7410 00007fff3fde844c 00007fff3fde8467  L..?....g..?....
    00007fff3fde7420 00007fff3fde8ace 00007fff3fde8cbb  ...?.......?....
    00007fff3fde7430 00007fff3fde8e74 0000000000000000  t..?............
    00007fff3fde7440 0000000000000021 00007fff3fdef000  !..........?....
    00007fff3fde7450 0000000000000033 00000000000006f0  3...............
    00007fff3fde7460 0000000000000010 00000000178afbfd  ................
    00007fff3fde7470 0000000000000006 0000000000001000  ................
    00007fff3fde7480 0000000000000011 0000000000000064  ........d.......

memory near r14 ([stack]):
    00007fff3fde6d00 00007fff3fde6d28 00007fff3fde73a8  (m.?.....s.?....
    00007fff3fde6d10 0000000000000001 00007b83e618d66b  ........k....{..
    00007fff3fde6d20 c7632a7a8fbc8b50 ffffffffffffffdf  P...z*c.........
    00007fff3fde6d30 0000000000000000 00000000ffffffff  ................
    00007fff3fde6d40 000007d000000bba 0000000000000000  ................
    00007fff3fde6d50 0000000000000000 0000000000000000  ................
```

```
    00007fff3fde6d60 0000000000000000 0000000000000000  ................
    00007fff3fde6d70 0000000000000000 0000000000000000  ................
    00007fff3fde6d80 0000000000000000 0000000000000000  ................
    00007fff3fde6d90 0000000000000000 0000000000000000  ................
    00007fff3fde6da0 0000000000000000 0000000000000000  ................
    00007fff3fde6db0 0000000000000000 00007b83e6180998  ............{..
    00007fff3fde6dc0 00007fff3fde6ed0 00007fff3fde73b8  .n.?.....s.?....
    00007fff3fde6dd0 00007fff3fde6ed0 0000000000000000  .n.?............
    00007fff3fde6de0 00007fff3fde73a8 00007b83e67d9a1b  .s.?......}..{..
    00007fff3fde6df0 0000000000000001 00007b83e67da5d3  ..........}..{..

memory near rsp ([stack]):
    00007fff3fde6d00 00007fff3fde6d28 00007fff3fde73a8  (m.?.....s.?....
    00007fff3fde6d10 0000000000000001 00007b83e618d66b  ........k....{..
    00007fff3fde6d20 c7632a7a8fbc8b50 ffffffffffffffdf  P...z*c.........
    00007fff3fde6d30 0000000000000000 00000000ffffffff  ................
    00007fff3fde6d40 000007d000000bba 0000000000000000  ................
    00007fff3fde6d50 0000000000000000 0000000000000000  ................
    00007fff3fde6d60 0000000000000000 0000000000000000  ................
    00007fff3fde6d70 0000000000000000 0000000000000000  ................
    00007fff3fde6d80 0000000000000000 0000000000000000  ................
    00007fff3fde6d90 0000000000000000 0000000000000000  ................
    00007fff3fde6da0 0000000000000000 0000000000000000  ................
    00007fff3fde6db0 0000000000000000 00007b83e6180998  ............{..
    00007fff3fde6dc0 00007fff3fde6ed0 00007fff3fde73b8  .n.?.....s.?....
    00007fff3fde6dd0 00007fff3fde6ed0 0000000000000000  .n.?............
    00007fff3fde6de0 00007fff3fde73a8 00007b83e67d9a1b  .s.?......}..{..
    00007fff3fde6df0 0000000000000001 00007b83e67da5d3  ..........}..{..

memory near rip (/apex/com.android.runtime/lib64/bionic/libc.so):
    00007b83e618d660 45e820245c89ffff 4824244489000757  ...\$ .EW...D$$H
    00007b83e618d670 00000000282444c7 8d4cf76349fb6348  .D$(....Hc.Ic.L.
    00007b83e618d680 00000006ba102454 0f050f00000129b8  T$.......)......
    00007b83e618d690 290ffffc2ad20510 100f000000a02484  ...*...).$......
    00007b83e618d6a0 84290ffffc2ab305 b48d480000009024  ..*...).$....H..
    00007b83e618d6b0 0006bf0000009024 075bcfe8d2310000  $.........1...[.
    00007b83e618d6c0 894c00000002bf00 00075bb0e8d231f6  ......L..1...[..
    00007b83e618d6d0 e8c03100000027bf bfc3894800075754  .'...1..TW..H...
    00007b83e618d6e0 45e8c031000000ba 570fc68949000757  ....1..EW..I...W
    00007b83e618d6f0 290f102444290fc0 802484290f202444  ..)D$..)D$ .).$.
    00007b83e618d700 702444290f000000 44290f602444290f  ....)D$p.)D$‘.)D
    00007b83e618d710 0f402444290f5024 182444c730244429  $P.)D$@.)D$0.D$.
    00007b83e618d720 20245c89ffffffff 24448900075683e8  .....\$ ..V...D$
    00007b83e618d730 0000282444c74824 f66349fb63480000  $H.D$(....Hc.Ic.
    00007b83e618d740 0006ba1024548d4c 0f00000129b80000  L.T$.......)....
    00007b83e618d750 45e80000007fbf05 ccccccccccc00075b  .......E[.......

memory map (118 entries):
    00006146'1a17e000-00006146'1a17efff r--         0      1000  /vendor/bin/hw/
        weiminn_daemon (BuildId: 64dca3fe723864a1e2dd2e698986fb43) (load bias 0
        x1000)
    00006146'1a17f000-00006146'1a17ffff r-x         0      1000  /vendor/bin/hw/
        weiminn_daemon (BuildId: 64dca3fe723864a1e2dd2e698986fb43) (load bias 0
        x1000)
    00006146'1a180000-00006146'1a181fff r--         0      2000  /vendor/bin/hw/
        weiminn_daemon (BuildId: 64dca3fe723864a1e2dd2e698986fb43) (load bias 0
        x1000)
    00006146'1a182000-00006146'1a182fff rw-      1000      1000  /vendor/bin/hw/
        weiminn_daemon (BuildId: 64dca3fe723864a1e2dd2e698986fb43) (load bias 0
```

```
        x1000)
141     00007b81'53015000-00007b81'83a44fff ---         0  30a30000  [anon:cfi shadow]
142     00007b81'83a45000-00007b81'83a45fff r--         0      1000  [anon:cfi shadow]
143     00007b81'83a46000-00007b81'90c33fff ---         0   d1ee000  [anon:cfi shadow]
144     00007b81'90c34000-00007b81'90c34fff r--         0      1000  [anon:cfi shadow]
145     00007b81'90c35000-00007b81'9300dfff ---         0   23d9000  [anon:cfi shadow]
146     00007b81'9300e000-00007b81'9300efff r--         0      1000  [anon:cfi shadow]
147     00007b81'9300f000-00007b81'd3014fff ---         0  40006000  [anon:cfi shadow]
148     00007b81'd3015000-00007b81'd3015fff ---         0      1000
149     00007b81'd3016000-00007b81'd3055fff rw-         0     40000  [anon:scudo:
        primary]
150     00007b81'd3056000-00007b81'e3021fff ---         0   ffcc000
151     00007b81'e3022000-00007b81'e3061fff rw-         0     40000  [anon:scudo:
        primary]
152     00007b81'e3062000-00007b81'f301bfff ---         0   ffba000
153     00007b81'f301c000-00007b81'f305bfff rw-         0     40000  [anon:scudo:
        primary]
154     00007b81'f305c000-00007b82'03019fff ---         0   ffbe000
155     00007b82'0301a000-00007b82'03059fff rw-         0     40000  [anon:scudo:
        primary]
156     00007b82'0305a000-00007b83'e3014fff ---         0  1dffbb000
157     00007b83'e3015000-00007b83'e3063fff r--         0     4f000  /apex/com.android
        .vndk.v33/lib64/libc++.so (BuildId: fa40b55330a4a2a3eca001f4cae01033) (
        load bias 0x1000)
158     00007b83'e3064000-00007b83'e30c1fff r-x     4e000     5e000  /apex/com.android
        .vndk.v33/lib64/libc++.so (BuildId: fa40b55330a4a2a3eca001f4cae01033) (
        load bias 0x1000)
159     00007b83'e30c2000-00007b83'e30c8fff r--     ab000      7000  /apex/com.android
        .vndk.v33/lib64/libc++.so (BuildId: fa40b55330a4a2a3eca001f4cae01033) (
        load bias 0x1000)
160     00007b83'e30c9000-00007b83'e30c9fff rw-     b1000      1000  /apex/com.android
        .vndk.v33/lib64/libc++.so (BuildId: fa40b55330a4a2a3eca001f4cae01033) (
        load bias 0x1000)
161     00007b83'e30ca000-00007b83'e30ccfff rw-         0      3000  [anon:.bss]
162     00007b83'e31cf000-00007b83'e31d1fff r--         0      3000  /system/lib64/
        libnetd_client.so (BuildId: 0ba64f6d28b890efbf31d3d283147280) (load bias 0
        x1000)
163     00007b83'e31d2000-00007b83'e31d2fff ---         0      1000
164     00007b83'e31d3000-00007b83'e31d6fff r-x      3000      4000  /system/lib64/
        libnetd_client.so (BuildId: 0ba64f6d28b890efbf31d3d283147280) (load bias 0
        x1000)
165     00007b83'e31d7000-00007b83'e31d7fff r--      6000      1000  /system/lib64/
        libnetd_client.so (BuildId: 0ba64f6d28b890efbf31d3d283147280) (load bias 0
        x1000)
166     00007b83'e31d8000-00007b83'e31d8fff rw-      6000      1000  /system/lib64/
        libnetd_client.so (BuildId: 0ba64f6d28b890efbf31d3d283147280) (load bias 0
        x1000)
167     00007b83'e3200000-00007b83'e5ffffff ---         0   2e00000
168     00007b83'e6057000-00007b83'e6057fff r--         0      1000  /apex/com.android
        .runtime/lib64/bionic/libdl.so (BuildId: efd82935135bb07f6cf82127470e5900)
         (load bias 0x1000)
169     00007b83'e6058000-00007b83'e6058fff r-x         0      1000  /apex/com.android
        .runtime/lib64/bionic/libdl.so (BuildId: efd82935135bb07f6cf82127470e5900)
         (load bias 0x1000)
170     00007b83'e6059000-00007b83'e6059fff r--         0      1000  /apex/com.android
        .runtime/lib64/bionic/libdl.so (BuildId: efd82935135bb07f6cf82127470e5900)
         (load bias 0x1000)
171     00007b83'e605a000-00007b83'e605afff ---         0      1000
172     00007b83'e605b000-00007b83'e605bfff r--         0      1000  [anon:.bss]
```

```
173     00007b83'e6096000-00007b83'e60b4fff r--         0     1f000  /apex/com.android
            .runtime/lib64/bionic/libm.so (BuildId: 9cfa4f2cea749f828172a4bab94dcf95)
            (load bias 0x1000)
174     00007b83'e60b5000-00007b83'e60e5fff r-x     1e000     31000  /apex/com.android
            .runtime/lib64/bionic/libm.so (BuildId: 9cfa4f2cea749f828172a4bab94dcf95)
            (load bias 0x1000)
175     00007b83'e60e6000-00007b83'e60e6fff r--     4e000      1000  /apex/com.android
            .runtime/lib64/bionic/libm.so (BuildId: 9cfa4f2cea749f828172a4bab94dcf95)
            (load bias 0x1000)
176     00007b83'e60e7000-00007b83'e60e7fff rw-     4e000      1000  /apex/com.android
            .runtime/lib64/bionic/libm.so (BuildId: 9cfa4f2cea749f828172a4bab94dcf95)
            (load bias 0x1000)
177     00007b83'e612e000-00007b83'e6171fff r--         0     44000  /apex/com.android
            .runtime/lib64/bionic/libc.so (BuildId: 57def992cb1772e13608c8efcafd893b)
            (load bias 0x1000)
178     00007b83'e6172000-00007b83'e6204fff r-x     43000     93000  /apex/com.android
            .runtime/lib64/bionic/libc.so (BuildId: 57def992cb1772e13608c8efcafd893b)
            (load bias 0x1000)
179     00007b83'e6205000-00007b83'e6209fff r--     d5000      5000  /apex/com.android
            .runtime/lib64/bionic/libc.so (BuildId: 57def992cb1772e13608c8efcafd893b)
            (load bias 0x1000)
180     00007b83'e620a000-00007b83'e620afff rw-     d9000      1000  /apex/com.android
            .runtime/lib64/bionic/libc.so (BuildId: 57def992cb1772e13608c8efcafd893b)
            (load bias 0x1000)
181     00007b83'e620b000-00007b83'e675cfff rw-         0    552000  [anon:.bss]
182     00007b83'e675d000-00007b83'e675dfff r--         0      1000  [anon:.bss]
183     00007b83'e675e000-00007b83'e6765fff rw-         0      8000  [anon:.bss]
184     00007b83'e676f000-00007b83'e67d2fff rw-         0     64000  [anon:
            linker_alloc]
185     00007b83'e67d3000-00007b83'e67d7fff r--         0      5000  /system/lib64/
            liblog.so (BuildId: acde2d0ef136fd6d1eb2a30987f39d55) (load bias 0x1000)
186     00007b83'e67d8000-00007b83'e67e1fff r-x      4000      a000  /system/lib64/
            liblog.so (BuildId: acde2d0ef136fd6d1eb2a30987f39d55) (load bias 0x1000)
187     00007b83'e67e2000-00007b83'e67e2fff r--      d000      1000  /system/lib64/
            liblog.so (BuildId: acde2d0ef136fd6d1eb2a30987f39d55) (load bias 0x1000)
188     00007b83'e67e3000-00007b83'e67e3fff rw-      d000      1000  /system/lib64/
            liblog.so (BuildId: acde2d0ef136fd6d1eb2a30987f39d55) (load bias 0x1000)
189     00007b83'e6800000-00007b83'e95fffff ---         0   2e00000
190     00007b83'e9621000-00007b83'e9640fff r--         0     20000  /dev/
            __properties__/u:object_r:heapprofd_prop:s0
191     00007b83'e9641000-00007b83'e9660fff r--         0     20000  /dev/
            __properties__/u:object_r:libc_debug_prop:s0
192     00007b83'e9661000-00007b83'e9669fff r--         0      9000  /apex/com.android
            .vndk.v33/lib64/libcutils.so (BuildId: 43606b529d94720adf378693c75eca35) (
            load bias 0x1000)
193     00007b83'e966a000-00007b83'e9675fff r-x      8000      c000  /apex/com.android
            .vndk.v33/lib64/libcutils.so (BuildId: 43606b529d94720adf378693c75eca35) (
            load bias 0x1000)
194     00007b83'e9676000-00007b83'e9677fff r--     13000      2000  /apex/com.android
            .vndk.v33/lib64/libcutils.so (BuildId: 43606b529d94720adf378693c75eca35) (
            load bias 0x1000)
195     00007b83'e9678000-00007b83'e9678fff rw-     14000      1000  /apex/com.android
            .vndk.v33/lib64/libcutils.so (BuildId: 43606b529d94720adf378693c75eca35) (
            load bias 0x1000)
196     00007b83'e9683000-00007b83'e9696fff r--         0     14000  /apex/com.android
            .vndk.v33/lib64/libbase.so (BuildId: 314908d7976b6d0a21139dcdb1a359d4) (
            load bias 0x1000)
197     00007b83'e9697000-00007b83'e96c2fff r-x     13000      2c000  /apex/com.android
            .vndk.v33/lib64/libbase.so (BuildId: 314908d7976b6d0a21139dcdb1a359d4) (
```

```
        load bias 0x1000)
198     00007b83'e96c3000-00007b83'e96c3fff r--     3e000      1000  /apex/com.android
        .vndk.v33/lib64/libbase.so (BuildId: 314908d7976b6d0a21139dcdb1a359d4) (
        load bias 0x1000)
199     00007b83'e96c4000-00007b83'e96c4fff rw-     3e000      1000  /apex/com.android
        .vndk.v33/lib64/libbase.so (BuildId: 314908d7976b6d0a21139dcdb1a359d4) (
        load bias 0x1000)
200     00007b83'e96c5000-00007b83'e96c5fff rw-         0      1000  [anon:.bss]
201     00007b83'e96e4000-00007b83'e9703fff r--         0     20000  /dev/
        __properties__/u:object_r:gwp_asan_prop:s0
202     00007b83'e9704000-00007b83'e9752fff r--         0     4f000  /system/lib64/
        libc++.so (BuildId: 7de31e7c740e102016d16ce256f97d3a) (load bias 0x1000)
203     00007b83'e9753000-00007b83'e97b0fff r-x     4e000     5e000  /system/lib64/
        libc++.so (BuildId: 7de31e7c740e102016d16ce256f97d3a) (load bias 0x1000)
204     00007b83'e97b1000-00007b83'e97b7fff r--     ab000      7000  /system/lib64/
        libc++.so (BuildId: 7de31e7c740e102016d16ce256f97d3a) (load bias 0x1000)
205     00007b83'e97b8000-00007b83'e97b8fff rw-     b1000      1000  /system/lib64/
        libc++.so (BuildId: 7de31e7c740e102016d16ce256f97d3a) (load bias 0x1000)
206     00007b83'e97b9000-00007b83'e97bbfff rw-         0      3000  [anon:.bss]
207     00007b83'e97c1000-00007b83'e97e0fff r--         0     20000  /dev/
        __properties__/u:object_r:debug_prop:s0
208     00007b83'e97e1000-00007b83'e9800fff r--         0     20000  /dev/
        __properties__/properties_serial
209     00007b83'e9801000-00007b83'e9801fff rw-         0      1000  [anon:
        bionic_alloc_small_objects]
210     00007b83'e981c000-00007b83'e982dfff r--         0     12000  /dev/
        __properties__/property_info
211     00007b83'e9832000-00007b83'e9851fff r--         0     20000  /dev/
        __properties__/u:object_r:build_prop:s0
212     00007b83'e9852000-00007b83'e9871fff r--         0     20000  /dev/
        __properties__/u:object_r:log_tag_prop:s0
213     00007b83'e9872000-00007b83'e9891fff r--         0     20000  /dev/
        __properties__/u:object_r:vendor_socket_hook_prop:s0
214     00007b83'e9892000-00007b83'e9959fff r--         0     c8000  [anon:
        linker_alloc]
215     00007b83'e995a000-00007b83'e9979fff r--         0     20000  /dev/
        __properties__/u:object_r:vndk_prop:s0
216     00007b83'e997b000-00007b83'e9982fff rw-         0      8000  [anon:
        bionic_alloc_small_objects]
217     00007b83'e9983000-00007b83'e9983fff rw-         0      1000  [anon:
        bionic_alloc_lob]
218     00007b83'e9984000-00007b83'e9985fff rw-         0      2000  [anon:
        bionic_alloc_small_objects]
219     00007b83'e9986000-00007b83'e9988fff rw-         0      3000  [anon:System
        property context nodes]
220     00007b83'e9989000-00007b83'e9989fff ---         0      1000
221     00007b83'e998a000-00007b83'e998cfff rw-         0      3000  [anon:
        stack_and_tls:main]
222     00007b83'e998d000-00007b83'e998dfff ---         0      1000
223     00007b83'e998e000-00007b83'e998ffff rw-         0      2000  [anon:
        bionic_alloc_lob]
224     00007b83'e9992000-00007b83'e9996fff rw-         0      5000  [anon:
        bionic_alloc_small_objects]
225     00007b83'e9997000-00007b83'e99fafff r--         0     64000  [anon:
        linker_alloc]
226     00007b83'e99fb000-00007b83'e99fbfff rw-         0      1000  [anon:
        bionic_alloc_small_objects]
227     00007b83'e99fc000-00007b83'e9a1bfff r--         0     20000  /dev/
        __properties__/u:object_r:debug_prop:s0
```

```
228     00007b83'e9a1c000-00007b83'e9a3bfff r--         0     20000  /dev/
            __properties__/u:object_r:build_prop:s0
229     00007b83'e9a3c000-00007b83'e9a3cfff ---         0      1000
230     00007b83'e9a3d000-00007b83'e9a44fff rw-         0      8000
231     00007b83'e9a45000-00007b83'e9a45fff ---         0      1000
232     00007b83'e9a46000-00007b83'e9a65fff r--         0     20000  /dev/
            __properties__/properties_serial
233     00007b83'e9a66000-00007b83'e9a68fff rw-         0      3000  [anon:System
            property context nodes]
234     00007b83'e9a69000-00007b83'e9a7afff r--         0     12000  /dev/
            __properties__/property_info
235     00007b83'e9a7b000-00007b83'e9adefff r--         0     64000  [anon:
            linker_alloc]
236     00007b83'e9adf000-00007b83'e9ae0fff rw-         0      2000  [anon:
            bionic_alloc_small_objects]
237     00007b83'e9ae1000-00007b83'e9ae1fff r--         0      1000  [anon:atexit
            handlers]
238     00007b83'e9ae2000-00007b83'e9ae2fff ---         0      1000
239     00007b83'e9ae3000-00007b83'e9aeafff rw-         0      8000  [anon:thread
            signal stack]
240     00007b83'e9aeb000-00007b83'e9aebfff rw-         0      1000  [anon:arc4random
            data]
241     00007b83'e9aec000-00007b83'e9aecfff rw-         0      1000  [anon:abort
            message]
242     00007b83'e9aed000-00007b83'e9aedfff r--         0      1000  [anon:atexit
            handlers]
243     00007b83'e9aee000-00007b83'e9aeefff rw-         0      1000  [anon:arc4random
            data]
244     00007b83'e9aef000-00007b83'e9b32fff r--         0     44000  /apex/com.android
            .runtime/bin/linker64 (BuildId: 88b9a0b1efb561bd3d51b1972ee9b024) (load
            bias 0x1000)
245     00007b83'e9b33000-00007b83'e9c27fff r-x     43000     f5000  /apex/com.android
            .runtime/bin/linker64 (BuildId: 88b9a0b1efb561bd3d51b1972ee9b024) (load
            bias 0x1000)
246     00007b83'e9c28000-00007b83'e9c2ffff r--    137000      8000  /apex/com.android
            .runtime/bin/linker64 (BuildId: 88b9a0b1efb561bd3d51b1972ee9b024) (load
            bias 0x1000)
247     00007b83'e9c30000-00007b83'e9c31fff rw-    13e000      2000  /apex/com.android
            .runtime/bin/linker64 (BuildId: 88b9a0b1efb561bd3d51b1972ee9b024) (load
            bias 0x1000)
248     00007b83'e9c32000-00007b83'e9c3afff rw-         0      9000  [anon:.bss]
249     00007b83'e9c3b000-00007b83'e9c3bfff r--         0      1000  [anon:.bss]
250     00007b83'e9c3c000-00007b83'e9c3dfff rw-         0      2000  [anon:.bss]
251     00007fff'3fdc8000-00007fff'3fde8fff rw-         0     21000  [stack]
252     00007fff'3fdeb000-00007fff'3fdeefff r--         0      4000  [vvar]
253     00007fff'3fdef000-00007fff'3fdeffff r-x         0      1000  [vdso]
254     ffffffff'ff600000-ffffffff'ff600fff --x         0      1000  [vsyscall]
255 --------- tail end of log main
256 01-02 13:41:59.096  3002  3002 D WEIMINN PROJ: STARTING WEIMINN PROJECT
257 01-02 13:42:01.096  3002  3002 F weiminn_daemon: Failed to load libnativehelper.so
        : dlopen failed: library "libnativehelper.so" not found
258
259 open files:
260     fd 0: /dev/null (unowned)
261     fd 1: /dev/null (unowned)
262     fd 2: /dev/null (unowned)
263     fd 3: socket:[57035] (unowned)
264     fd 4: /dev/pmsg0 (unowned)
265 --------- log main
```

```
01-02 13:41:59.096  3002  3002 D WEIMINN PROJ: STARTING WEIMINN PROJECT
01-02 13:42:01.096  3002  3002 F weiminn_daemon: Failed to load libnativehelper.so
    : dlopen failed: library "libnativehelper.so" not found
```

I think it's because we are calling into `libnativehelper.so` without loading it first using `JniInvocation`. So we need to figure out the way to initialize JNI inovation and store the instance.

Test out calling just `libnativehelper.c` instead of all the way into `art` modules.

3.3 January 4-7, 2024

3.3.1 Load Native Shared Libraries to Daemon

Permanently set SELinux to permissive

Go to `aosp/system/core/init/selinux.cpp` and change `StatusFromProperty()` and `IsEnforcing()` to return `PERMISSIVE` hardcodedly:

```
EnforcingStatus StatusFromProperty() {
    return SELINUX_PERMISSIVE; //in early stage, the function returns permissive
        status
    EnforcingStatus status = SELINUX_PERMISSIVE;
    ImportKernelCmdline([&](const std::string& key, const std::string& value) {
        if (key == "androidboot.selinux" && value == "permissive") {
            status = SELINUX_PERMISSIVE;
        }
    });

    if (status == SELINUX_ENFORCING) {
                        status = SELINUX_PERMISSIVE;
    }
    return SELINUX_PERMISSIVE;
}

bool IsEnforcing() {
    return false; //selinux returns false under any enforcing circumstances.
    if (ALLOW_PERMISSIVE_SELINUX) {
        return StatusFromProperty() == SELINUX_PERMISSIVE;
    }
    return true;
}
```

Configure Daemon VNDK

According to Android VNDK documentation[4], the library that want to use VNDK or LLNDK cannot be related to ART.

[4] `https://source.android.com/docs/core/architecture/vndk?hl=en#framework-shared-libraries` and `https://source.android.com/static/docs/core/architecture/images/vndk_design_android_o.pdf`

Tried to assign SELinux context to the daemon[5], but gave up cos there might be further work to do regarding shared library access.

Changing `libnativehelper` to `llndk` or `vndk` in it's `android.bp` also doesn't help.

Making `libnativehelper` `apex_available` is even worse because it will mess up your code and your Android Emulator won't start up even after fixing the code.

So, it's time to give up and just get on with the Schema sharing that Zichen told us to do.

Connect to Runtime

Copy and paste the customized files into the AOSP folder to overwrite.

Tried to set it up for emulator build but a bit too difficult, so I'll just use the given Pixel 7 Pro. So, download driver for Pixel 7 Pro:

```
curl -O https://dl.google.com/dl/android/aosp/google_devices-cheetah-td1a.220804.009.a2-724bfafc.tgz
tar -xvzf google_devices-cheetah-td1a.220804.009.a2-724bfafc.tgz
./extract-google_devices-cheetah.sh
```

Reclone the AOSP repo because the latest branch of Android 13 is not compatible with Minima. Don't delete the whole `aosp13` source folder, instead go inside and delete subfolders apart from `.repo` and . Afterwards, clone the different version:

```
git ls-remote -h https://android.googlesource.com/platform/manifest.git
mkdir aosp && cd aosp
repo init -u https://android.googlesource.com/platform/manifest -b android-13.0.0_r11   # For Android 13
repo sync -c -j$(nproc --all)     # Sync the current branch using all available processing units in the system
source build/envsetup.sh
lunch aosp_cheetah-userdebug
make -j31
adb reboot bootloader  # Make sure your device's bootloader is unlocked before proceeding.
fastboot -w flashall
```

Changed the value of `LOG_NDEBUG` to 0 that is defined on top of `aosp/frameworks/base/core/jni/AndroidRuntime.cpp`.

Connect Runtime to Bionic

Need to figure out `art`'s `native_bridge.cc` talks to `bionic`'s `libdl.cpp`.

Some of the headers are prebuilt inside `aosp/prebuilt`. Just ignore them cos you can find the real headers inside `bionic`, and `art`.

Okay, time to give up on adding my own function. Instead just try to sneak pointer through the flow. Changes in the arguments will be a challenge.

[5] `https://discuss.96boards.org/t/run-executable-from-init-service-with-root-permissions/8257/2`

Added extra function because overloading gives a lot of error. But I'm still having error because I was extending a shared system library:

```
lib_name: "libdl"
arch: "arm64"
functions_added {
    return_type: "void *"
    function_name: "android_dlopen_ext2"
    source_file: "bionic/libc/include/android/dlext.h"
    parameters {
        referenced_type: "const char *"
        default_arg: false
        is_this_ptr: false
    }
    parameters {
        referenced_type: "int"
        default_arg: false
        is_this_ptr: false
    }
    parameters {
        referenced_type: "const android_dlextinfo *"
        default_arg: false
        is_this_ptr: false
    }
    parameters {
        referenced_type: "void *"
        default_arg: false
        is_this_ptr: false
    }
    linker_set_key: "android_dlopen_ext2"
    access: public_access
}
added_elf_functions {
    name: "android_dlopen_ext2"
}
compatibility_status: EXTENSION
```

Added extra function because overloading gives a lot of error. Added the function name to `bionic/libdl/libdl.map.txt`, and compile. But I'm still having error because I was extending a shared system library:

```
lib_name: "libdl"
arch: "arm64"
functions_added {
    return_type: "void *"
    function_name: "android_dlopen_ext2"
    source_file: "bionic/libc/include/android/dlext.h"
    parameters {
        referenced_type: "const char *"
        default_arg: false
        is_this_ptr: false
    }
    parameters {
        referenced_type: "int"
        default_arg: false
        is_this_ptr: false
    }
    parameters {
```

```
        referenced_type: "const android_dlextinfo *"
        default_arg: false
        is_this_ptr: false
    }
    parameters {
        referenced_type: "void *"
        default_arg: false
        is_this_ptr: false
    }
    linker_set_key: "android_dlopen_ext2"
    access: public_access
}
added_elf_functions {
    name: "android_dlopen_ext2"
}
compatibility_status: EXTENSION
```

Go to `prebuilts/abi-dumps/ndk/33/64/arm64/source-based/libdl.so.lsdump` and in the following `functions` array, we can only see the entry for the old `android_dlopen_ext`:

```
{
    "function_name" : "android_dlopen_ext",
    "linker_set_key" : "android_dlopen_ext",
    "parameters" :
    [
        {
        "referenced_type" : "_ZTIPKc"
        },
        {
        "referenced_type" : "_ZTIi"
        },
        {
        "referenced_type" : "_ZTIPK17android_dlextinfo"
        }
    ],
    "return_type" : "_ZTIPv",
    "source_file" : "bionic/libc/include/android/dlext.h"
},
```

and same goes for `elf_functions` array:

```
{
    "binding" : "weak",
    "name" : "android_dlopen_ext"
},
```

The problem turns out to be the the builder checking for ABI compatibility, so run this command to dump your changes to the ABI database:

```
python3 development/vndk/tools/header-checker/utils/create_reference_dumps.py -l
    libdl
```

Given up on overloading the function. Now, modifying `android_extinfo` whose instances are passed from `OpenSystemLibrary` in `art/libnativebridge/native_bridge.cc` to `android_dlopen_ext` in `bionic/libdl/libdl.cpp`. Have to run the ABI dump after modifying the `struct` of `android_extinfo`.

The `android_dlopen_ext` object is passed from `OpenSystemLibrary` all the way to `do_dlopen` in `linker.cpp`. But for some reason, it is not possible to access the members of the `dlext` object as the object itself is `null`, so the code below is unusable:

```
LD_LOG(kLogErrors, "[weiminn] linker.cpp RECEIVED FROM NATIVE BRIDGE!!!: %s",
    extinfo->weiminn_msg);
```

Using the code will cause Android stuck in Recovery mode in infinite loop, even though the project successfully compiles.

Successfully called a custom function inside `linker_phdr.cpp` from `dlfcn.cpp`. So, we are skipping `linker.cpp` which is not required by Zicheng anyway.

3.4 January 11-15, 2024

3.4.1 Dronlomaly Tool Demo Paper

Setup Development Environment on Ubuntu 23

Download `ffmpeg` from Ubuntu official source site[6]. Installing on Ubuntu 23, need to patch `ffmpeg` according to some forum[7] where we have to fix some assembly code like:

```
/*
* simple math operations
* Copyright (c) 2006 Michael Niedermayer <michaelni@gmx.at> et al
*
* This file is part of FFmpeg.
*
* FFmpeg is free software; you can redistribute it and/or
* modify it under the terms of the GNU Lesser General Public
* License as published by the Free Software Foundation; either
* version 2.1 of the License, or (at your option) any later version.
*
* FFmpeg is distributed in the hope that it will be useful,
* but WITHOUT ANY WARRANTY; without even the implied warranty of
* MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the GNU
* Lesser General Public License for more details.
*
* You should have received a copy of the GNU Lesser General Public
* License along with FFmpeg; if not, write to the Free Software
* Foundation, Inc., 51 Franklin Street, Fifth Floor, Boston, MA 02110-1301 USA
*/

#ifndef AVCODEC_X86_MATHOPS_H
#define AVCODEC_X86_MATHOPS_H

#include "config.h"

#include "libavutil/common.h"
#include "libavutil/x86/asm.h"
```

[6] https://launchpad.net/ubuntu/+source/ffmpeg/7:3.4.11-0ubuntu0.1

[7] bbs.archlinux.org/viewtopic.php?id=289424

```
29
30 #if HAVE_INLINE_ASM
31
32 #if ARCH_X86_32
33
34 #define MULL MULL
35 static av_always_inline av_const int MULL(int a, int b, unsigned shift)
36 {
37     int rt, dummy;
38     if (__builtin_constant_p(shift))
39     __asm__ (
40         "imull␣%3␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣\n\t"
41         "shrdl␣%4,␣%%edx,␣%%eax␣\n\t"
42         :"=a"(rt), "=d"(dummy)
43         // :"a"(a), "rm"(b), "ci"((uint8_t)shift)
44         :"a"(a), "rm"(b), "i"(shift & 0x1F)
45     );
46     else
47     __asm__ (
48             "imull␣%3␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣\n\t"
49             "shrdl␣%4,␣%%edx,␣%%eax␣\n\t"
50             :"=a"(rt), "=d"(dummy)
51             :"a"(a), "rm"(b), "c"((uint8_t)shift)
52         );
53
54     return rt;
55 }
56
57 #define MULH MULH
58 static av_always_inline av_const int MULH(int a, int b)
59 {
60     int rt, dummy;
61     __asm__ (
62         "imull␣%3"
63         :"=d"(rt), "=a"(dummy)
64         :"a"(a), "rm"(b)
65     );
66     return rt;
67 }
68
69 #define MUL64 MUL64
70 static av_always_inline av_const int64_t MUL64(int a, int b)
71 {
72     int64_t rt;
73     __asm__ (
74         "imull␣%2"
75         :"=A"(rt)
76         :"a"(a), "rm"(b)
77     );
78     return rt;
79 }
80
81 #endif /* ARCH_X86_32 */
82
83 #if HAVE_I686
84 /* median of 3 */
85 #define mid_pred mid_pred
86 static inline av_const int mid_pred(int a, int b, int c)
87 {
```

```
88      int i=b;
89      __asm__ (
90          "cmp␣␣␣␣%2,␣%1␣\n\t"
91          "cmovg␣␣%1,␣%0␣\n\t"
92          "cmovg␣␣%2,␣%1␣\n\t"
93          "cmp␣␣␣␣%3,␣%1␣\n\t"
94          "cmovl␣␣%3,␣%1␣\n\t"
95          "cmp␣␣␣␣%1,␣%0␣\n\t"
96          "cmovg␣␣%1,␣%0␣\n\t"
97          :"+&r"(i), "+&r"(a)
98          :"r"(b), "r"(c)
99      );
100     return i;
101 }
102
103 #if HAVE_6REGS
104 #define COPY3_IF_LT(x, y, a, b, c, d)\
105 __asm__ volatile(\
106     "cmpl␣␣%0,␣%3␣␣␣␣␣␣␣\n\t"\
107     "cmovl␣%3,␣%0␣␣␣␣␣␣␣\n\t"\
108     "cmovl␣%4,␣%1␣␣␣␣␣␣␣\n\t"\
109     "cmovl␣%5,␣%2␣␣␣␣␣␣␣\n\t"\
110     : "+&r" (x), "+&r" (a), "+r" (c)\
111     : "r" (y), "r" (b), "r" (d)\
112 );
113 #endif /* HAVE_6REGS */
114
115 #endif /* HAVE_I686 */
116
117 #define MASK_ABS(mask, level)                    \
118     __asm__ ("cdq␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣␣\n\t"      \
119              "xorl␣%1,␣%0␣␣␣␣␣␣␣␣␣␣␣␣\n\t"      \
120              "subl␣%1,␣%0␣␣␣␣␣␣␣␣␣␣␣␣\n\t"      \
121              : "+a"(level), "=&d"(mask))
122
123 // avoid +32 for shift optimization (gcc should do that ...)
124 #define NEG_SSR32 NEG_SSR32
125 static inline  int32_t NEG_SSR32( int32_t a, int8_t s){
126     if (__builtin_constant_p(s))
127     __asm__ ("sarl␣%1,␣%0\n\t"
128         : "+r" (a)
129         //  : "ic" ((uint8_t)(-s))
130         : "i" (-s & 0x1F)
131     );
132     else
133         __asm__ ("sarl␣%1,␣%0\n\t"
134             : "+r" (a)
135             : "c" ((uint8_t)(-s))
136             // : "i" (-s & 0x1F)
137         );
138     return a;
139 }
140
141 #define NEG_USR32 NEG_USR32
142 static inline uint32_t NEG_USR32(uint32_t a, int8_t s){
143     if (__builtin_constant_p(s))
144     __asm__ ("shrl␣%1,␣%0\n\t"
145         : "+r" (a)
146         //  : "ic" ((uint8_t)(-s))
```

```
147         : "i" (-s & 0x1F)
148     );
149     else
150         __asm__ ("sarl␣%1,␣%0\n\t"
151             : "+r" (a)
152             : "c" ((uint8_t)(-s))
153             // : "i" (-s & 0x1F)
154         );
155     return a;
156 }
157
158 #endif /* HAVE_INLINE_ASM */
159 #endif /* AVCODEC_X86_MATHOPS_H */
```

Afterwards, you should be able to install:

```
1 ./configure
2 make
3 sudo make install
```

Running Dronlomaly

Need to fix some compile time error that is leftover from previous year, and also the resultant of migration of Ubuntu 23.

Add `#include <cstdlib>` to `osdk-core/modules/src/filemgr/impl/downloadbufferqueue.cpp`.

Now, need to install the RPC and Boost library:

```
1 sudo apt install libxmlrpc-c++8-dev libboost-all-dev
```

Got to `build/sample/platform/linux/telemetry/CMakeFiles/djiosdk-telemetry-sample.dir/link.txt` and add `-lm -lz -lswresample` to the end of the first line, and copy `UserConfig.txt` at the root of the project into `build/bin/`, and run `./djiosdk-telemetry-sample`:

```
1 cd ~/Documents/x1_backup/DronLomaly/1_TelemetrySubscriber/ && rm -rf build &&
      mkdir build && cd build && cmake .. && make && cp ../../UserConfig.txt bin
```

Since we have to modify the CMakeFiles, we are not supposed to `rm` the whole directory anymore, so, we'll just run `make` to update the binaries after making changes in the code.

I fucked up and installed Python 3.7 from source and the versions are mixed up right now. Successfully reversed it using:

```
1  rm -f /usr/local/bin/python3.7
2  sudo rm -f /usr/local/bin/python3.7
3  sudo rm -f /usr/local/bin/pip3.7
4  sudo rm -f /usr/local/bin/pydoc
5  sudo rm -rf /usr/local/include/python3.7m/
6  sudo rm -f /usr/local/lib/libpython3.7m.a
7  sudo rm -rf /usr/local/lib/python3.7
8  sudo rm -rf /usr/local/lib/pkgconfig/
9  sudo rm -f /usr/local/bin/idle
10 sudo rm -f /usr/local/bin/easy_install-2.7
```

Packages need to run:

```
pip3 install torch torchvision torchaudio --index-url https://download.pytorch.org/whl/cpu
pip3 install matplotlib pandas
pip3 install pyqt5
sudo apt install python3-tk
```

It works! The key is to NOT install anything `qt`-related and install `python3-tk` instead.

Validate the figures with experiment

3.5 January 16-20, 2024

3.5.1 Explore Migration of Zicheng's Works to AOSP14

Clone AOSP14

Tried cloning AOSP 14 into new directory:

```
mkdir aosp14 && cd aosp14
repo init -u https://android.googlesource.com/platform/manifest -b android-14.0.0.r_21
```

But faced this error:

```
manifests:
fatal: couldn't find remote ref refs/heads/android-14.0.0.r_21
manifests: sleeping 4.0 seconds before retrying
fatal: cannot obtain manifest https://android.googlesource.com/platform/manifest
================================================================================
Repo command failed: UpdateManifestError
    Unable to sync manifest default.xml
```

Checking the available branches with:

```
git ls-remote -h https://android.googlesource.com/platform/manifest.git
```

And the result is:

```
...
06e1764f504727281253313fbf6c227cebd65e4c  refs/heads/android-13.0.0_r79
2f7b75202188e6deee159b2dea97719a51f63c2f  refs/heads/android-13.0.0_r8
4ca496b8eaa717f861e193233cd3917d9fbbb5a7  refs/heads/android-13.0.0_r80
259db423b147ea6f75b25a87a47190a17b1fda10  refs/heads/android-13.0.0_r81
ed487956fff8d6b616d99ace142203d6b89aa877  refs/heads/android-13.0.0_r82
f5d5c1675fabbca4cebc0d1b618ff6f7b6f14025  refs/heads/android-13.0.0_r83
0bac787fd054b65de0e755dd8f32b1f07cc0b485  refs/heads/android-13.0.0_r9
e3f9241982f55ef4cec97df0c55e9b87d37a5656  refs/heads/android-14.0.0_r1
32f134303b62e8815287a61ad285cc0171fb3091  refs/heads/android-14.0.0_r10
29fddb193223ac701779eb45a926b21e9e6c9585  refs/heads/android-14.0.0_r11
1ea2801d54e826ea03e3a6c33e09c2c36da4df41  refs/heads/android-14.0.0_r12
ab70a6753ba6dfa223eec03762de67a3e001111f  refs/heads/android-14.0.0_r13
d774d22bad0a0dcc3494566b52f48b40afb2c0dd  refs/heads/android-14.0.0_r14
323da1dc43d2c9ace9f97ddf5744fdbeb5c0d4e7  refs/heads/android-14.0.0_r15
e43bd2ae656e593e68015f922b7f5b1af335bf0c  refs/heads/android-14.0.0_r16
d091bf89b3c2e459dc46fe4238695205990228a8  refs/heads/android-14.0.0_r17
dcd243f609d59f6d919660898949775d0976ed0b  refs/heads/android-14.0.0_r18
```

```
bd6b6c3427247e3cdf23c4daafdd4e050488aadb  refs/heads/android-14.0.0_r19
cae010b8c39e45a9fc675fce989a284c5e39ebed  refs/heads/android-14.0.0_r2
d25293c4ced217d523f7773a3426fee6e8c5160c  refs/heads/android-14.0.0_r20
ce85fafc1db1bafbe98e326a9ac1fde211f0495d  refs/heads/android-14.0.0_r21
...
```

The branch of our current AOSP 13 according to `.repo/manifests/default.xml` is:

```
<?xml version="1.0" encoding="UTF-8"?>
    <manifest>

      <remote  name="aosp"
               fetch=".."
               review="https://android-review.googlesource.com/" />
      <default revision="refs/tags/android-13.0.0_r11"
               remote="aosp"
               sync-j="4" />
```

Instead of switching branch to a totally different android version, try switching to another branch of 13:

```
cd aosp13
repo init -u https://android.googlesource.com/platform/manifest -b android-13.0.0.
    r_83
```

Also fail! STUPID ERROR! should `_r83`, NOT `.r_83`! NOW FIXED! Cloning into new directory now.

3.6 January 21-31, 2024

3.6.1 Understand Comprehensive Android Invocation Flow

System Server

Startup process[8]

ServiceManager vs SystemServiceManager [9]

Looper[10] is at the end of System Server to pop messages from message queue and invoke the corresponding methods to handle it.''

System UI

WindowManagerService[11]

Loading of System UI [12]

[8] https://blog.csdn.net/q1210249579/article/details/128793307

[9] https://blog.csdn.net/b1480521874/article/details/79422909

[10] https://stackoverflow.com/questions/35931899/why-main-threads-looper-loop-doesnt-block-ui-threa

[11] https://blog.csdn.net/CallmeZhe/article/details/113989896

[12] https://stackoverflow.com/questions/37465026/when-systemui-loads-in-android-boot

Activity Manager

The Activity manager is started by Android's Zygote's System Services
- Android application launch process[13]
- Role of ActivityManager[14]
- Role[15] of ActivityThread[16]
- Role[17] of Instrumentation[18]
- Activity Record[19]
- Tasks[20]
- Starting Activity[21]
- Start Activty to Zygote Flow[22]

ART Invocation

Method Execute Flow[23]
- Dex2Oat[24]

[13] https://multi-core-dump.blogspot.com/2010/04/android-application-launch.html, https://multi-core-dump.blogspot.com/2010/04/android-application-launch-part-2.html, and https://blog.csdn.net/u012481172/article/details/49658633

[14] https://developer.android.com/reference/android/app/ActivityManager#nested-classes

[15] https://blog.csdn.net/hzwailll/article/details/85339714

[16] https://android.googlesource.com/platform/frameworks/base/+/master/core/java/android/app/ActivityThread.java

[17] https://stackoverflow.com/questions/29140889/when-is-instrumentation-involved-in-app-start

[18] https://developer.android.com/reference/android/app/Instrumentation

[19] https://stackoverflow.com/questions/18127984/what-is-activity-record-object-in-android

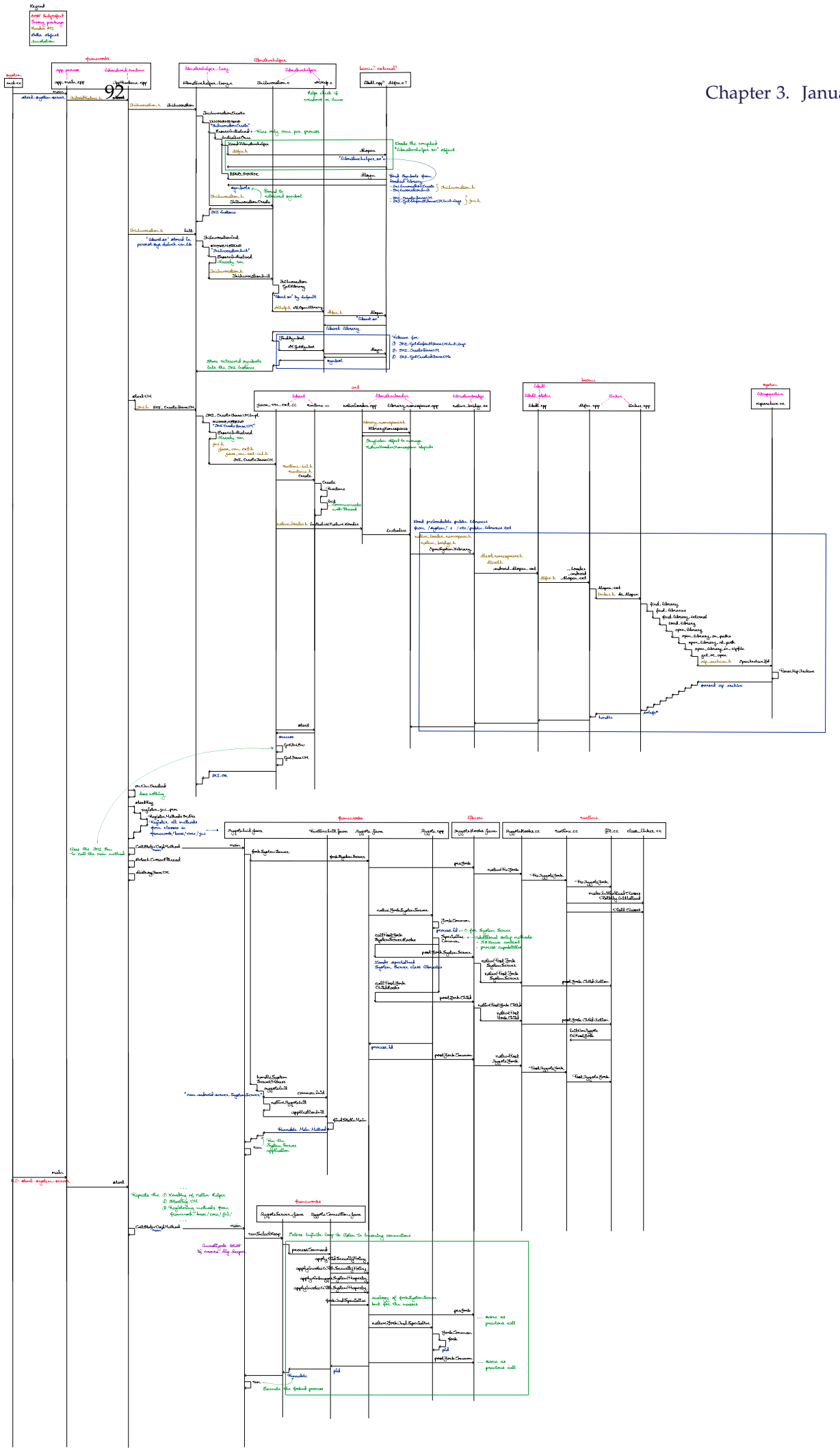
[20] https://www.youtube.com/watch?v=MvIlVsXxXmY

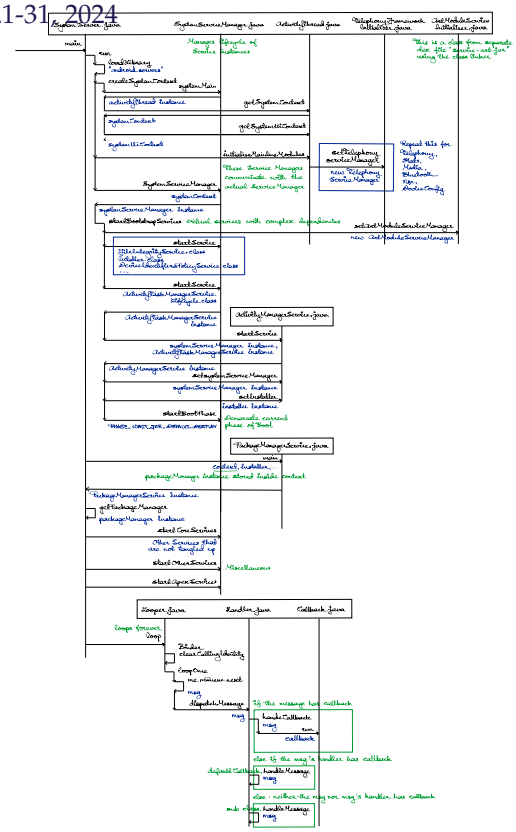
[21] https://duanqz.github.io/2016-07-29-Activity-LaunchProcess-Part1

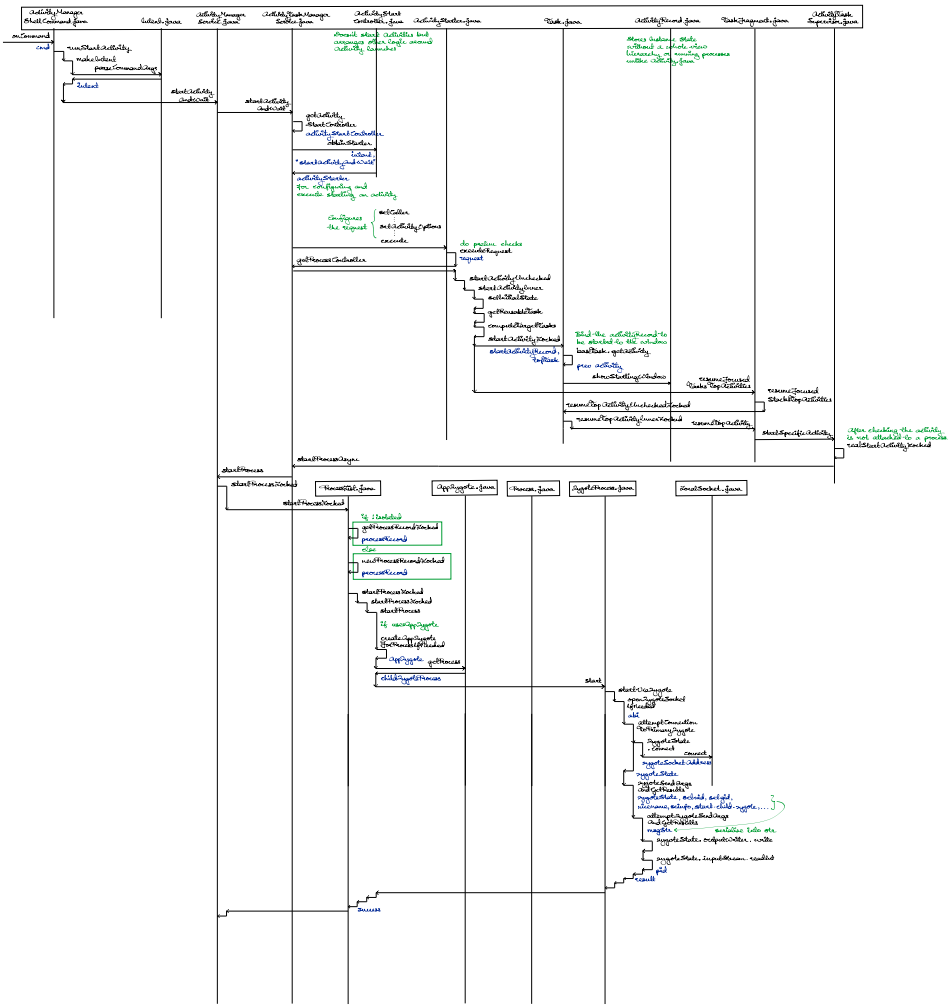
[22] [https://github.com/Marukohe/blog-notes/issues/4]

[23] https://huanle19891345.github.io/en/android/art/jni/java_jni%E6%96%B9%E6%B3%95%E8%B0%83%E7%94%A8%E5%8E%9F%E7%90%86/

[24] https://huanle19891345.github.io/en/android/art/1%E7%B1%BB%E7%BC%96%E8%AF%91/dex2oat/







Chapter 4

Febuary

4.1 Febuary 11-12, 2024

4.1.1 Understand Papers on Android Framework Level

Characterizing and Detecting Configuration Compatibility Issues in Android Apps (ASE 2021)

Identify compatiblity issues from many XML configuration files, caused by inconsistent processing of attributes across different Android APIs. It's also hard to identify code changes causing such inconsistencies. Path-sensitive analysis is accurate but expensive. Android Developers and API Differences Reports can miss many configuration changes that manifest runtime inconsistencies.

Empirical Study. Data collected from bug-related code revisions from well-maintained open-source Android apps.

- **RQ1: Issue types and root causes.** Unavailable configuration APIs, Inconsistent configuration APIs, Inconsistent Android internal XML configuration files, Inconsistent attribute dependencies, Inconsistent attribute usages, and Inconsistent attribute default values.
- **RQ2: Issue symptoms.** 45.4% crash, 44.9% inconsistent look-and-feel.

ConfDroid.

- **Configuration Constraint Model.** To deal with inconsistencies in APIs that handle configuration, constraint tuple $\{\mathcal{A}, \mathcal{F}, \mathcal{X}\}$ is defined where $\mathcal{A}$ stands for attribute, $\mathcal{X}$ stands for XML tag $\mathcal{A}$ is located in, and $\mathcal{F}$ stands for data format assignable to $\mathcal{A}$.
- **Build Trimmed ICFG.** The problematic code changes reside in the class that invokes configurations APIs. The call graphs and each method's CFGs are combined to give Trimmed ICFG.

- **Extract Android Configuration Constraints.**
- **Generate Detection Rules.**

Evaluation.

- **RQ3: Effectiveness of detection rule extraction.**
  Baselines: Lint[1], Orplocator[2], cDep[3]
- **RQ4: Usefulness.**

Compatibility Issue Detection for Android Apps Based on Path-Sensitive Semantic Analysis (ICSE 2023)

Compatibility Issues due to deprecated APIs. Difficult to extract constraints for different check patterns across different classes and methods, and semantic analysis of constraints in each API usage path considering API lifetime.

PSDroid.

1. **Call Graph Generation .** Extract call graph from the API using Soot, and FlowDroid.
2. **Path Extraction.** Distinguish the APIs used by the main packages or TPLs in the app.
3. **API Usage Check Pattern Analysis.**
4. **Path-sensitive Analysis.**
5. **API Lifetime Modeling.**
6. **API Compatibility Issue Detection.**

Experiments.

1. **RQ1: Detecting different types of API compatibility issues.**
2. **RQ2: Detecting API compatibility issues effectively.**
3. **RQ3: Outperforming existing tools on detecting API compatiblity issues.**
4. **RQ4: Feedbacks on issue reports.**

Limitations. Inherits limitations from static analysis in terms of reflection handling, native code, multi-threading, and unresolved types. False positives on dead codes. Cannot solve complex constraints. Questionable accuracy of API lifetime modelling. Bias of manual analysis.

[1] `https://developer.android.com/studio/write/lint`
[2] `https://zhendong2050.github.io/res/ORPLocator_ISSRE_2016.pdf`
[3] `https://www.cs.cornell.edu/~legunsen/pubs/ChenETAL20CDep.pdf`

Natidroid: Cross-Language Android Permission Specification (FSE 2022)

Invocation chain: Initialize `CameraManager` and call its `openCamera()` inside the SDK which calls `CameraService.cpp` in the native library. This is not detected by SOTA (Axplorer[4], Arcade[5], Pscout[6]) as they only analyze the Java framework, not native codes.

NatiDroid. Addresses the cross-language permission mapping problem.

1. **Pre-processing.** Prepare the intermediate artifacts from the AOSP codebase using Soot and Clang to allow the analysis of Android Framework.
2. **Entry-points Identification.**

   AIDL-based communication as the IPC mechanism for Java classess to communicate with native libraries in a client-server form.

   JNI-based communication as a dynamic linker for Java and C++ classes to call each other.
3. **Cross-language CFG Generation.** Leverage forward analysis on the native side from each identified entry-point. If it includes security checkpoint, continue to do backward analysis to build Java-side CFG. Afterwards, connect the 2 CFGs.
4. **Protection mapping extraction.** Perform DFS from Java node to find security checks in the native layer.

Evaluation.

1. **Protection Mapping in Android Native Libraries.**
2. **Applications of Protection Mappings.**

   Permission Over-privilege Detection.

   Component Hijacking Detection.

Discussion and Limitations.

1. **Android Versions.**
2. **Custom ROMs.**
3. **Static Analysis.**

[4] `https://www.usenix.org/system/files/conference/usenixsecurity16/sec16_paper_backes-android.pdf`

[5] `https://www.cs.purdue.edu/homes/taog/papers/CCS18.pdf`

[6] `https://security.csl.toronto.edu/papers/PScout-CCS2012-web.pdf`

4.2 Febuary 13, 2024

4.2.1 Conduct Experiments on AOSP 14

Mine Permission Mappings for AOSP 14

Set up Java and compile the Java code:

```
sudo apt install openjdk-8-jdk-headless   # version 8u382-ga-1ubuntu1
rm -rf out && mkdir out && javac src/*.java src/javaLink/*.java src/cppLink/*.java
     src/util/*.java -cp "./libs/*" -d out && java -cp "./out:./libs/*"
    findJavaLink
sudo update-alternatives --config java
```

Gets error message:

```
Exception in thread "main" java.lang.RuntimeException: java.util.concurrent.
    ExecutionException: java.lang.Exception: Error: The path '/Library/Java/
    JavaVirtualMachines/jdk1.8.0_231.jdk/Contents/Home/jre/lib/rt.jar' does not
    exist.
    at soot.SourceLocator.getClassSourceType(SourceLocator.java:312)
    at soot.SourceLocator.lookupInClassPath(SourceLocator.java:615)
    at soot.asm.AsmClassProvider.find(AsmClassProvider.java:39)
    at soot.SourceLocator.getClassSource(SourceLocator.java:187)
    at soot.SootResolver.bringToHierarchyUnchecked(SootResolver.java:231)
    at soot.SootResolver.bringToHierarchy(SootResolver.java:221)
    at soot.SootResolver.bringToSignatures(SootResolver.java:292)
    at soot.SootResolver.bringToBodies(SootResolver.java:332)
    at soot.SootResolver.processResolveWorklist(SootResolver.java:171)
    at soot.SootResolver.resolveClass(SootResolver.java:141)
    at soot.Scene.forceResolve(Scene.java:2095)
    at javaLink.JavaLink.run(JavaLink.java:78)
    at findJavaLink.main(findJavaLink.java:14)
Caused by: java.util.concurrent.ExecutionException: java.lang.Exception: Error:
    The path '/Library/Java/JavaVirtualMachines/jdk1.8.0_231.jdk/Contents/Home/jre
    /lib/rt.jar' does not exist.
    at com.google.common.util.concurrent.AbstractFuture.getDoneValue(
        AbstractFuture.java:552)
    at com.google.common.util.concurrent.AbstractFuture.get(AbstractFuture.java
        :513)
    at com.google.common.util.concurrent.AbstractFuture$TrustedFuture.get(
        AbstractFuture.java:90)
    at com.google.common.util.concurrent.Uninterruptibles.getUninterruptibly(
        Uninterruptibles.java:197)
    at com.google.common.cache.LocalCache$Segment.getAndRecordStats(LocalCache.
        java:2229)
    at com.google.common.cache.LocalCache$Segment.loadSync(LocalCache.java:2195)
    at com.google.common.cache.LocalCache$Segment.lockedGetOrLoad(LocalCache.java
        :2153)
    at com.google.common.cache.LocalCache$Segment.get(LocalCache.java:2043)
    at com.google.common.cache.LocalCache.get(LocalCache.java:3851)
    at com.google.common.cache.LocalCache.getOrLoad(LocalCache.java:3875)
    at com.google.common.cache.LocalCache$LocalLoadingCache.get(LocalCache.java
        :4800)
    at soot.SourceLocator.getClassSourceType(SourceLocator.java:310)
    ... 12 more
Caused by: java.lang.Exception: Error: The path '/Library/Java/JavaVirtualMachines
    /jdk1.8.0_231.jdk/Contents/Home/jre/lib/rt.jar' does not exist.
```

```
30      at soot.SourceLocator$1.load(SourceLocator.java:73)
31      at soot.SourceLocator$1.load(SourceLocator.java:68)
32      at com.google.common.cache.LocalCache$LoadingValueReference.loadFuture(
            LocalCache.java:3445)
33      at com.google.common.cache.LocalCache$Segment.loadSync(LocalCache.java:2194)
34      ... 18 more
```

So, find the available Java libraries in our machine using `sudo find / -iname rt.jar`:

```
1  /home/weiminn/Documents/aosp13/prebuilts/jdk/jdk8/darwin-x86/jre/lib/rt.jar
2  /home/weiminn/Documents/aosp13/prebuilts/jdk/jdk8/linux-x86/jre/lib/rt.jar
3  /home/weiminn/Documents/aosp14/prebuilts/jdk/jdk8/darwin-x86/jre/lib/rt.jar
4  /home/weiminn/Documents/aosp14/prebuilts/jdk/jdk8/linux-x86/jre/lib/rt.jar
5  find: '/proc/1246576': No such file or directory
6  /usr/lib/jvm/java-8-openjdk-amd64/jre/lib/rt.jar
7  find: '/run/user/1000/gvfs': Permission denied
8  find: '/run/user/1000/doc': Permission denied
```

Change the following contents of `Config.java` to:

```
1  //      static String MAC_jreDir = "/Library/Java/JavaVirtualMachines/jdk1.8.0_231.
       jdk/Contents/Home/jre/lib/rt.jar";
2  //      static String MAC_jceDir = "/Library/Java/JavaVirtualMachines/jdk1.8.0_231.
       jdk/Contents/Home/jre/lib/jce.jar";
3
4  static String MAC_jreDir = "/usr/lib/jvm/java-8-openjdk-amd64/jre/lib/rt.jar";
5  static String MAC_jceDir = "/usr/lib/jvm/java-8-openjdk-amd64/jre/lib/jce.jar";
6
7  //      static String MAC_ANDROID_JAR = "/android-hidden-api-master/android-26/
       android.jar";
8  //      static String MAC_SERVICES_JAR = "/android-hidden-api-master/android-26/
       services.jar";
9
10 static String MAC_ANDROID_JAR = "/home/weiminn/Android/Sdk/platforms/android-34/
       android.jar";
11 static String MAC_SERVICES_JAR = "/home/weiminn/Documents/aosp14/out/target/
       product/emulator_x86_64/system/framework/services.jar";
```

Error message:

```
1  Exception in thread "main" java.lang.RuntimeException: java.util.concurrent.
       ExecutionException: java.lang.Exception: Error: The path '/home/weiminn/
       Documents/NatiDroid/jar8.1/services.devicepolicy_intermediates.jar' does not
       exist.
2      at soot.SourceLocator.getClassSourceType(SourceLocator.java:312)
3      at soot.SourceLocator.lookupInClassPath(SourceLocator.java:615)
4      at soot.asm.AsmClassProvider.find(AsmClassProvider.java:39)
5      at soot.SourceLocator.getClassSource(SourceLocator.java:187)
6      at soot.SootResolver.bringToHierarchyUnchecked(SootResolver.java:231)
7      at soot.SootResolver.bringToHierarchy(SootResolver.java:221)
8      at soot.SootResolver.bringToSignatures(SootResolver.java:292)
9      at soot.SootResolver.bringToBodies(SootResolver.java:332)
10     at soot.SootResolver.processResolveWorklist(SootResolver.java:171)
11     at soot.SootResolver.resolveClass(SootResolver.java:141)
12     at soot.Scene.forceResolve(Scene.java:2095)
13     at javaLink.JavaLink.run(JavaLink.java:78)
14     at findJavaLink.main(findJavaLink.java:14)
15 Caused by: java.util.concurrent.ExecutionException: java.lang.Exception: Error:
       The path '/home/weiminn/Documents/NatiDroid/jar8.1/services.
```

```
    devicepolicy_intermediates.jar' does not exist.
16      at com.google.common.util.concurrent.AbstractFuture.getDoneValue(
            AbstractFuture.java:552)
17      at com.google.common.util.concurrent.AbstractFuture.get(AbstractFuture.java
            :513)
18      at com.google.common.util.concurrent.AbstractFuture$TrustedFuture.get(
            AbstractFuture.java:90)
19      at com.google.common.util.concurrent.Uninterruptibles.getUninterruptibly(
            Uninterruptibles.java:197)
20      at com.google.common.cache.LocalCache$Segment.getAndRecordStats(LocalCache.
            java:2229)
21      at com.google.common.cache.LocalCache$Segment.loadSync(LocalCache.java:2195)
22      at com.google.common.cache.LocalCache$Segment.lockedGetOrLoad(LocalCache.java
            :2153)
23      at com.google.common.cache.LocalCache$Segment.get(LocalCache.java:2043)
24      at com.google.common.cache.LocalCache.get(LocalCache.java:3851)
25      at com.google.common.cache.LocalCache.getOrLoad(LocalCache.java:3875)
26      at com.google.common.cache.LocalCache$LocalLoadingCache.get(LocalCache.java
            :4800)
27      at soot.SourceLocator.getClassSourceType(SourceLocator.java:310)
28      ... 12 more
29  Caused by: java.lang.Exception: Error: The path '/home/weiminn/Documents/NatiDroid
        /jar8.1/services.devicepolicy_intermediates.jar' does not exist.
30      at soot.SourceLocator$1.load(SourceLocator.java:73)
31      at soot.SourceLocator$1.load(SourceLocator.java:68)
32      at com.google.common.cache.LocalCache$LoadingValueReference.loadFuture(
            LocalCache.java:3445)
33      at com.google.common.cache.LocalCache$Segment.loadSync(LocalCache.java:2194)
34      ... 18 more
```

Modify /home/weiminn/Documents/NatiDroid/py/collect_jar.py:

```
1  version = '7.0'
2  project_path = '/android-7.0.0_r33/out/target/common/obj/JAVA_LIBRARIES'
3
4  version = '14.0'
5  project_path = '/home/weiminn/Documents/aosp14/out/target/common/obj/
       JAVA_LIBRARIES'
```

4.3 Febuary 14-15, 2024

4.3.1 Figure out NatiDroid for AOSP14

Solved Java part of Natidroid

```
1  git clone https://github.com/Sable/soot.git
2  git checkout develop
3  sudo apt install maven
4  sudo update-alternatives --config java
5  mvn clean compile assembly:single
6  rm -rf out && mkdir out && javac src/*.java src/javaLink/*.java src/cppLink/*.java
       src/util/*.java -cp "./libs/*" -d out && java -cp "./out:./soot/target/
       sootclasses-trunk-jar-with-dependencies.jar" findJavaLink
```

Workspace:

```
# terminal 1
rm -rf out && mkdir out && javac src/*.java src/javaLink/*.java src/cppLink/*.java
     src/util/*.java -cp "./soot/target/sootclasses-trunk-jar-with-dependencies.
    jar:./libs/fastjson-1.2.73.jar" -d out && java -cp "./out:./soot/target/
    sootclasses-trunk-jar-with-dependencies.jar" findJavaLink
# terminal 2
clear && find ./ \( -iname '*.java' -a ! -iname '*test*' \) | xargs grep --color -
    in 'internalTransform.*;'
# terminal 3
mvn clean compile assembly:single
```

Chapter 5

March

5.1 March 05-13, 2024

5.1.1 Migrate Zicheng's code

Code differencing

file	13 to Debloated 13	13 to 14
art_dex_file_loader.cc	No change	Removed MemMapContainer. Replace DexFileLoader::OpenCommon now protected with ArtDexFileLoader::Open, and remove its other overloads.
dex_file_loader.cc	No change	Remove DexFileLoader::GetMultiDexChecksums, DexFileLoader::OpenAll, DexFileLoader::OpenOneDexFileFromZip, DexFileLoader::OpenAllDexFilesFromZip. Modified DexFileLoader::Open and added its overloads, DexFileLoader::OpenCommon and added its overloads. Added DexFileLoader::InitAndReadMagic, DexFileLoader::OpenWithDataSection, DexFileLoader::OpenFromZipEntry
native_loader.cpp	Trivial loggings	No change

file	13 to Debloated 13	13 to 14
native_loader_namespace.cpp	Trivial loggings	No change
odrefresh.cc	Change from `args.emplace_back("--compiler-filter=speed");` to `args.emplace_back("--compiler-filter=verify");`	Tons of change
quick_trampoline_entrypoints.cc	No change	Lots of change
interpreter_common.cc	Trivial Logging	Modified `ShouldStayInSwitchInterpreter`, `MoveToExceptionHandler`, `DoCallCommon`, `ArtInterpreterToCompiledCodeBridge`, `InvokeBootstrapMethod`, `DoCall`. Added `UnlockHeldMonitors`
interpreter_switch.cc	Trivial JNI headers imported	Modified `ShouldStayInSwitchInterpreter`, `MoveToExceptionHandler`, `DoCallCommon`, `ArtInterpreterToCompiledCodeBridge`, `InvokeBootstrapMethod`, `DoCall`. Added `UnlockHeldMonitors`

file	13 to Debloated 13	13 to 14
interpreter_switch_impl-inl.h	Trivial JNI headers imported	Modified template settings for CheckTransactionAbort, CheckForceReturn, HandlePendingException, HandleReturn, HandleGet, HandlePut, HandleInvoke, RETURN_OBJECT, MONITOR_ENTER, MONITOR_EXIT, NEW_ARRAY, FILLED_NEW_ARRAY, FILLED_NEW_ARRAY_RANGE, ExecuteSwitchImplCpp. Modified Preamble, CONST_CLASS, CHECK_CAST, INSTANCE_OF, NEW_INSTANCE, THROW, CHECK_CAST. Added DoAssignabilityChecks
interpreter_switch_impl.h	Trivial logging headers imported	Modified template settings for ExecuteSwitchImplCpp, ExecuteSwitchImpl.
interpreter.cc	No changes	Modified ExecuteSwitch, Execute, EnterInterpreterFromInvoke, EnterInterpreterFromDeoptimize, EnterInterpreterFromEntryPoint.
jit.cc, jit_code_cache.cc	No changes	Changes

file	13 to Debloated 13	13 to 14
`java_vm_ext.cc`	Modified `FindSymbol` to check if MINIMA symbol	Modified `JavaVMExt::JavaVMExt`, `JavaVMExt::Create`, `JavaVMExt::AddGlobalRef`, `JavaVMExt::AddWeakGlobalRef`, `JavaVMExt::DeleteGlobalRef`, `JavaVMExt::DeleteWeakGlobalRef`, `JavaVMExt::DisallowNewWeakGlobals`, `JavaVMExt::AllowNewWeakGlobals`, `JavaVMExt::DecodeGlobal`, `JavaVMExt::GetIndirectRefKind`, `JavaVMExt::DecodeWeakGlobalDuringShut` `JavaVMExt::LoadNativeLibrary`, `JavaVMExt::FindCodeForNativeMethod`, `JavaVMExt::GetLibrarySearchPath`. Added `JavaVMExt::Initialize`, `JavaVMExt::DecodeWeakGlobalAsStrong`. Remove `JavaVMExt::SweepJniWeakGlobals`

Table 5.1: Differences

Code differencer

```
1  import os
2  import shutil
3  import difflib
4
5  def html_prep(files, title, workspace, out):
6      html_output = """
7          <!DOCTYPE html>
8          <html>
9          <head>
10         <style>
11         table, th, td {{
12             border: 1px solid black;
13         }}
14         </style>
15         </head>
16         <body>
17         <h2>{}</h2>
18         <body>
19
20         <table>
21             <thead>
22             <tr>
23                 <th>{}</th>
```

```
            </tr>
            </thead>
            <tbody>
        """.format(title, out)

    for file in files:
        html_output += """
            <tr>
                <td><a href="{}_diff.html">{}</a></td>
            </tr>""".format(file, file[len(workspace+out):])

    # Close HTML tags
    html_output += "</table></body></html>"
    return html_output

def compare_files(file1, file2, workspace):

    """
    Compares two C++ source files using the difflib module.

    Args:
        file1: Path to the first C++ source file.
        file2: Path to the second C++ source file.

    Returns:
        A string containing the differences between the two files,
        or None if the files are identical.
    """

    if os.path.isdir(file1) or os.path.isdir(file2):
        return

    html_output = ""

    try:

        with open(file1, 'r') as f1, open(file2, 'r') as f2:
            # Read content of files line by line
            data1 = f1.readlines()
            data2 = f2.readlines()

        # Use difflib to compare the lines
        diff = difflib.unified_diff(data1, data2, fromfile=file1, tofile=file2)

        if not diff:
            return None  # Files are identical

        # Generate basic HTML structure
        html_output = """
    <!DOCTYPE html>
    <html>
    <head>
    <style>
    .added {{ background-color: lightgreen; }}
    .removed {{ background-color: lightcoral; }}
    </style>
    </head>
    <body>
    <h2>Differences between {} vs. {}</h2>
```

```
83      <pre>""".format(file1[len(workspace):], file2[len(workspace):])
84
85          # Add each line with highlighting
86          for line in diff:
87              if line.startswith("+"):
88                  html_output += "<span class='added'>{}</span>\n".format(line.strip
                        ())
89              elif line.startswith("-"):
90                  html_output += "<span class='removed'>{}</span>\n".format(line.
                        strip())
91              else:
92                  html_output += "{}\n".format(line.strip())
93
94          # Close HTML tags
95          html_output += "</pre></body></html>"
96
97      except FileNotFoundError as e:
98          pass
99
100     return html_output
101
102 def read_directory_contents(directory):
103     """
104     Reads the contents of a directory and its subdirectories recursively.
105
106     Args:
107         directory: Path to the directory to read.
108
109     Returns:
110         A list of full paths to all files within the directory and subdirectories.
111     """
112
113     all_files = []
114     for root, dirs, files in os.walk(directory):
115         for file in files:
116             # if file != '.git':
117             # Construct the full path to the file
118             full_path = os.path.join(root, file)
119             if not os.path.isdir(full_path):
120                 all_files.append(full_path)
121     return all_files
122
123 def switch_project_path(path, dest_proj):
124     parsed_path = path.split('/')
125     parsed_path[4] = dest_proj
126     return '/'.join(parsed_path)
127
128 def create_dir_for_path_to_file(path):
129     parsed_path = path.split('/')
130     dir_only_path = '/'.join(parsed_path[:-1])
131     try:
132         os.makedirs(dir_only_path)  # Create directory and any missing parent
                directories
133     except FileExistsError:
134         pass  # Ignore if the directory already exists
135
136 def remove_outputs(workspace, out):
137     try:
138         # Use shutil.rmtree with the ignore_errors argument
```

```
139         shutil.rmtree(workspace + out, ignore_errors=True)
140         print(f"Directory deleted successfully: {workspace + out}")
141     except OSError as e:
142         raise OSError(f"Error deleting directory: {workspace + out}. Reason: {e}")
                from e
143
144 def compare_and_print(src, tgt, ref, workspace, out):
145     remove_outputs(workspace, out)
146     processed_files = []
147     for f in read_directory_contents(ref): # load list of customized aosp files
148         # create path/to/dir
149         if not os.path.isdir(f):
150             output_path = switch_project_path(f, 'diff/' + out)
151             create_dir_for_path_to_file(output_path)
152             diff = compare_files(switch_project_path(f, src.split('/')[4]),
                    switch_project_path(f, tgt.split('/')[4]), out)
153
154             with open(output_path+"_diff.html", "w") as f:
155                 if diff:
156                     if diff is not "":
157                         f.write(diff)
158                     else:
159                         f.write("""
160                             <!DOCTYPE html>
161                             <html>
162                             <head>
163                             <style>
164                             .added {{ background-color: lightgreen; }}
165                             .removed {{ background-color: lightcoral; }}
166                             </style>
167                             </head>
168                             <body>
169                             <h2>No Differences between {} vs. {}</h2>
170                             </body></html>""".format(switch_project_path(f, src.
                                split('/')[4]), switch_project_path(f, tgt.split('
                                /')[4])))
171                     processed_files.append(output_path)
172
173     with open(workspace + out + "/index.html", "w") as f:
174         f.write(html_prep(processed_files, src.split('/')[4] + " vs. " + tgt.split
                ('/')[4] + " Differenced", workspace, out))
175
176 workspace = "/home/weiminn/Documents/diff/"
177
178 # they must follow aosp dir structure
179 aosp_de_dir = "/home/weiminn/Documents/customized_aosp" # used as reference on
        what to compare
180 aosp_13_dir = "/home/weiminn/Documents/aosp13"
181 aosp_14_dir = "/home/weiminn/Documents/aosp14"
182
183 # compare aosp13 vs aosp13 debloated
184 compare_and_print(aosp_13_dir, aosp_de_dir, aosp_de_dir, workspace, "13vs13debloat
        ")
185 # compare aosp13 vs aosp14
186 compare_and_print(aosp_13_dir, aosp_14_dir, aosp_de_dir, workspace, "13vs14")
```

Understand Customized AOSP

`art_quick_invoke_static_stub`[1]
`art_quick_generic_jni_trampoline`[2]
`artQuickGenericJniTrampoline`[3]
ART Execution[4]
Forking process, binding application, launch activity [5]

5.2 March 14-30, 2024

5.2.1 Migrate Zicheng's code

Customize AOSP 14

file	Customized AOSP13	Changes in 14
`java_vm_ext.cc`	Modify `FindSymbol`.	No changes for `FindSymbol`.
`art_method.h`	Modify `UpdateCounter` declaration.	No changes for `FindSymbol`.
`art_method-inl.h`	Modify `UpdateCounter` definition (added unused variable declarations)	No changes for `FindSymbol`.
`art_method.cc`	Modify `Invoke`, and `PrettyMethod`.	No changes for `Invoke`.
`app_info.h`	Add `GetPackageName` public declaration.	No related changes.
`app_info.cc`	Add `GetPackageName` definition.	No related changes.
`runtime.h`	Add `NativeLibFunc` struct, public declaration for a lot of functions and variables.	No related changes.

Table 5.2: Customizing AOSP 14

Scripts

Script to run the emulator and log console outputs:

[1] `https://zhuanlan.zhihu.com/p/521498157`
[2] `https://juejin.cn/post/7249288285809524773`
[3] `https://blog.csdn.net/sinat_38172893/article/details/74612596`
[4] `https://blog.csdn.net/sinat_38172893/article/details/72934122`
[5] `https://medium.com/android-news/android-application-launch-explained-from-zygote-to-your-activi`

```
emulator &
adb wait-for-device
A=$(adb shell getprop sys.boot_completed | tr -d '\r')

while [ "$A" != "1" ]; do
        sleep 1
        A=$(adb shell getprop sys.boot_completed | tr -d '\r')
done

adb root
echo "[WEIMINN] Enabling logging"
adb shell setprop debug.ld.all dlerror,dlopen
rm -f logcat.txt
echo "[WEIMINN] Logging with Logcat to logcat.txt"
adb logcat >> logcat.txt
```

Script to kill running emulator process:

```
adb devices | grep emulator | cut -f1 | while read line; do adb -s $line emu kill;
    done
```

Script for finding a string:

```
cd /home/weiminn/Documents/aosp14/

clear

find \
    ./frameworks/ ./art/ ./bionic/ \
    \( -iname '*.java' -o -iname '*.cpp' -o -iname '*.cc' -o -iname '*.hpp' -o -
        iname '*.h' -o -iname '*.S' \) \
    -a ! -iname '*test*' -a ! -iname '*out*' \
    | xargs grep --color -sin 'invoke'
```

Comment to annotate added code:

```
////////////////////// DYNDROID-START //////////////////////
////////////////////// DYNDROID-END //////////////////////
```

Problems

Faced problem in `runtime.h` after copying in

```
void setLoadingSchema(bool loading, std::string s){
    ALOGW("[Zicheng_Content_Provider] runtime.h setLoadingSchema() package:%s, %s"
        , s.c_str(), loading ? "true" : "false");
    loading_schema_ = loading;
}

void setLoadedSchema(bool loaded, std::string s){
    ALOGW("[Zicheng_Content_Provider] runtime.h setLoadedSchema() package:%s", s.
        c_str());
    loaded_schema_ = loaded;
}

void setShouldReadSchema(bool should, std::string s){
    ALOGW("[Zicheng_Content_Provider] runtime.h setShouldReadSchema() package:%s, 
        %s", s.c_str(), should ? "true" : "false");
```

```
13      should_read_schema_ = should;
14  }
```

because there is no definition for `ALOGW`, so I put `#include "utils/Log.h"` at the top of `runtime.h`, and it worked!

Need to edit and compile `runtime.h` and `runtime.cc` after editing `art_method.cc`, as it calls `Runtime::MYmatch_target_method`.

Changes to `void Instrumentation::InitializeMethodsCode` by both DynDroid and AOSP 14.

What does `.clang-format` mean?

5.3 March 31, 2024

5.3.1 Troubleshoot DynDroid on AOSP 14

Integrate Changes to Zygote code

Put customized code into remaining `dalvik_systemZygoteHooks.cc`, `odrefresh.cc`, and `odrefresh_main.cc`.

Test Run Minima in Emulator

Android is still crashing when using `adb install command`:

```
1  adb install success_apps/53_com.technoskill.cricketscore.apk
2  Performing Streamed Install
3  adb: failed to install success_apps/53_com.technoskill.cricketscore.apk: cmd:
       Failure calling service package: Broken pipe (32)
```

Test Package Manager in AOSP14 Clean

AOSP 14 Clean on P7Pro works for `adb install`.

Some have incompatible API versions:

```
1  adb install success_apps/68_im.dev.pregnancy.apk
2  Performing Streamed Install
3  adb: failed to install success_apps/68_im.dev.pregnancy.apk: Failure [
       INSTALL_FAILED_DEPRECATED_SDK_VERSION: App package must target at least SDK
       version 23, but found 16]
```

Preload Minima and Test Apps on Clean AOSP 14

Cannot build anymore:

```
1  internal error: bazel command failed: fork/exec ./build/bazel/bin/bazel: no such
       file or directory
```

Successfully preloaded `MedicalDrugDictionary.apk`, but the app crashes on load.

Deleted `out` directory, and successfully reran the `make` command.

Weird problem where `fastboot -w flashall` does not remove the apps from previous version of OS. So, just do `fastboot -w` and it'll wipe properly.

Somehow preloading APKs causes them to crash at load:

```
1  03-31 15:04:36.501  4596  4596 W System.err: java.io.StreamCorruptedException:
       invalid stream header: 4DF493E3
2  03-31 15:04:36.501  4596  4596 W System.err:  at java.io.ObjectInputStream.
       readStreamHeader(ObjectInputStream.java:865)
3  03-31 15:04:36.501  4596  4596 W System.err:  at java.io.ObjectInputStream.<init>(
       ObjectInputStream.java:356)
4  03-31 15:04:36.501  4596  4596 W System.err:  at com.atomic.apps.medical.drug.
       dictionary.a.b(Unknown Source:10)
5  03-31 15:04:36.501  4596  4596 W System.err:  at com.atomic.apps.medical.drug.
       dictionary.a.c(Unknown Source:2)
6  03-31 15:04:36.502  4596  4596 W System.err:  at com.atomic.apps.medical.drug.
       dictionary.a.b(Unknown Source:4)
7  03-31 15:04:36.502  4596  4596 W System.err:  at com.atomic.apps.medical.drug.
       dictionary.a.<init>(Unknown Source:12)
8  03-31 15:04:36.502  4596  4596 W System.err:  at com.atomic.apps.medical.drug.
       dictionary.a.a(Unknown Source:6)
9  03-31 15:04:36.502  4596  4596 W System.err:  at com.atomic.apps.medical.drug.
       dictionary.DrugsListActivity.onCreate(Unknown Source:21)
10 03-31 15:04:36.502  4596  4596 W System.err:  at android.app.Activity.
       performCreate(Activity.java:8621)
11 03-31 15:04:36.502  4596  4596 W System.err:  at android.app.Activity.
       performCreate(Activity.java:8599)
12 03-31 15:04:36.502  4596  4596 W System.err:  at android.app.Instrumentation.
       callActivityOnCreate(Instrumentation.java:1456)
13 03-31 15:04:36.502  4596  4596 W System.err:  at android.app.ActivityThread.
       performLaunchActivity(ActivityThread.java:3804)
14 03-31 15:04:36.502  4596  4596 W System.err:  at android.app.ActivityThread.
       handleLaunchActivity(ActivityThread.java:3963)
15 03-31 15:04:36.502  4596  4596 W System.err:  at android.app.servertransaction.
       LaunchActivityItem.execute(LaunchActivityItem.java:103)
16 03-31 15:04:36.502  4596  4596 W System.err:  at android.app.servertransaction.
       TransactionExecutor.executeCallbacks(TransactionExecutor.java:139)
17 03-31 15:04:36.502  4596  4596 W System.err:  at android.app.servertransaction.
       TransactionExecutor.execute(TransactionExecutor.java:96)
18 03-31 15:04:36.502  4596  4596 W System.err:  at android.app.ActivityThread$H.
       handleMessage(ActivityThread.java:2468)
19 03-31 15:04:36.502  4596  4596 W System.err:  at android.os.Handler.
       dispatchMessage(Handler.java:106)
20 03-31 15:04:36.502  4596  4596 W System.err:  at android.os.Looper.loopOnce(Looper
       .java:205)
21 03-31 15:04:36.502  4596  4596 W System.err:  at android.os.Looper.loop(Looper.
       java:294)
22 03-31 15:04:36.502  4596  4596 W System.err:  at android.app.ActivityThread.main(
       ActivityThread.java:8248)
23 03-31 15:04:36.502  4596  4596 W System.err:  at java.lang.reflect.Method.invoke(
       Native Method)
24 03-31 15:04:36.502  4596  4596 W System.err:  at com.android.internal.os.
       RuntimeInit$MethodAndArgsCaller.run(RuntimeInit.java:552)
25 03-31 15:04:36.502  4596  4596 W System.err:  at com.android.internal.os.
       ZygoteInit.main(ZygoteInit.java:971)
26 03-31 15:04:36.502  4596  4596 W System.err: java.io.StreamCorruptedException:
```

```
        invalid stream header: 35BBE049
27  03-31 15:04:36.502  4596  4596 W System.err:  at java.io.ObjectInputStream.
        readStreamHeader(ObjectInputStream.java:865)
28  03-31 15:04:36.502  4596  4596 W System.err:  at java.io.ObjectInputStream.<init>(
        ObjectInputStream.java:356)
29  03-31 15:04:36.502  4596  4596 W System.err:  at com.atomic.apps.medical.drug.
        dictionary.a.b(Unknown Source:10)
30  03-31 15:04:36.502  4596  4596 W System.err:  at com.atomic.apps.medical.drug.
        dictionary.a.c(Unknown Source:10)
31  03-31 15:04:36.502  4596  4596 W System.err:  at com.atomic.apps.medical.drug.
        dictionary.a.b(Unknown Source:4)
32  03-31 15:04:36.502  4596  4596 W System.err:  at com.atomic.apps.medical.drug.
        dictionary.a.<init>(Unknown Source:12)
33  03-31 15:04:36.502  4596  4596 W System.err:  at com.atomic.apps.medical.drug.
        dictionary.a.a(Unknown Source:6)
34  03-31 15:04:36.502  4596  4596 W System.err:  at com.atomic.apps.medical.drug.
        dictionary.DrugsListActivity.onCreate(Unknown Source:21)
35  03-31 15:04:36.502  4596  4596 W System.err:  at android.app.Activity.
        performCreate(Activity.java:8621)
36  03-31 15:04:36.502  4596  4596 W System.err:  at android.app.Activity.
        performCreate(Activity.java:8599)
37  03-31 15:04:36.502  4596  4596 W System.err:  at android.app.Instrumentation.
        callActivityOnCreate(Instrumentation.java:1456)
38  03-31 15:04:36.502  4596  4596 W System.err:  at android.app.ActivityThread.
        performLaunchActivity(ActivityThread.java:3804)
39  03-31 15:04:36.502  4596  4596 W System.err:  at android.app.ActivityThread.
        handleLaunchActivity(ActivityThread.java:3963)
40  03-31 15:04:36.502  4596  4596 W System.err:  at android.app.servertransaction.
        LaunchActivityItem.execute(LaunchActivityItem.java:103)
41  03-31 15:04:36.502  4596  4596 W System.err:  at android.app.servertransaction.
        TransactionExecutor.executeCallbacks(TransactionExecutor.java:139)
42  03-31 15:04:36.502  4596  4596 W System.err:  at android.app.servertransaction.
        TransactionExecutor.execute(TransactionExecutor.java:96)
43  03-31 15:04:36.502  4596  4596 W System.err:  at android.app.ActivityThread$H.
        handleMessage(ActivityThread.java:2468)
44  03-31 15:04:36.502  4596  4596 W System.err:  at android.os.Handler.
        dispatchMessage(Handler.java:106)
45  03-31 15:04:36.502  4596  4596 W System.err:  at android.os.Looper.loopOnce(Looper
        .java:205)
46  03-31 15:04:36.502  4596  4596 W System.err:  at android.os.Looper.loop(Looper.
        java:294)
47  03-31 15:04:36.502  4596  4596 W System.err:  at android.app.ActivityThread.main(
        ActivityThread.java:8248)
48  03-31 15:04:36.502  4596  4596 W System.err:  at java.lang.reflect.Method.invoke(
        Native Method)
49  03-31 15:04:36.502  4596  4596 W System.err:  at com.android.internal.os.
        RuntimeInit$MethodAndArgsCaller.run(RuntimeInit.java:552)
50  03-31 15:04:36.502  4596  4596 W System.err:  at com.android.internal.os.
        ZygoteInit.main(ZygoteInit.java:971)
51  03-31 15:04:36.502  4596  4596 D com.atomic.apps.medical.drug.dictionary: Using B
52  03-31 15:04:36.502  4596  4596 D AndroidRuntime: Shutting down VM
53  03-31 15:04:36.502  4596  4596 E AndroidRuntime: FATAL EXCEPTION: main
54  03-31 15:04:36.502  4596  4596 E AndroidRuntime: Process: com.atomic.apps.medical.
        drug.dictionary, PID: 4596
55  03-31 15:04:36.502  4596  4596 E AndroidRuntime: java.lang.RuntimeException:
        Unable to start activity ComponentInfo{com.atomic.apps.medical.drug.dictionary
        /com.atomic.apps.medical.drug.dictionary.DrugsListActivity}: java.lang.
        NullPointerException: Attempt to invoke virtual method 'byte[] java.lang.
        String.getBytes()' on a null object reference
```

```
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at android.app.ActivityThread.performLaunchActivity(ActivityThread.java:3822)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at android.app.ActivityThread.handleLaunchActivity(ActivityThread.java:3963)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at android.app.servertransaction.LaunchActivityItem.execute(LaunchActivityItem.java:103)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at android.app.servertransaction.TransactionExecutor.executeCallbacks(TransactionExecutor.java:139)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at android.app.servertransaction.TransactionExecutor.execute(TransactionExecutor.java:96)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at android.app.ActivityThread$H.handleMessage(ActivityThread.java:2468)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at android.os.Handler.dispatchMessage(Handler.java:106)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at android.os.Looper.loopOnce(Looper.java:205)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at android.os.Looper.loop(Looper.java:294)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at android.app.ActivityThread.main(ActivityThread.java:8248)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at java.lang.reflect.Method.invoke(Native Method)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at com.android.internal.os.RuntimeInit$MethodAndArgsCaller.run(RuntimeInit.java:552)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at com.android.internal.os.ZygoteInit.main(ZygoteInit.java:971)
03-31 15:04:36.502  4596  4596 E AndroidRuntime: Caused by: java.lang.NullPointerException: Attempt to invoke virtual method 'byte[] java.lang.String.getBytes()' on a null object reference
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at com.atomic.apps.medical.drug.dictionary.a.a(Unknown Source:0)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at com.atomic.apps.medical.drug.dictionary.a.b(Unknown Source:8)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at com.atomic.apps.medical.drug.dictionary.a.<init>(Unknown Source:12)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at com.atomic.apps.medical.drug.dictionary.a.a(Unknown Source:6)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at com.atomic.apps.medical.drug.dictionary.DrugsListActivity.onCreate(Unknown Source:21)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at android.app.Activity.performCreate(Activity.java:8621)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at android.app.Activity.performCreate(Activity.java:8599)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at android.app.Instrumentation.callActivityOnCreate(Instrumentation.java:1456)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  at android.app.ActivityThread.performLaunchActivity(ActivityThread.java:3804)
03-31 15:04:36.502  4596  4596 E AndroidRuntime:  ... 12 more
03-31 15:04:36.504  1496  2267 W ActivityTaskManager:   Force finishing activity com.atomic.apps.medical.drug.dictionary/.DrugsListActivity
```

Replace Framework and Run

`PackageManager.java`, `DefaultPermissionGrantPolicy.java`, `PermissionManagerServiceImpl.java`, `ParsingPackageUtils.java` has only trivial logging code.

`PermissionManagerService.java` has some changes to requested permissions in

onPackageInstalled. PackageParser.java has changes to parseBaseApkCommon.

Same problem with emulator version:

```
adb install success_apps/60_com.atomic.apps.medical.drug.dictionary.apk
Performing Streamed Install
adb: failed to install success_apps/60_com.atomic.apps.medical.drug.dictionary.apk
    : cmd: Failure calling service package: Broken pipe (32)
```

Logcat output:

```
03-31 15:47:11.367  6659  6709 E AndroidRuntime: *** FATAL EXCEPTION IN SYSTEM
    PROCESS: PackageManager
03-31 15:47:11.367  6659  6709 E AndroidRuntime: java.lang.
    UnsupportedOperationException
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at java.util.
    Collections$UnmodifiableCollection.add(Collections.java:1114)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at com.android.server.pm.
    permission.PermissionManagerService$PermissionManagerServiceInternalImpl.
    onPackageInstalled(PermissionManagerService.java:706)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at com.android.server.pm.
    InstallPackageHelper.updateSettingsInternalLI(InstallPackageHelper.java:2370)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at com.android.server.pm.
    InstallPackageHelper.updateSettingsLI(InstallPackageHelper.java:2165)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at com.android.server.pm.
    InstallPackageHelper.commitPackagesLocked(InstallPackageHelper.java:2134)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at com.android.server.pm.
    InstallPackageHelper.installPackagesLI(InstallPackageHelper.java:1031)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at com.android.server.pm.
    InstallPackageHelper.installPackagesTraced(InstallPackageHelper.java:915)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at com.android.server.pm.
    InstallingSession.processApkInstallRequests(InstallingSession.java:540)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at com.android.server.pm.
    InstallingSession.processInstallRequests(InstallingSession.java:529)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at com.android.server.pm.
    InstallingSession.lambda$processPendingInstall$0(InstallingSession.java:288)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at com.android.server.pm.
    InstallingSession.$r8$lambda$tqRjKCgCJYNNnnY7Qw5M5BHLup8(InstallingSession.
    java:0)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at com.android.server.pm.
    InstallingSession$$ExternalSyntheticLambda1.run(R8$$SyntheticClass:0)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at android.os.Handler.
    handleCallback(Handler.java:958)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at android.os.Handler.
    dispatchMessage(Handler.java:99)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at android.os.Looper.loopOnce(
    Looper.java:205)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at android.os.Looper.loop(Looper
    .java:294)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at android.os.HandlerThread.run(
    HandlerThread.java:67)
03-31 15:47:11.367  6659  6709 E AndroidRuntime:  at com.android.server.
    ServiceThread.run(ServiceThread.java:46)
```

Problematic code:

```
String name = "edu.smu.minimaconfig.MyContentProvider.READ";
int index_1 = pkg.getRequestedPermissions().indexOf(name);
if (index_1 == -1) {
    pkg.getRequestedPermissions().add(name.intern());
```

```
5       Slog.w("zicheng_framework", "[Zicheng_frameworks]onPackageInstalled() add
            permission:"
6               + name + " in package: " + pkg.getPackageName());
7   } else {
8       Slog.w("zicheng_framework", "[Zicheng_frameworks]onPackageInstalled() Ignoring
             duplicate uses-permissions/uses-permissions-sdk-m: "
9               + name + " in package: " + pkg.getPackageName());
10  }
11  if(pkg.getRequestedPermissions().size()>0)
12      for(int kk=0;kk<pkg.getRequestedPermissions().size();kk++)
13          Slog.w("zicheng_framework", "[Zicheng_frameworks]PermissionManagerService.
                java onPackageInstalled()"+
14                  " in package: " + pkg.getPackageName() + "permission num: "+kk
                        +":"+pkg.getRequestedPermissions().get(kk));
```

Removed this line of code from emulator project also. The app can be successfully `adb installed` but the app crashes after loading splash screen for a long time.

Chapter 6

April

6.1 April 01, 2024

6.1.1 Complete Lifecycle Hook Execution Flow

Android Lifecycle Hooks

`onCreate`, `onStart`, `onPause`, `onStop`, `onResume`, `onDestroy`[1]

`onCreate` Hook Ran by `ActivityThread`

Look for `ActivityThread.java` which has `performLaunchActivity` method which calls `onCreate`[2]

It is called by `ClientTransactionHandler`'s `handleLaunchActivity` which is called by [3]

What's the difference between `BIND_APPLICATION` and `attachapplication`?

`BIND_APPLICATION` is the message handled by `ActivityThread` which goes on to call `attachApplication`.

What's the difference between Launch Activity vs Start Activity?

`BIND_APPLICATION`[4] message is sent to the system server's looper after new process is spawned, to bind the application to the process.

[1] `https://developer.android.com/guide/components/activities/activity-lifecycle`
[2] `https://www.jianshu.com/p/c8e09bc142fa`
[3] `https://blog.csdn.net/shulianghan/article/details/120263706`
[4] `https://medium.com/android-news/android-application-launch-explained-from-zygote-to-your-activity-oncreate-8a8f`

`LAUNCH_ACIVITY` is another message after binding the application to launch the main activity of the application [5][6][7][8][9][10]

How does Zygote call `ActivityThread`'s `main`?

`ZygoteInit`'s `main` calls `ActivityThread`'s constructor which prepares the main looper where all app events are executed[11].

`runp.sh` for Building, Flashing and Logging Pipeline

```
1  adb reboot bootloader
2
3  echo "[WEIMINN] Wiping data"
4  fastboot erase userdata
5
6  echo "[WEIMINN] Building AOSP"
7  cd /media/weiminn/Data/aosp14new
8  source build/envsetup.sh
9  lunch aosp_cheetah-userdebug
10 make
11
12 echo "[WEIMINN] Flashing ROM"
13 flash_start=`date +%s`
14 fastboot -w flashall
15 flash_end=`date +%s`
16 echo Flash time was `expr $flash_end - $flash_start` seconds.
17
18 boot_start=`date +%s`
19 adb wait-for-device
20
21 echo "[WEIMINN] Waiting for boot completion"
22 A=$(adb shell getprop sys.boot_completed | tr -d '\r')
23 while [ "$A" != "1" ]; do
24 echo "[WEIMINN] Waiting for boot completion"
25 sleep .5
26 A=$(adb shell getprop sys.boot_completed | tr -d '\r')
27 done
28 boot_end=`date +%s`
29 echo Boot time was `expr $boot_end - $boot_start` seconds.
30
31 adb root
32
33 echo "[WEIMINN] Enabling logging"
34 adb shell setprop debug.ld.all dlerror,dlopen
35
```

[5] https://blog.csdn.net/Tenderness4/article/details/83353636
[6] https://juejin.cn/post/7005062882966634526
[7] https://www.zhihu.com/tardis/zm/art/468648584?source_id=1003
[8] https://sleticalboy.github.io/android/2019/04/13/app%E5%90%AF%E5%8A%A8%E6%B5%81%E7%A8%8B%E5%88%86%E6%9E%90-02/
[9] https://sleticalboy.github.io/assets/android/android-app-start.svg
[10] https://dev.to/pyricau/android-vitals-how-adb-measures-app-startup-5n7
[11] https://stackoverflow.com/questions/46300145/what-the-matter-between-zygote-and-ui-thread-of-an

```
rm -f logcat.txt
echo "[WEIMINN] Logging with Logcat to logcat.txt"
adb logcat >> logcat.txt
```

6.2 April 02-07, 2024

6.2.1 Complete ART Execution Flow

How is Java Code loaded into Android Runtime?

Deep Dive into ART[12], and Method Execution Flow[13], LinkCode[14][15], Loading OAT files[16], Executing Methods[17], Virtual Machine[18], Loading Classes and Methods[19]

Loading OAT Files

An Application has only one `classes.dex` file which is compiled into and OAT file via LLVM compiler and stored in the `oatexec` section of the OAT file. It is also possible to load DEX file during run time while are also translated into OAT.

Loading OAT Methods

`FindClass` in `jni_internal.cc` accesses singleton instance of the Runtime, singleton instance of `ClassLinker`, and `ClassLoader` instance. And the pointer to the `ClassLoader` instance is passed into the `FindClass` function of `class_linker.cc`.

6.3 April 08, 2024

6.3.1 Meeting with iSprint

Minutes

Attendees: Prof. Shar, Albert, Vikas, Phong Phan, Yan Naing, Wei Minn

1. Albert's agenda: 1) Publication of research on this discovered malware, and 2) Discuss plans for the next iteration of Shieldcon this year.

[12] https://www.youtube.com/watch?v=mFq0vNvUgj8

[13] https://huanle19891345.github.io/en/android/art/jni/java_jni%E6%96%B9%E6%B3%95%E8%B0%83%E7%94%A8%E5%8E%9F%E7%90%86/

[14] https://cloud.tencent.com/developer/article/2343052

[15] https://blog.csdn.net/luoshengyang/article/details/39533503

[16] https://blog.csdn.net/luoshengyang/article/details/39307813

[17] https://blog.csdn.net/Luoshengyang/article/details/40289405

[18] https://blog.csdn.net/luoshengyang/article/details/8914953

[19] https://blog.csdn.net/luoshengyang/article/details/39533503

2. Albert would like to continue holding Shieldcon with SMU; he is eager to find a better venue than the previous time; the exact timing of the conference depends on the finding of the malware; he plans to leverage publicity of the conference.

3. Albert mentioned the preliminary survey conducted on the banks regarding measures for the vulnerabilities in their apps. Many banks did not respond to this malware attack.

4. Phong presents FjordPhantom, virtualization-based malware. He demonstrated a container can run on any phone and requires no root no root required. It utilizes virtualization to run a container that wraps a malware that hooks the target app that looks identical to bank app

5. This type of malware is very flexible and module; can easily repackage any android app.

6. Albert Chings said they discoverd another similar malware a few weeks ago; but still conducting experiments to confirm.

7. This malware relys on sideloading of APK into your Android phone.

8. Phong's Demo of FjordPhantom on emulator:

a. Install demo bank APK via sideloading

b. Install screenreader app via sideloading

c. Demo bank app warns of enabled accessibility, and do not allow you to proceed

d. Inject container inside the app using a Python script and re-sideload the now tampered OCBC app

e. With modified OCBC app, even with screenreader and accessibility turned on, there is no warning message, and the user can proceed.

9. The container also contains Hooking framework which plays essential role in this atack.

10. Albert asserted that more than 80% of the bank apps are susceptible to this attack

11. Albert blames this vulnerability on poorly written apps.

12. Albert calls for more research and warn the public about this malware.

13. Prof. Shar aims for ASE conference which will be around July.

14. Vikas asked asked about the company that first detected this malware at the end of 23, and inquired about the differences between their release and i-Sprint's plans; Albert confirmed that they are partners with the company that discovered it.

15: Albert said he is planning an extension to last year's paper, and asked Prof. Shar of any better way to proceed.

16: Prof. Shar plans on focusing on this particular attack, rather than as a continuation of last year's work.

17: Albert suggested two separate papers: 1) this attack, and 2) pregress of previous work one year later.

18: Prof. Shar insists to focus on attack for the time being.

19: Albert shares about the concerns that CSA and other agencies across the region

have about this attack; he also talked about the potential for more publicity for i-Sprint and SMU regarding the release of this malware.

20: Prof. Shar asked Albert on how much information can be disclose in the paper with regards to the banks, and the detials of the attacks?

21: Albert replies that we cannot divulge the affected banks' names, and instead can follow the press releases of i-Sprint. He added that the banks have already been warned.

22: Prof. Shar assigns Wei Minn to take the lead for this paper.

23. After brief discussion about the Shieldcon date, we agreed to meet up again in person for more details like last time.

24: Prof. Shar asked for 1 or 2 weeks to get back to i-Sprint.

25: Albert, Phong and Vikas leaves Meeting

26: Prof. Shar tasked Wei Minn with setting the skeleton for the paper (follow Vikas' example from last time) and get David involved only toward the end.

6.4 April 09-15, 2024

6.4.1 Recompile AOSP 13

Why is it not logging to Logcat?

Log is not showing, even if `LOG_NDEBUG` is set to `0` in `AndroidRuntime.cpp`.

Okay, now it works and I didn't edit anything further.

6.4.2 Which components are involved in ART?

Finishing up the sequence flow.

6.4.3 Components of Debloater Flow in AOSP 13

ART Procedures in Debloating Flow

File	Procedure
`libartbase`	
`os_linux.h`	Add declaration `CreateMINIMAFile`
`os_linux.h`	Add declaration `CreateDirectories2`
`os_linux.cc`	Add definition `CreateMINIMAFile`
`os_linux.cc`	Add definition `CreateDirectories2`
`libdexfile`	
`art_dex_file_loader.cc`	Modify definition `ArtDexFileLoader::Open`

File	Procedure
dex_file_loader.cc	Modify definition DexFileLoader::OpenCommon
libnativeloader	
native_loader_namespace.cpp	Modify definition NativeLoaderNamespace::Load
native_loader.cpp	Modify definition OpenNativeLibrary
native_loader.cpp	Modify definition OpenNativeLibraryInNamespace
oderefresh	
oderefresh.cc	Modify definition AddDex2OatProfileAndCompilerFilter
oderefresh_main.cc	Modify definition InitializeConfig
runtime	
app_info.h	Add declaration GetPackageName
app_info.cc	Modify definition GetPackageName
art_method-inl.h	Modify declaration ArtMethod::CheckIncompatibleClassChange
art_method-inl.h	Modify declaration ArtMethod::UpdateCounter
art_method.h	Modify declaration ArtMethod::UpdateCounter
art_method.cc	Modify declaration ArtMethod::Invoke
art_method.cc	Modify declaration ArtMethod::PrettyMethod
class_linker.cc	Modify declaration ClassLinker::FindClass
class_linker.cc	Modify declaration LinkCode
class_linker.cc	Modify declaration ClassLinker::LoadClass
instrumentation.cc	Modify declaration CanUseNterp
instrumentation.cc	Modify declaration Instrumentation::InitializeMethodsCode
oat_file_manager.cc	Modify declaration OatFileManager::OpenDexFilesFromOat_Impl
runtime.h	Add declaration struct NativeLibFunc;
runtime.h	Add declaration MYmatch_hook_method
runtime.h	Add declaration MYmatch_target_method
runtime.h	Add declaration MYreadFile
runtime.h	Add declaration MYmake_file
runtime.h	Add declaration read_content
runtime.h	Add definition getLoadingSchema
runtime.h	Add definition getLoadedSchema
runtime.h	Add definition getShouldReadSchema
runtime.h	Add definition setLoadingSchema
runtime.h	Add definition setLoadedSchema

File	Procedure
runtime.h	Add definition setShouldReadSchema
runtime.h	Add definition getDebugging
runtime.h	Add definition getTarget_method_string_vector
runtime.h	Add definition setTarget_method_string_vector
runtime.h	Add definition getMINIMA_file_path
runtime.h	Add definition getMINIMA_folder_path
runtime.h	Add definition getHookMethodName
runtime.h	Add declaration MINIMA_file_path
runtime.h	Add declaration hook_method_name
runtime.h	Add declaration target_method_string_vector
runtime.h	Add declaration target_native_func_string_vector
runtime.h	Add declaration debugging
runtime.h	Add declaration api_prefix_List
runtime.h	Add declaration loaded_schema_
runtime.h	Add declaration loading_schema_
runtime.h	Add declaration should_read_schema_
runtime.cc	Add definition StringAppendV
runtime.cc	Add definition StringPrintf
runtime.cc	Add definition StringAppendF
runtime.cc	Add definition Runtime::MINIMA_file_path
runtime.cc	Add definition Runtime::hook_method_name
runtime.cc	Add definition Runtime::debugging
runtime.cc	Add definition Runtime::target_method_string_vector
runtime.cc	Add definition Runtime::target_native_func_string_vector
runtime.cc	Add definition api_prefix_List
runtime.cc	Add definition NativeLibFunc
runtime.cc	Modify definition Runtime
runtime.cc	Modify definition Create
runtime.cc	Modify definition Start
runtime.cc	Modify definition Init
runtime.cc	Add definition MYmatch_hook_method
runtime.cc	Add definition java2cpp
runtime.cc	Add definition is_within_JNImethod_list
runtime.cc	Add definition Runtime::read_content
runtime.cc	Add definition is_packageMethod
runtime.cc	Add definition Runtime::MYmatch_target_method
runtime.cc	Add definition Runtime::MYmake_file
runtime.cc	Add definition Runtime::MYreadFile

File	Procedure
trace.cc	Add definition modifyFilePermissions
trace.cc	Modify definition Trace::Start
trace.cc	Modify definition Trace::Trace
trace.cc	Modify definition Trace::MethodEntered
trace.cc	Modify definition Trace::MethodExited
runtime/entrypoints quick_trampoline_entry_ points.cc	Modify definition artQuickToInterpreterBridge
runtime/interpreter	
interpreter_common.cc	Modify definition DoCallCommon
interpreter_switch_ impl-inl.h	Modify definition ExecuteSwitchImplCpp
interpreter_switch_impl.h	Modify definition ExecuteSwitchImpl
interpreter.cc	Modify definition Execute
interpreter.cc	Modify definition EnterInterpreterFromEntryPoint
runtime/jit	
jit.cc	Modify definition MethodEntered
runtime/jni	
java_vm_ext.cc	Modify definition FindSymbol
java_vm_ext.cc	Modify definition JavaVMExt::LoadNativeLibrary
jni_internal.cc	Modify definition FindClass
runtime/mirror	
class.cc	Modify definition FindClassMethodWithSignature
runtime/native	
dalvik_system_DexFile.cc	Modify definition DexFile_openDexFileNative
dalvik_system_ ZygoteHooks.cc	Add definition modifyFilePermissions1
dalvik_system_ ZygoteHooks.cc	Modify definition ZygoteHooks_nativePostForkChild

Table 6.1: ART Procedures involved in Debloation

Bionic Procedures in Debloating Flow

File	Procedure
libc	
execinfo/include/bionic/execinfo.h	Delete evertyhing and add ../../../include/execinfo.h
fts/include/bionic/fts.h	Delete evertyhing and add ../../../include/fts.h
libdl	
libdl.cpp	Modify definition android_dlopen_ext
linker	
dlfcn.cpp	Modify definition dlopen_ext
dlfcn.cpp	Modify definition __loader_android_dlopen_ext
linker_phdr.h	Add declaration add_de_lib_name_vec
linker_phdr.h	Add declaration add_de_func_name_vec
linker_phdr.h	Add declaration match_target_so_name
linker_phdr.h	Add declaration match_target_func_name
linker_phdr.h	Add declaration dynsym_fragment_
linker_phdr.h	Add declaration dynsym_table_
linker_phdr.h	Add declaration de_dynsym_vec
linker_phdr.h	Add declaration de_func_name_vec
linker_phdr.h	Add declaration de_natlib_name_vec
linker_phdr.h	Add declaration handled_array
linker_phdr.cpp	Add definition debug_zicheng_native
linker_phdr.cpp	Modify definition ElfReader
linker_phdr.cpp	Modify definition ElfReader::Load
linker_phdr.cpp	Add definition compareDynsymPointers
linker_phdr.cpp	Add definition compareDynsyms
linker_phdr.cpp	Modify definition ElfReader::ReadProgramHeaders
linker_phdr.cpp	Modify definition ElfReader::ReadSectionHeaders
linker_phdr.cpp	Modify definition ElfReader::ReadDynamicSection
linker_phdr.cpp	Modify definition phdr_table_get_load_size
linker_phdr.cpp	Modify definition ElfReader::ReserveAddressSpace
linker_phdr.cpp	Modify definition ElfReader::LoadSegments
linker_phdr.cpp	Add definition

File	Procedure
	`ElfReader::add_de_func_name_vec`
`linker_phdr.cpp`	Add definition
	`ElfReader::add_de_lib_name_vec`
`linker_phdr.cpp`	Add definition
	`ElfReader::match_target_so_name`
`linker_phdr.cpp`	Add definition
	`ElfReader::match_target_func_name`
`linker.cpp`	Modify definition
	`open_library_in_zipfile`
`linker.cpp`	Modify definition `find_libraries`
`linker.cpp`	Modify definition `find_library`
`linker.cpp`	Modify definition `do_dlopen`

Table 6.2: Bionic Procedures involved in Debloation

Framework Procedures in Debloating Flow

File	Procedure
`base/core/java/android/content/pm`	
`PackageManager.java`	Modify method `getPackageArchiveInfo`
`PackageParser.java`	Modify method `generatePackageInfo`
`PackageParser.java`	Modify method `generatePackageInfo` (overloaded)
`PackageParser.java`	Modify method `parseBaseApkCommon`
`PackageParser.java`	Modify method `parseUsesPermission`
`services/core/java/com/android/server/pm/permission`	
`DefaultPermissionGrantPolicy.java`	Modify method `grantRuntimePermissions`
`PermissionManagerService.java`	Modify method `onPackageInstalled`
`PermissionManagerServiceImpl.java`	Add lot of trivial logging code
`services/core/java/com/android/server/pm/pkg/parsing`	
`ParsingPackageUtils.java`	Modify method `parseSplitBaseAppChildTags`

Table 6.3: Framework Procedures involved in Debloation

6.4.4 Test Customized Code without the External Headers

There seems to be a group of files where the contents are emptied out and references another file instead: `bionic/libc/execinfo/include/bionic/execinfo.h`, `bionic/libc/fts/include/bionic/fts.h`, `bionic/tools/versioner/platforms/libc.map.txt`, `bionic/tools/versioner/current`, `bionic/tools/versioner/dependencies`, , , `bionic/libfdtrack/.clang-format`, and `bionic/.clang-format`. `boot-image-profile.txt` also has a lot of changes.

Now having problem: build system doesn't detect any changes after updating code. Deleted the `out` and recompile again. Now it works.

6.4.5 ART Loading Process of OAT Files

The process of ART start up is already been explored[20][21]. New thing contributed is the Application installation process by Package Manager Service.

Optimizating DEX into OAT files

Procedure	Description
`frameworks/base/services/core/java/com/android/server/pm/Installer.java`	
`dexopt`	Optimize DEX bytecode in the APK
`frameworks/native/cmds/installd/dexopt.cpp`	
`dexopt`	
`frameworks/native/cmds/installd/run_dex2oat.cpp`	
`RunDex2Oat::RunDex2Oat`	
`RunDex2Oat::Initialize`	
`RunDex2Oat::Exec`	

Table 6.4: APK Installation Process

Loading OAT

Procedure	Description
`art/runtime/runtime.cc`	

[20] `https://blog.csdn.net/luoshengyang/article/details/18006645`
[21] `https://blog.csdn.net/luoshengyang/article/details/39307813`

Procedure	Description
`Runtime::Create`	Create ART virtual machine, which will be used to start Zygote Process which runs System Server and Android Apps.
`Runtime::Init`	Parses and parameters for the startup of ART (if image file (an OAT file contianing multiple DEX files) is not specified, `/system/framework/boot.art` will be prepared in advance in the system partition to be used as ART virtual machine); create an ART Heap based on the parameters
`art/runtime/gc/heap.cc`	
`Heap::Heap`	
`art/runtime/gc/space/image_space.cc`	
`ImageSpace::`	
`LoadBootImage`	
`ImageSpace::`	
`BootImageLoader::`	
`LoadFromSystem`	
`ImageSpace::`	
`BootImageLoader::`	
`LoadImage`	
`ImageSpace::`	
`BootImageLoader::`	
`ReserveBootImageMemory`	
`art/libartbase/base/mem_map.cc`	
`MemMap::MapAnonymous`	
`art/runtime/gc/space/image_space.cc`	
`ImageSpace::`	
`BootImageLoader::`	
`LoadComponents`	
`ImageSpace::`	Calls `OatFile::Open`
`BootImageLoader::`	
`OpenOatFile`	
`art/runtime/oat_file.cc`	
`OatFile::Open`	Called by `ImageSpace::BootImageLoader::OpenOatFile`

Procedure	Description
`OatFile::OpenOatFile`	Calls `OatFileBase::OpenOatFile` template method based on `DlOpenOatFile` or `ElfOatFile`, both of which extends `OatFileBase`.
`art/runtime/oat_file.cc`	
`OatFileBase::Setup`	`OatFileBase` extends `OatFile`. Called as template instance by `OatFile::OpenOatFile`.
`OatDexFile::OatDexFile`	New instance of `OatDexFile::OatDexFile` created by `OatFileBase::Setup`
`GetOatHeader`	
`art/runtime/elf_file.cc`	
`ElfOatFile::Load`	Called as template instance by `OatFile::OpenOatFile` if it implements `ElfOatFile`.
`ElfOatFile::` `ElfFileOpen`	
`ElfFile::Open`	
`art/runtime/gc/space/image_space.cc`	
`ImageSpace::` `BootImageLayout::` `LoadFromSystem`	
`ImageSpace::` `BootImageLayout::` `LoadOrValidateFromSystem`	
`ImageSpace::` `BootImageLayout::` `LoadOrValidate`	
`art/runtime/runtime.cc`	
`JavaVMExt::Create`	Java VM instance for the caller to interact with the ART.
`ClassLinker::` `CreateFromCompiler`	Called if the first continuous space in this list is not an Image space (current process is not a Zygote process, but a `dex2oat` process started when application is installed). To be used by ART for loading Java classes.
`ClassLinker::` `CreateFromImage`	Called if the first continuous space in this list is an Image space. To be used by ART for loading Java classes.

Table 6.5: OAT Loading Process

6.5 April 16-29, 2024

6.5.1 ART Loading Process of Classes and Methods

Need to get the corresponding OAT class in the OAT file using the number of target DEX class.

Procedure	Description
`frameworks/base/core/jni/AndroidRuntime.cpp`	
`AndroidRuntime::start`	
`AndroidRuntime::startVm`	
`art/runtime/jni/java_vm_ext.cc`	
`JNI_CreateJavaVM`	
`art/runtime/runtime.cc`	
`Runtime::Create`	Before starting ART, you have to first create ART virtual machine, which will be used to start Zygote Process which runs System Server and Android Apps.
`Runtime::Init`	Parses and parameters for the startup of ART (if image file (an OAT file contianing multiple DEX files) is not specified, `/system/framework/boot.art` will be prepared in advance in the system partition to be used as ART virtual machine); create an ART Heap based on the parameters
`art/runtime/thread.h`	
`GetJniEnv`	Get APIs to ART Java VM of current running thread. The APIs are wrapped in `struct JNIEnvExt` which is an extension of `JNIEnv`, and stores `JNINativeInterface`.
`libnativehelper/include_jni/jni.h`	
`JNIEnv`	Wraps functions to call ART Java VM to execute Java classes and methods.
`JNINativeInterface`	Wraps functions to call ART Java VM to execute Java classes and methods. Among them is `JNI::FindClass` which is defined in `art/runtime/jni/jni_internal.cc`.
`art/runtime/jni/jni_internal.cc`	

Procedure	Description
FindClass	Check if runtime instance has started, and then calls ClassLinker's FindClass. If not started, calls ClassLinker's FindSystemClass (which also calls ClassLinker) instead.
art/runtime/class_linker.cc	
ClassLinker::FindClass	
ClassLinker::LookupClass	Check whether the class has already been loaded. If so, just return the corresponding class object.
ClassLinker::FindInClassPath	Find the class in DexFile, if class_loader is null. Then call ClassLinker::DefineClass to load the class from the loaded DEX.
ClassLinker::DefineClass	Use the class_loader object (of java.lang.ClassLoader type) to load the specified class.
ClassLinker::LoadClass	Load the specified class from specified DEX file, and add it to the loaded class list of ClassLinker using InsertClass. Get the class index number of the loading class in the DEX file using GetIndexForClassDef to obtain OatCLass structure in the corresponding OAT file through the class index number. Each member functions of the class being loaded will be instantiated as ArtMethod objects.
LinkCode	Determine if the loaded classes and methods are executed though the interpreter, or with local machine instructions.
art/runtime/instrumentation.cc	
Instrumentation::InitializeMethodsCode	
Instrumentation::UpdateMethodsCode	
Instrumentation::UpdateMethodsCodeImpl	
UpdateEntryPoints	
art/runtime/art_method.h	
SetEntryPointFromQuickCompiledCode	
SetEntryPointFromQuickCompiledCodePtrSize	
SetNativePointer	
art/runtime/jit/jit.cc	

Procedure	Description
EntryPointFromQuickCompiledCodeOffset	
art/runtime/jni/jni_env_ext.cc GetJniEnv	Get APIs to ART Java VM of current running thread. The APIs are wrapped in struct JNIEnv.
art/runtime/thread.h GetJniEnv	Called by JNI_CreateJavaVM

Table 6.6: Class Loading Process

Imagespace[22][23], and Heap [24]

6.5.2 ART Execution Process of Classes and Methods

Procedure	Description
art/runtime/runtime.cc Runtime::Init	
art/runtime/thread..cc Thread::Attach Thread::Init Thread:: InitTlsEntryPoints	
art/runtime/arch/arm64/entrypoints_init_arm64.cc InitEntryPoints	
art/runtime/entrypoints/quick/quick_default_init_entrypoints.h DefaultInitEntryPoints	
art/runtime/class_linker.cc LinkCode	In AOSP 13 it doesn't call artInterpreterToCompiledCodeBridge directly for setEntryPointFromInterpreter but only setEntryPointFromJni
art/runtime/instrumentation.cc	

[22] https://www.jianshu.com/p/f45ce55c088c
[23] https://www.jianshu.com/p/4310756f590e
[24] https://www.dalvik.work/2021/05/28/dalvik-art-heap-gc/

Procedure	Description
Instrumentation:: InitializeMethodsCode UpdateEntrypoints	Called multiple times for GetQuickToInterpreterBridge, GetQuickInstrumentationEntryPoint, GetQuickGenericJniStub, GetQuickToInterpreterBridge, GetQuickResolutionStub, interpreter::GetNterpEntryPoint, GetQuickGenericJniStub, GetQuickInstrumentationEntryPoint, GetOptimizedCodeFor
art/runtime/entrypoints/runtime_asm_entrypoints.h GetQuickToInterpreterBridge	
art/runtime/arch/arm64/quick_entrypoints_arm64.S art_quick_to_ interpreter_bridge	
art/runtime/interpreter/interpreter.cc ArtInterpreterToInterpreterBridge	
art/runtime/arch/arm64/quick_entrypoints_arm64.S art_quick_resolution_ trampoline	
art/runtime/entrypoints/quick/quick_trampoline_entrypoints.cc artQuickResolutionTrampoline	
art/runtime/oat.cc OatHeader:: GetQuickResolutionTrampoline	Should be defined in the class_linker.cc, but in AOSP13, it's in oat.cc. Supposed to return quick_resolution_trampoline_ is now defined in both oat_writer.h and class_linker.h.
art/runtime/native/dalvik_system_DexFile.cc DexFile_ defineClassNative	
art/runtime/class_linker.cc ClassLinker:: RegisterDexFileLocked ClassLinker:: RegisterDexFile	

Procedure	Description
ClassLinker:: AllocDexCache	
art/runtime/mirror/dex_cache.cc Dex:: RegisterDexFileLocked	
art/runtime/class_linker-inl.h ClassLinker:: ResolveMethod	
art/runtime/class_linker.cc ClassLinker:: DefineClass ClassLinker:: LoadMethod	

Table 6.7: ART Execution Process

Chapter 7

May

7.1 May 05-06, 2024

7.1.1 Run Zicheng's code without the weird text files

The logcat is still showing old logic even though I swapped files back. So I changed log output from "WEIMINN" to "WEIMINN2" but I got this error:

```
[  8% 85/1028] //art/build/boot:art-bootclasspath-fragment dexpreopt art j
FAILED: out/soong/cheetah/dex_artjars/android/apex/art_boot_images/javalib
/arm64/boot-apache-xml.art out/soong/cheetah/dex_artjars/android/apex/art_
boot_images/javalib/arm64/boot-apache-xml.oat out/soong/cheetah/dex_artjar
s/android/apex/art_boot_images/javalib/arm64/boot-apache-xml.vdex out/soon
g/cheetah/dex_artjars/android/apex/art_boot_images/javalib/arm64/boot-boun
cycastle.art out/soong/cheetah/dex_artjars/android/apex/art_boot_images/ja
valib/arm64/boot-bouncycastle.oat out/soong/cheetah/dex_artjars/android/ap
ex/art_boot_images/javalib/arm64/boot-bouncycastle.vdex out/soong/cheetah/
dex_artjars/android/apex/art_boot_images/javalib/arm64/boot-core-libart.ar
t out/soong/cheetah/dex_artjars/android/apex/art_boot_images/javalib/arm64
/boot-core-libart.oat out/soong/cheetah/dex_artjars/android/apex/art_boot_
images/javalib/arm64/boot-core-libart.vdex out/soong/cheetah/dex_artjars/a
ndroid/apex/art_boot_images/javalib/arm64/boot-okhttp.art out/soong/cheeta
h/dex_artjars/android/apex/art_boot_images/javalib/arm64/boot-okhttp.oat o
ut/soong/cheetah/dex_artjars/android/apex/art_boot_images/javalib/arm64/bo
ot-okhttp.vdex out/soong/cheetah/dex_artjars/android/apex/art_boot_images/
javalib/arm64/boot.art out/soong/cheetah/dex_artjars/android/apex/art_boot
_images/javalib/arm64/boot.invocation out/soong/cheetah/dex_artjars/androi
d/apex/art_boot_images/javalib/arm64/boot.oat out/soong/cheetah/dex_artjar
s/android/apex/art_boot_images/javalib/arm64/boot.vdex out/soong/cheetah/d
ex_artjars_unstripped/android/apex/art_boot_images/javalib/arm64/boot-apac
he-xml.oat out/soong/cheetah/dex_artjars_unstripped/android/apex/art_boot_
images/javalib/arm64/boot-bouncycastle.oat out/soong/cheetah/dex_artjars_u
nstripped/android/apex/art_boot_images/javalib/arm64/boot-core-libart.oat
out/soong/cheetah/dex_artjars_unstripped/android/apex/art_boot_images/java
lib/arm64/boot-okhttp.oat out/soong/cheetah/dex_artjars_unstripped/android
/apex/art_boot_images/javalib/arm64/boot.oat
mkdir -p out/soong/cheetah/dex_artjars_unstripped/android/apex/art_boot_im
ages/javalib/arm64 && rm -f out/soong/cheetah/dex_artjars_unstripped/andro
id/apex/art_boot_images/javalib/arm64/*.art out/soong/cheetah/dex_artjars_
unstripped/android/apex/art_boot_images/javalib/arm64/*.oat out/soong/chee
```

```
tah/dex_artjars_unstripped/android/apex/art_boot_images/javalib/arm64/*.in
vocation && rm -f out/soong/cheetah/dex_artjars/android/apex/art_boot_imag
es/javalib/arm64/*.art out/soong/cheetah/dex_artjars/android/apex/art_boot
_images/javalib/arm64/*.oat out/soong/cheetah/dex_artjars/android/apex/art
_boot_images/javalib/arm64/*.invocation && ANDROID_LOG_TAGS="*:e" out/host
/linux-x86/bin/dex2oatd --avoid-storing-invocation --write-invocation-to=o
ut/soong/cheetah/dex_artjars/android/apex/art_boot_images/javalib/arm64/bo
ot.invocation --runtime-arg -Xms64m --runtime-arg -Xmx64m --profile-file=o
ut/soong/cheetah/dex_artjars/boot.prof --dirty-image-objects=frameworks/ba
se/config/dirty-image-objects --base=0x70000000 --preloaded-classes=art/bu
ild/boot/preloaded-classes --dex-file=out/soong/cheetah/dex_artjars_input/
core-oj.jar --dex-file=out/soong/cheetah/dex_artjars_input/core-libart.jar
    --dex-file=out/soong/cheetah/dex_artjars_input/okhttp.jar --dex-file=out/
soong/cheetah/dex_artjars_input/bouncycastle.jar --dex-file=out/soong/chee
tah/dex_artjars_input/apache-xml.jar --dex-location=/apex/com.android.art/
javalib/core-oj.jar --dex-location=/apex/com.android.art/javalib/core-liba
rt.jar --dex-location=/apex/com.android.art/javalib/okhttp.jar --dex-locat
ion=/apex/com.android.art/javalib/bouncycastle.jar --dex-location=/apex/co
m.android.art/javalib/apache-xml.jar --generate-debug-info --generate-buil
d-id --image-format=lz4hc --oat-symbols=out/soong/cheetah/dex_artjars_unst
ripped/android/apex/art_boot_images/javalib/arm64/boot.oat --strip --oat-f
ile=out/soong/cheetah/dex_artjars/android/apex/art_boot_images/javalib/arm
64/boot.oat --oat-location=out/soong/cheetah/dex_artjars/android/apex/art_
boot_images/javalib/boot.oat --image=out/soong/cheetah/dex_artjars/android
/apex/art_boot_images/javalib/arm64/boot.art --instruction-set=arm64 --and
roid-root=out/empty --no-inline-from=core-oj.jar --force-determinism --abo
rt-on-hard-verifier-error --instruction-set-variant=cortex-a55 --instructi
on-set-features=default --generate-mini-debug-info || ( echo 'ERROR: Dex2o
at failed to compile a boot image.It is likely that the boot classpath is
inconsistent.Rebuild with ART_BOOT_IMAGE_EXTRA_ARGS="--runtime-arg -verbos
e:verifier" to see verification errors.' ; false ) # hash of input list: b
b4c783e60c5fe8f723f06a1fc27caeedeb88883dae99b303257caf0b2276d92
dex2oatd F 05-05 20:54:42   158   158 art_method.h:604] Check failed: IsIm
agePointerSize(pointer_size)
Runtime aborting...
All threads:
DALVIK THREADS (1):
"main" prio=5 tid=1 Runnable (still starting up)
    | group="" sCount=0 ucsCount=0 flags=0 obj=(nil) self=0x64b1e64dbe30
    | sysTid=158 nice=19 cgrp=default sched=0/0 handle=0x7dbfeaf10740
    | state=R schedstat=( 23324439 37432 5 ) utm=1 stm=0 core=3 HZ=100
    | stack=0x7ffd468d7000-0x7ffd468d9000 stackSize=8192KB
    | held mutexes= "abort lock" "mutator lock"(shared held)
    native: #00 pc 0000000000e9a168  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (UnwindStackCurrent::UnwindFromContext(unsigned
long, void*)+88)
    native: #01 pc 0000000000e94d9d  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::DumpNativeStack(std::__1::basic_ostream<ch
ar, std::__1::char_traits<char> >&, int, BacktraceMap*, char const*, art::
ArtMethod*, void*, bool)+141)
    native: #02 pc 0000000000ec8616  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Thread::DumpStack(std::__1::basic_ostream<
char, std::__1::char_traits<char> >&, bool, BacktraceMap*, bool) const+422
)
    native: #03 pc 0000000000ef19ff  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::DumpCheckpoint::Run(art::Thread*)+575)
    native: #04 pc 0000000000eea690  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::ThreadList::RunCheckpoint(art::Closure*, a
rt::Closure*)+288)
```

```
    native: #05 pc 0000000000eea275  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::ThreadList::Dump(std::__1::basic_ostream<c
har, std::__1::char_traits<char> >&, bool)+357)
    native: #06 pc 0000000000dbae0a  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::AbortState::Dump(std::__1::basic_ostream<c
har, std::__1::char_traits<char> >&) const+186)
    native: #07 pc 0000000000d9f46f  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::Abort(char const*)+399)
    native: #08 pc 00000000016cfd1c  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (android::base::SetAborter(std::__1::function<vo
id (char const*)>&&)::$_3::__invoke(char const*)+60)
    native:   std::__1::__compressed_pair_elem<std::__1::basic_string<char,
std::__1::char_traits<char>, std::__1::allocator<char> >::__rep, 0, false>
::__compressed_pair_elem()
    native:    external/libcxx/include/memory:2140
    native:   std::__1::__compressed_pair<std::__1::basic_string<char, std::
__1::char_traits<char>, std::__1::allocator<char> >::__rep, std::__1::allo
cator<char> >::__compressed_pair<true, void>()
    native:    external/libcxx/include/memory:2234
    native:   std::__1::basic_string<char, std::__1::char_traits<char>, std:
:__1::allocator<char> >::basic_string<decltype(nullptr)>(char const*)
    native:    external/libcxx/include/string:820
    native:   UnwindStackCurrent::UnwindFromContext(unsigned long, void*)
    native:    system/unwinding/libbacktrace/UnwindStack.cpp:180
    native:   art::DumpNativeStack(std::__1::basic_ostream<char, std::__1::c
har_traits<char> >&, int, BacktraceMap*, char const*, art::ArtMethod*, voi
d*, bool)
    native:    art/runtime/native_stack_dump.cc:339
    native: #09 pc 00000000016cf9a8  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (android::base::LogMessage::~LogMessage()+328)
    native:   art::Thread::DumpStack(std::__1::basic_ostream<char, std::__1:
:char_traits<char> >&, bool, BacktraceMap*, bool) const
    native:    art/runtime/thread.cc:2298
    native: #10 pc 00000000006000f2  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::ArtMethod::SetDataPtrSize(void const*, art
::PointerSize)+226)
    native:   art::DumpCheckpoint::Run(art::Thread*)
    native:    art/runtime/thread_list.cc:213
    native:   art::ThreadList::RunCheckpoint(art::Closure*, art::Closure*)
    native:    art/runtime/thread_list.cc:374
    native:   art::ThreadList::Dump(std::__1::basic_ostream<char, std::__1::
char_traits<char> >&, bool)
    native:    art/runtime/thread_list.cc:257
    native:   art::AbortState::Dump(std::__1::basic_ostream<char, std::__1::
char_traits<char> >&) const
    native:    art/runtime/runtime.cc:761
    native:   art::Dumpable<art::AbortState>::Dump(std::__1::basic_ostream<c
har, std::__1::char_traits<char> >&) const
    native:    art/libartbase/base/dumpable.h:38
    native:   std::__1::basic_ostream<char, std::__1::char_traits<char> >& a
rt::operator<< <art::AbortState>(std::__1::basic_ostream<char, std::__1::c
har_traits<char> >&, art::Dumpable<art::AbortState> const&)
    native:    art/libartbase/base/dumpable.h:49
    native:   art::Runtime::Abort(char const*)
    native:    art/runtime/runtime.cc:884
    native: #11 pc 0000000000daf16d  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::CreateResolutionMethod()+285)
    native: #12 pc 0000000000741453  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::ClassLinker::InitWithoutImage(std::__1::ve
```

```
ctor<std::__1::unique_ptr<art::DexFile const, std::__1::default_delete<art
::DexFile const> >, std::__1::allocator<std::__1::unique_ptr<art::DexFile
const, std::__1::default_delete<art::DexFile const> > > >, std::__1::basic
_string<char, std::__1::char_traits<char>, std::__1::allocator<char> >*)+6
307)
    native: #13 pc 0000000000da4709  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::Init(art::RuntimeArgumentMap&&)+1
8073)
    native: #14 pc 0000000000d9fef7  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::Create(art::RuntimeArgumentMap&&)
+135)
    native: #15 pc 0000000000491e0f  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Dex2Oat::CreateRuntime(art::RuntimeArgumen
tMap&&)+127)
    native: #16 pc 0000000000484526  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Dex2Oat::Setup()+2118)
    native: #17 pc 000000000047edcc  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (main+1452)
    native:   android::base::SetAborter(std::__1::function<void (char const*
)>&&)::$_3::__invoke(char const*)
    native:    external/libcxx/include/functional:1799
    native:   android::base::LogMessage::~LogMessage()
    native:    system/libbase/logging.cpp:504
    native:   art::ArtMethod::SetDataPtrSize(void const*, art::PointerSize)
    native:    art/runtime/art_method.h:604
    native:   art::ArtMethod::SetEntryPointFromJniPtrSize(void const*, art::
PointerSize)
    native:    art/runtime/art_method.h:594
    native:   art::Runtime::CreateResolutionMethod()
    native:    art/runtime/runtime.cc:2789
    native:   art::ClassLinker::InitWithoutImage(std::__1::vector<std::__1::
unique_ptr<art::DexFile const, std::__1::default_delete<art::DexFile const
> >, std::__1::allocator<std::__1::unique_ptr<art::DexFile const, std::__1
::default_delete<art::DexFile const> > > >, std::__1::basic_string<char, s
td::__1::char_traits<char>, std::__1::allocator<char> >*)
    native:    art/runtime/class_linker.cc:787
    native:   art::Runtime::Init(art::RuntimeArgumentMap&&)
    native:    art/runtime/runtime.cc:2077
    native:   art::Runtime::Create(art::RuntimeArgumentMap&&)
    native:    art/runtime/runtime.cc:1046
    native:   art::Dex2Oat::CreateRuntime(art::RuntimeArgumentMap&&)
    native:    art/dex2oat/dex2oat.cc:2711
    native:   art::Dex2Oat::Setup()
    native:    art/dex2oat/dex2oat.cc:1522
    native:   main
    native:    art/dex2oat/dex2oat.cc:3168
    native: #18 pc 000000000002814f  /usr/lib/x86_64-linux-gnu/libc.so.6 (??
?) (BuildId: b20cbdb62d7717c13dc61a48b7b2e673a7edf233)
    native: #19 pc 0000000000028208  /usr/lib/x86_64-linux-gnu/libc.so.6 (__
libc_start_main+136) (BuildId: b20cbdb62d7717c13dc61a48b7b2e673a7edf233)
    native:   __libc_start_main_impl
    native:    ./csu/../csu/libc-start.c:360
    native: #20 pc 00000000004241a8  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (???)
    (no managed stack frames)

dex2oatd E 05-05 20:54:51   158   158 thread-inl.h:170] holding "abort loc
k" at point where thread suspension is expected
Aborting thread:
```

```
"main" prio=5 tid=1 Runnable (still starting up)
    | group="" sCount=0 ucsCount=0 flags=0 obj=(nil) self=0x64b1e64dbe30
    | sysTid=158 nice=19 cgrp=default sched=0/0 handle=0x7dbfeaf10740
    | state=R schedstat=( 46296127 29382693 40 ) utm=4 stm=0 core=8 HZ=100
    | stack=0x7ffd468d7000-0x7ffd468d9000 stackSize=8192KB
    | held mutexes= "abort lock" "mutator lock"(shared held)
    native: #00 pc 0000000000e9a168  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (UnwindStackCurrent::UnwindFromContext(unsigned
long, void*)+88)
    native: #01 pc 0000000000e94d9d  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::DumpNativeStack(std::__1::basic_ostream<ch
ar, std::__1::char_traits<char> >&, int, BacktraceMap*, char const*, art::
ArtMethod*, void*, bool)+141)
    native: #02 pc 0000000000ec8616  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Thread::DumpStack(std::__1::basic_ostream<
char, std::__1::char_traits<char> >&, bool, BacktraceMap*, bool) const+422
)
    native: #03 pc 0000000000dbb0dd  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::AbortState::DumpThread(std::__1::basic_ost
ream<char, std::__1::char_traits<char> >&, art::Thread*) const+93)
    native: #04 pc 0000000000d9f46f  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::Abort(char const*)+399)
    native:   std::__1::__compressed_pair_elem<std::__1::basic_string<char,
std::__1::char_traits<char>, std::__1::allocator<char> >::__rep, 0, false>
::__compressed_pair_elem()
    native:    external/libcxx/include/memory:2140
    native:   std::__1::__compressed_pair<std::__1::basic_string<char, std::
__1::char_traits<char>, std::__1::allocator<char> >::__rep, std::__1::allo
cator<char> >::__compressed_pair<true, void>()
    native:    external/libcxx/include/memory:2234
    native:   std::__1::basic_string<char, std::__1::char_traits<char>, std:
:__1::allocator<char> >::basic_string<decltype(nullptr)>(char const*)
    native:    external/libcxx/include/string:820
    native:   UnwindStackCurrent::UnwindFromContext(unsigned long, void*)
    native:    system/unwinding/libbacktrace/UnwindStack.cpp:180
    native:   art::DumpNativeStack(std::__1::basic_ostream<char, std::__1::c
har_traits<char> >&, int, BacktraceMap*, char const*, art::ArtMethod*, voi
d*, bool)
    native:    art/runtime/native_stack_dump.cc:339
    native: #05 pc 00000000016cfd1c  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (android::base::SetAborter(std::__1::function<vo
id (char const*)>&&)::$_3::__invoke(char const*)+60)
    native:   art::Thread::DumpStack(std::__1::basic_ostream<char, std::__1:
:char_traits<char> >&, bool, BacktraceMap*, bool) const
    native:    art/runtime/thread.cc:2298
    native:   art::AbortState::DumpThread(std::__1::basic_ostream<char, std:
:__1::char_traits<char> >&, art::Thread*) const
    native:    art/runtime/runtime.cc:782
    native:   art::Dumpable<art::AbortState>::Dump(std::__1::basic_ostream<c
har, std::__1::char_traits<char> >&) const
    native:    art/libartbase/base/dumpable.h:38
    native:   std::__1::basic_ostream<char, std::__1::char_traits<char> >& a
rt::operator<< <art::AbortState>(std::__1::basic_ostream<char, std::__1::c
har_traits<char> >&, art::Dumpable<art::AbortState> const&)
    native:    art/libartbase/base/dumpable.h:49
    native:   art::Runtime::Abort(char const*)
    native:    art/runtime/runtime.cc:884
    native: #06 pc 00000000016cf9a8  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (android::base::LogMessage::~LogMessage()+328)
```

```
    native: #07 pc 00000000006000f2  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::ArtMethod::SetDataPtrSize(void const*, art
::PointerSize)+226)
    native: #08 pc 0000000000daf16d  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::CreateResolutionMethod()+285)
    native: #09 pc 0000000000741453  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::ClassLinker::InitWithoutImage(std::__1::ve
ctor<std::__1::unique_ptr<art::DexFile const, std::__1::default_delete<art
::DexFile const> >, std::__1::allocator<std::__1::unique_ptr<art::DexFile
const, std::__1::default_delete<art::DexFile const> > > >, std::__1::basic
_string<char, std::__1::char_traits<char>, std::__1::allocator<char> >*)+6
307)
    native: #10 pc 0000000000da4709  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::Init(art::RuntimeArgumentMap&&)+1
8073)
    native:   android::base::SetAborter(std::__1::function<void (char const*
)>&&)::$_3::__invoke(char const*)
    native:    external/libcxx/include/functional:1799
    native:   android::base::LogMessage::~LogMessage()
    native:    system/libbase/logging.cpp:504
    native:   art::ArtMethod::SetDataPtrSize(void const*, art::PointerSize)
    native:    art/runtime/art_method.h:604
    native:   art::ArtMethod::SetEntryPointFromJniPtrSize(void const*, art::
PointerSize)
    native:    art/runtime/art_method.h:594
    native:   art::Runtime::CreateResolutionMethod()
    native:    art/runtime/runtime.cc:2789
    native:   art::ClassLinker::InitWithoutImage(std::__1::vector<std::__1::
unique_ptr<art::DexFile const, std::__1::default_delete<art::DexFile const
> >, std::__1::allocator<std::__1::unique_ptr<art::DexFile const, std::__1
::default_delete<art::DexFile const> > > >, std::__1::basic_string<char, s
td::__1::char_traits<char>, std::__1::allocator<char> >*)
    native:    art/runtime/class_linker.cc:787
    native:   art::Runtime::Init(art::RuntimeArgumentMap&&)
    native:    art/runtime/runtime.cc:2077
    native: #11 pc 0000000000d9fef7  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::Create(art::RuntimeArgumentMap&&)
+135)
    native:   art::Runtime::Create(art::RuntimeArgumentMap&&)
    native:    art/runtime/runtime.cc:1046
    native: #12 pc 0000000000491e0f  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Dex2Oat::CreateRuntime(art::RuntimeArgumen
tMap&&)+127)
    native:   art::Dex2Oat::CreateRuntime(art::RuntimeArgumentMap&&)
    native:    art/dex2oat/dex2oat.cc:2711
    native: #13 pc 0000000000484526  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Dex2Oat::Setup()+2118)
    native:   art::Dex2Oat::Setup()
    native:    art/dex2oat/dex2oat.cc:1522
    native: #14 pc 000000000047edcc  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (main+1452)
    native:   main
    native:    art/dex2oat/dex2oat.cc:3168
    native: #15 pc 000000000002814f  /usr/lib/x86_64-linux-gnu/libc.so.6 (??
?) (BuildId: b20cbdb62d7717c13dc61a48b7b2e673a7edf233)
    native: #16 pc 0000000000028208  /usr/lib/x86_64-linux-gnu/libc.so.6 (__
libc_start_main+136) (BuildId: b20cbdb62d7717c13dc61a48b7b2e673a7edf233)
    native:   __libc_start_main_impl
    native:    ./csu/../csu/libc-start.c:360
```

```
    native: #17 pc 00000000004241a8  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (???)
    (no managed stack frames)
Aborted (core dumped)
ERROR: Dex2oat failed to compile a boot image.It is likely that the boot c
lasspath is inconsistent.Rebuild with ART_BOOT_IMAGE_EXTRA_ARGS="--runtime
-arg -verbose:verifier" to see verification errors.
[  8% 86/1028] //art/build/boot:art-bootclasspath-fragment dexpreopt art j
FAILED: out/soong/cheetah/dex_artjars/android/apex/art_boot_images/javalib
/arm/boot-apache-xml.art out/soong/cheetah/dex_artjars/android/apex/art_bo
ot_images/javalib/arm/boot-apache-xml.oat out/soong/cheetah/dex_artjars/an
droid/apex/art_boot_images/javalib/arm/boot-apache-xml.vdex out/soong/chee
tah/dex_artjars/android/apex/art_boot_images/javalib/arm/boot-bouncycastle
.art out/soong/cheetah/dex_artjars/android/apex/art_boot_images/javalib/ar
m/boot-bouncycastle.oat out/soong/cheetah/dex_artjars/android/apex/art_boo
t_images/javalib/arm/boot-bouncycastle.vdex out/soong/cheetah/dex_artjars/
android/apex/art_boot_images/javalib/arm/boot-core-libart.art out/soong/ch
eetah/dex_artjars/android/apex/art_boot_images/javalib/arm/boot-core-libar
t.oat out/soong/cheetah/dex_artjars/android/apex/art_boot_images/javalib/a
rm/boot-core-libart.vdex out/soong/cheetah/dex_artjars/android/apex/art_bo
ot_images/javalib/arm/boot-okhttp.art out/soong/cheetah/dex_artjars/androi
d/apex/art_boot_images/javalib/arm/boot-okhttp.oat out/soong/cheetah/dex_a
rtjars/android/apex/art_boot_images/javalib/arm/boot-okhttp.vdex out/soong
/cheetah/dex_artjars/android/apex/art_boot_images/javalib/arm/boot.art out
/soong/cheetah/dex_artjars/android/apex/art_boot_images/javalib/arm/boot.i
nvocation out/soong/cheetah/dex_artjars/android/apex/art_boot_images/javal
ib/arm/boot.oat out/soong/cheetah/dex_artjars/android/apex/art_boot_images
/javalib/arm/boot.vdex out/soong/cheetah/dex_artjars_unstripped/android/ap
ex/art_boot_images/javalib/arm/boot-apache-xml.oat out/soong/cheetah/dex_a
rtjars_unstripped/android/apex/art_boot_images/javalib/arm/boot-bouncycast
le.oat out/soong/cheetah/dex_artjars_unstripped/android/apex/art_boot_imag
es/javalib/arm/boot-core-libart.oat out/soong/cheetah/dex_artjars_unstripp
ed/android/apex/art_boot_images/javalib/arm/boot-okhttp.oat out/soong/chee
tah/dex_artjars_unstripped/android/apex/art_boot_images/javalib/arm/boot.o
at
mkdir -p out/soong/cheetah/dex_artjars_unstripped/android/apex/art_boot_im
ages/javalib/arm && rm -f out/soong/cheetah/dex_artjars_unstripped/android
/apex/art_boot_images/javalib/arm/*.art out/soong/cheetah/dex_artjars_unst
ripped/android/apex/art_boot_images/javalib/arm/*.oat out/soong/cheetah/de
x_artjars_unstripped/android/apex/art_boot_images/javalib/arm/*.invocation
    && rm -f out/soong/cheetah/dex_artjars/android/apex/art_boot_images/javal
ib/arm/*.art out/soong/cheetah/dex_artjars/android/apex/art_boot_images/ja
valib/arm/*.oat out/soong/cheetah/dex_artjars/android/apex/art_boot_images
/javalib/arm/*.invocation && ANDROID_LOG_TAGS="*:e" out/host/linux-x86/bin
/dex2oatd --avoid-storing-invocation --write-invocation-to=out/soong/cheet
ah/dex_artjars/android/apex/art_boot_images/javalib/arm/boot.invocation --
runtime-arg -Xms64m --runtime-arg -Xmx64m --profile-file=out/soong/cheetah
/dex_artjars/boot.prof --dirty-image-objects=frameworks/base/config/dirty-
image-objects --base=0x70000000 --preloaded-classes=art/build/boot/preload
ed-classes --dex-file=out/soong/cheetah/dex_artjars_input/core-oj.jar --de
x-file=out/soong/cheetah/dex_artjars_input/core-libart.jar --dex-file=out/
soong/cheetah/dex_artjars_input/okhttp.jar --dex-file=out/soong/cheetah/de
x_artjars_input/bouncycastle.jar --dex-file=out/soong/cheetah/dex_artjars_
input/apache-xml.jar --dex-location=/apex/com.android.art/javalib/core-oj.
jar --dex-location=/apex/com.android.art/javalib/core-libart.jar --dex-loc
ation=/apex/com.android.art/javalib/okhttp.jar --dex-location=/apex/com.an
droid.art/javalib/bouncycastle.jar --dex-location=/apex/com.android.art/ja
valib/apache-xml.jar --generate-debug-info --generate-build-id --image-for
mat=lz4hc --oat-symbols=out/soong/cheetah/dex_artjars_unstripped/android/a
```

```
pex/art_boot_images/javalib/arm/boot.oat --strip --oat-file=out/soong/chee
tah/dex_artjars/android/apex/art_boot_images/javalib/arm/boot.oat --oat-lo
cation=out/soong/cheetah/dex_artjars/android/apex/art_boot_images/javalib/
boot.oat --image=out/soong/cheetah/dex_artjars/android/apex/art_boot_image
s/javalib/arm/boot.art --instruction-set=arm --android-root=out/empty --no
-inline-from=core-oj.jar --force-determinism --abort-on-hard-verifier-erro
r --instruction-set-variant=generic --instruction-set-features=default --g
enerate-mini-debug-info || ( echo 'ERROR: Dex2oat failed to compile a boot
    image.It is likely that the boot classpath is inconsistent.Rebuild with A
RT_BOOT_IMAGE_EXTRA_ARGS="--runtime-arg -verbose:verifier" to see verifica
tion errors.' ; false ) # hash of input list: bb4c783e60c5fe8f723f06a1fc27
caeedeb88883dae99b303257caf0b2276d92
dex2oatd F 05-05 20:54:42   159   159 art_method.h:604] Check failed: IsIm
agePointerSize(pointer_size)
Runtime aborting...
All threads:
DALVIK THREADS (1):
"main" prio=5 tid=1 Runnable (still starting up)
    | group="" sCount=0 ucsCount=0 flags=0 obj=(nil) self=0x63f93b0df6f0
    | sysTid=159 nice=19 cgrp=default sched=0/0 handle=0x7d8aae500740
    | state=R schedstat=( 22175087 3260 6 ) utm=2 stm=0 core=10 HZ=100
    | stack=0x7ffdfc378000-0x7ffdfc37a000 stackSize=8184KB
    | held mutexes= "abort lock" "mutator lock"(shared held)
    native: #00 pc 0000000000e9a168  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (UnwindStackCurrent::UnwindFromContext(unsigned
long, void*)+88)
    native: #01 pc 0000000000e94d9d  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::DumpNativeStack(std::__1::basic_ostream<ch
ar, std::__1::char_traits<char> >&, int, BacktraceMap*, char const*, art::
ArtMethod*, void*, bool)+141)
    native: #02 pc 0000000000ec8616  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Thread::DumpStack(std::__1::basic_ostream<
char, std::__1::char_traits<char> >&, bool, BacktraceMap*, bool) const+422
)
    native: #03 pc 0000000000ef19ff  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::DumpCheckpoint::Run(art::Thread*)+575)
    native: #04 pc 0000000000eea690  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::ThreadList::RunCheckpoint(art::Closure*, a
rt::Closure*)+288)
    native: #05 pc 0000000000eea275  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::ThreadList::Dump(std::__1::basic_ostream<c
har, std::__1::char_traits<char> >&, bool)+357)
    native: #06 pc 0000000000dbae0a  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::AbortState::Dump(std::__1::basic_ostream<c
har, std::__1::char_traits<char> >&) const+186)
    native: #07 pc 0000000000d9f46f  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::Abort(char const*)+399)
    native: #08 pc 00000000016cfd1c  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (android::base::SetAborter(std::__1::function<vo
id (char const*)>&&)::$_3::__invoke(char const*)+60)
    native: #09 pc 00000000016cf9a8  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (android::base::LogMessage::~LogMessage()+328)
    native: #10 pc 00000000006000f2  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::ArtMethod::SetDataPtrSize(void const*, art
::PointerSize)+226)
    native: #11 pc 0000000000daf16d  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::CreateResolutionMethod()+285)
    native:   std::__1::__compressed_pair_elem<std::__1::basic_string<char,
std::__1::char_traits<char>, std::__1::allocator<char> >::__rep, 0, false>
```

```
::__compressed_pair_elem()
    native:    external/libcxx/include/memory:2140
    native:   std::__1::__compressed_pair<std::__1::basic_string<char, std::
__1::char_traits<char>, std::__1::allocator<char> >::__rep, std::__1::allo
cator<char> >::__compressed_pair<true, void>()
    native:    external/libcxx/include/memory:2234
    native:   std::__1::basic_string<char, std::__1::char_traits<char>, std:
:__1::allocator<char> >::basic_string<decltype(nullptr)>(char const*)
    native:    external/libcxx/include/string:820
    native:   UnwindStackCurrent::UnwindFromContext(unsigned long, void*)
    native:    system/unwinding/libbacktrace/UnwindStack.cpp:180
    native:   art::DumpNativeStack(std::__1::basic_ostream<char, std::__1::c
har_traits<char> >&, int, BacktraceMap*, char const*, art::ArtMethod*, voi
d*, bool)
    native:    art/runtime/native_stack_dump.cc:339
    native: #12 pc 0000000000741453  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::ClassLinker::InitWithoutImage(std::__1::ve
ctor<std::__1::unique_ptr<art::DexFile const, std::__1::default_delete<art
::DexFile const> >, std::__1::allocator<std::__1::unique_ptr<art::DexFile
const, std::__1::default_delete<art::DexFile const> > > >, std::__1::basic
_string<char, std::__1::char_traits<char>, std::__1::allocator<char> >*)+6
307)
    native:   art::Thread::DumpStack(std::__1::basic_ostream<char, std::__1:
:char_traits<char> >&, bool, BacktraceMap*, bool) const
    native:    art/runtime/thread.cc:2298
    native: #13 pc 0000000000da4709  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::Init(art::RuntimeArgumentMap&&)+1
8073)
    native:   art::DumpCheckpoint::Run(art::Thread*)
    native:    art/runtime/thread_list.cc:213
    native:   art::ThreadList::RunCheckpoint(art::Closure*, art::Closure*)
    native:    art/runtime/thread_list.cc:374
    native:   art::ThreadList::Dump(std::__1::basic_ostream<char, std::__1::
char_traits<char> >&, bool)
    native:    art/runtime/thread_list.cc:257
    native:   art::AbortState::Dump(std::__1::basic_ostream<char, std::__1::
char_traits<char> >&) const
    native:    art/runtime/runtime.cc:761
    native:   art::Dumpable<art::AbortState>::Dump(std::__1::basic_ostream<c
har, std::__1::char_traits<char> >&) const
    native:    art/libartbase/base/dumpable.h:38
    native:   std::__1::basic_ostream<char, std::__1::char_traits<char> >& a
rt::operator<< <art::AbortState>(std::__1::basic_ostream<char, std::__1::c
har_traits<char> >&, art::Dumpable<art::AbortState> const&)
    native:    art/libartbase/base/dumpable.h:49
    native:   art::Runtime::Abort(char const*)
    native:    art/runtime/runtime.cc:884
    native: #14 pc 0000000000d9fef7  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::Create(art::RuntimeArgumentMap&&)
+135)
    native: #15 pc 0000000000491e0f  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Dex2Oat::CreateRuntime(art::RuntimeArgumen
tMap&&)+127)
    native: #16 pc 0000000000484526  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Dex2Oat::Setup()+2118)
    native: #17 pc 000000000047edcc  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (main+1452)
    native: #18 pc 000000000002814f  /usr/lib/x86_64-linux-gnu/libc.so.6 (??
?) (BuildId: b20cbdb62d7717c13dc61a48b7b2e673a7edf233)
```

```
    native: #19 pc 0000000000028208  /usr/lib/x86_64-linux-gnu/libc.so.6 (__
libc_start_main+136) (BuildId: b20cbdb62d7717c13dc61a48b7b2e673a7edf233)
    native:   __libc_start_main_impl
    native:    ./csu/../csu/libc-start.c:360
    native: #20 pc 00000000004241a8  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (???)
    (no managed stack frames)

dex2oatd E 05-05 20:54:51   159   159 thread-inl.h:170] holding "abort loc
k" at point where thread suspension is expected
Aborting thread:
"main" prio=5 tid=1 Runnable (still starting up)
    | group="" sCount=0 ucsCount=0 flags=0 obj=(nil) self=0x63f93b0df6f0
    | sysTid=159 nice=19 cgrp=default sched=0/0 handle=0x7d8aae500740
    | state=R schedstat=( 46410502 17203600 40 ) utm=4 stm=0 core=18 HZ=100
    | stack=0x7ffdfc378000-0x7ffdfc37a000 stackSize=8184KB
    | held mutexes= "abort lock" "mutator lock"(shared held)
    native: #00 pc 0000000000e9a168  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (UnwindStackCurrent::UnwindFromContext(unsigned
long, void*)+88)
    native: #01 pc 0000000000e94d9d  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::DumpNativeStack(std::__1::basic_ostream<ch
ar, std::__1::char_traits<char> >&, int, BacktraceMap*, char const*, art::
ArtMethod*, void*, bool)+141)
    native: #02 pc 0000000000ec8616  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Thread::DumpStack(std::__1::basic_ostream<
char, std::__1::char_traits<char> >&, bool, BacktraceMap*, bool) const+422
)
    native: #03 pc 0000000000dbb0dd  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::AbortState::DumpThread(std::__1::basic_ost
ream<char, std::__1::char_traits<char> >&, art::Thread*) const+93)
    native: #04 pc 0000000000d9f46f  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::Abort(char const*)+399)
    native:   std::__1::__compressed_pair_elem<std::__1::basic_string<char,
std::__1::char_traits<char>, std::__1::allocator<char> >::__rep, 0, false>
::__compressed_pair_elem()
    native:    external/libcxx/include/memory:2140
    native:   std::__1::__compressed_pair<std::__1::basic_string<char, std::
__1::char_traits<char>, std::__1::allocator<char> >::__rep, std::__1::allo
cator<char> >::__compressed_pair<true, void>()
    native:    external/libcxx/include/memory:2234
    native:   std::__1::basic_string<char, std::__1::char_traits<char>, std:
:__1::allocator<char> >::basic_string<decltype(nullptr)>(char const*)
    native:    external/libcxx/include/string:820
    native:   UnwindStackCurrent::UnwindFromContext(unsigned long, void*)
    native:    system/unwinding/libbacktrace/UnwindStack.cpp:180
    native:   art::DumpNativeStack(std::__1::basic_ostream<char, std::__1::c
har_traits<char> >&, int, BacktraceMap*, char const*, art::ArtMethod*, voi
d*, bool)
    native:    art/runtime/native_stack_dump.cc:339
    native: #05 pc 00000000016cfd1c  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (android::base::SetAborter(std::__1::function<vo
id (char const*)>&&)::$_3::__invoke(char const*)+60)
    native:   art::Thread::DumpStack(std::__1::basic_ostream<char, std::__1:
:char_traits<char> >&, bool, BacktraceMap*, bool) const
    native:    art/runtime/thread.cc:2298
    native:   art::AbortState::DumpThread(std::__1::basic_ostream<char, std:
:__1::char_traits<char> >&, art::Thread*) const
    native:    art/runtime/runtime.cc:782
```

```
    native:   art::Dumpable<art::AbortState>::Dump(std::__1::basic_ostream<c
har, std::__1::char_traits<char> >&) const
    native:    art/libartbase/base/dumpable.h:38
    native:   std::__1::basic_ostream<char, std::__1::char_traits<char> >& a
rt::operator<< <art::AbortState>(std::__1::basic_ostream<char, std::__1::c
har_traits<char> >&, art::Dumpable<art::AbortState> const&)
    native:    art/libartbase/base/dumpable.h:49
    native:   art::Runtime::Abort(char const*)
    native:    art/runtime/runtime.cc:884
    native: #06 pc 00000000016cf9a8  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (android::base::LogMessage::~LogMessage()+328)
    native: #07 pc 00000000006000f2  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::ArtMethod::SetDataPtrSize(void const*, art
::PointerSize)+226)
    native: #08 pc 0000000000daf16d  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::CreateResolutionMethod()+285)
    native: #09 pc 0000000000741453  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::ClassLinker::InitWithoutImage(std::__1::ve
ctor<std::__1::unique_ptr<art::DexFile const, std::__1::default_delete<art
::DexFile const> >, std::__1::allocator<std::__1::unique_ptr<art::DexFile
const, std::__1::default_delete<art::DexFile const> > > >, std::__1::basic
_string<char, std::__1::char_traits<char>, std::__1::allocator<char> >*)+6
307)
    native: #10 pc 0000000000da4709  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::Init(art::RuntimeArgumentMap&&)+1
8073)
    native:   android::base::SetAborter(std::__1::function<void (char const*
)>&&)::$_3::__invoke(char const*)
    native:    external/libcxx/include/functional:1799
    native:   android::base::LogMessage::~LogMessage()
    native:    system/libbase/logging.cpp:504
    native:   art::ArtMethod::SetDataPtrSize(void const*, art::PointerSize)
    native:    art/runtime/art_method.h:604
    native:   art::ArtMethod::SetEntryPointFromJniPtrSize(void const*, art::
PointerSize)
    native:    art/runtime/art_method.h:594
    native:   art::Runtime::CreateResolutionMethod()
    native:    art/runtime/runtime.cc:2789
    native:   art::ClassLinker::InitWithoutImage(std::__1::vector<std::__1::
unique_ptr<art::DexFile const, std::__1::default_delete<art::DexFile const
> >, std::__1::allocator<std::__1::unique_ptr<art::DexFile const, std::__1
::default_delete<art::DexFile const> > > >, std::__1::basic_string<char, s
td::__1::char_traits<char>, std::__1::allocator<char> >*)
    native:    art/runtime/class_linker.cc:787
    native:   art::Runtime::Init(art::RuntimeArgumentMap&&)
    native:    art/runtime/runtime.cc:2077
    native: #11 pc 0000000000d9fef7  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Runtime::Create(art::RuntimeArgumentMap&&)
+135)
    native:   art::Runtime::Create(art::RuntimeArgumentMap&&)
    native:    art/runtime/runtime.cc:1046
    native: #12 pc 0000000000491e0f  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Dex2Oat::CreateRuntime(art::RuntimeArgumen
tMap&&)+127)
    native:   art::Dex2Oat::CreateRuntime(art::RuntimeArgumentMap&&)
    native:    art/dex2oat/dex2oat.cc:2711
    native: #13 pc 0000000000484526  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (art::Dex2Oat::Setup()+2118)
    native:   art::Dex2Oat::Setup()
```

```
    native:    art/dex2oat/dex2oat.cc:1522
    native: #14 pc 000000000047edcc  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (main+1452)
    native:   main
    native:    art/dex2oat/dex2oat.cc:3168
    native: #15 pc 000000000002814f  /usr/lib/x86_64-linux-gnu/libc.so.6 (??
?) (BuildId: b20cbdb62d7717c13dc61a48b7b2e673a7edf233)
    native: #16 pc 0000000000028208  /usr/lib/x86_64-linux-gnu/libc.so.6 (__
libc_start_main+136) (BuildId: b20cbdb62d7717c13dc61a48b7b2e673a7edf233)
    native:   __libc_start_main_impl
    native:    ./csu/../csu/libc-start.c:360
    native: #17 pc 00000000004241a8  /home/weiminn/Documents/aosp13/out/host
/linux-x86/bin/dex2oatd64 (???)
    (no managed stack frames)
Aborted (core dumped)
ERROR: Dex2oat failed to compile a boot image.It is likely that the boot c
lasspath is inconsistent.Rebuild with ART_BOOT_IMAGE_EXTRA_ARGS="--runtime
-arg -verbose:verifier" to see verification errors.
20:54:57 ninja failed with: exit status 1

#### failed to build some targets (18 seconds) ####
```

Deleted the contents of the AOSP 13 project and resynced, and now got new:

```
[  0% 107/19930] //packages/modules/NeuralNetworks/runtime:libneuralnetwor
FAILED: out/soong/.intermediates/packages/modules/NeuralNetworks/runtime/l
ibneuralnetworks/android_arm64_armv8-2a_cortex-a55_shared_apex30/libneural
networks.so.lsdump
prebuilts/clang-tools/linux-x86/bin/header-abi-linker --root-dir . --root-
dir $OUT_DIR:out -o out/soong/.intermediates/packages/modules/NeuralNetwor
ks/runtime/libneuralnetworks/android_arm64_armv8-2a_cortex-a55_shared_apex
30/libneuralnetworks.so.lsdump -so out/soong/.intermediates/packages/modul
es/NeuralNetworks/runtime/libneuralnetworks/android_arm64_armv8-2a_cortex-
a55_shared_apex30/libneuralnetworks.so -v packages/modules/NeuralNetworks/
runtime/libneuralnetworks.map.txt -arch arm64 -Ipackages/modules/NeuralNet
works/runtime/include -Iframeworks/native/cmds/lshal/libprocpartition/incl
ude -Ibuild/soong/cc/libbuildversion/include -Iout/soong/.intermediates/pa
ckages/modules/NeuralNetworks/runtime/statslog_neuralnetworks.h/gen @out/s
oong/.intermediates/packages/modules/NeuralNetworks/runtime/libneuralnetwo
rks/android_arm64_armv8-2a_cortex-a55_shared_apex30/libneuralnetworks.so.l
sdump.rsp
Failed to parse JSON: * Line 1, Column 1
  Syntax error: value, object or array expected.

ReadDump failed
libc++abi: Pure virtual function called!
Aborted (core dumped)
21:57:03 ninja failed with: exit status 1
```

Also finding a lot of warning messages like:

```
no declaration found for ELF symbol with id acoshl@@LIBC
no declaration found for ELF symbol with id acosl@@LIBC
no declaration found for ELF symbol with id asinhl@@LIBC
no declaration found for ELF symbol with id asinl@@LIBC
no declaration found for ELF symbol with id atan2l@@LIBC
no declaration found for ELF symbol with id atanhl@@LIBC
no declaration found for ELF symbol with id atanl@@LIBC
no declaration found for ELF symbol with id cbrtl@@LIBC
no declaration found for ELF symbol with id ceill@@LIBC
```

```
no declaration found for ELF symbol with id coshl@@LIBC
no declaration found for ELF symbol with id cosl@@LIBC
no declaration found for ELF symbol with id csqrtl@@LIBC
no declaration found for ELF symbol with id erfcl@@LIBC
no declaration found for ELF symbol with id erfl@@LIBC
no declaration found for ELF symbol with id expm1l@@LIBC
no declaration found for ELF symbol with id floor@@LIBC
no declaration found for ELF symbol with id floorl@@LIBC
no declaration found for ELF symbol with id fmal@@LIBC
no declaration found for ELF symbol with id frexpl@@LIBC
no declaration found for ELF symbol with id hypotl@@LIBC
no declaration found for ELF symbol with id ldexpf@@LIBC
no declaration found for ELF symbol with id ldexpl@@LIBC
no declaration found for ELF symbol with id lgammal@@LIBC
no declaration found for ELF symbol with id lgammal_r@@LIBC
no declaration found for ELF symbol with id log10l@@LIBC
no declaration found for ELF symbol with id log1pl@@LIBC
no declaration found for ELF symbol with id logbl@@LIBC
no declaration found for ELF symbol with id nanl@@LIBC
no declaration found for ELF symbol with id nextafterl@@LIBC
no declaration found for ELF symbol with id nexttoward@@LIBC
no declaration found for ELF symbol with id nexttowardl@@LIBC
no declaration found for ELF symbol with id remainderl@@LIBC
no declaration found for ELF symbol with id remquol@@LIBC
no declaration found for ELF symbol with id rintl@@LIBC
no declaration found for ELF symbol with id scalbnl@@LIBC
no declaration found for ELF symbol with id sinhl@@LIBC
no declaration found for ELF symbol with id sinl@@LIBC
no declaration found for ELF symbol with id sqrt@@LIBC
no declaration found for ELF symbol with id sqrtf@@LIBC
no declaration found for ELF symbol with id sqrtl@@LIBC
no declaration found for ELF symbol with id tanhl@@LIBC
no declaration found for ELF symbol with id tanl@@LIBC
no declaration found for ELF symbol with id truncl@@LIBC
```

Now it compiles successfully, but stuck in infinite loop at boot.

Check the driver number for Pixel 7 Pro[1] and the number is TD1A.220804.031. Now download the driver binary for TD1A.220804.031[2]. And now it works! Turns out I forgot to run the driver install script after I synced the repo.

The logic is still not updating after I added in some logging code with [WEIMINN] tag inside the `frameworks/base/core/jni/AndroidRuntime.cpp`. The build system doesn't seem to be recognizing the changes in the source code. So I find the compiled framework objects in `out` using `find./out-inameframework` and deleted the entire `out/soong/.intermediates/frameworks`, and run the `make` command again. Now it recompiles, but still not updating the logic inside the flashed ROM. Rebooting the machine also doesn't work.

For the record, this is the command to find a string in the project:

```
clear && find ./frameworks/ ./art/ ./bionic/ ./device/ ./build/ ./libnativehelper
    \( -iname '*.java' -o -iname '*.cpp' -o -iname '*.cc' -o -iname '*.hpp' -o -
    iname '*.h' -o -iname '*.S' -o -iname '*.mk' \) -a ! -iname '*test*' -a ! -
```

[1] https://source.android.com/docs/setup/reference/build-numbers

[2] https://developers.google.com/android/drivers

```
    iname '*out*' | xargs grep --color -sin 'docall('
```

Relunch for emulator with this script:

```
echo "[WEIMINN] Building AOSP"
cd /home/weiminn/Documents/aosp13_new
source build/envsetup.sh
lunch sdk_phone_x86_64-userdebug
make

emulator &

boot_start=`date +%s`
adb wait-for-device

echo "[WEIMINN] Waiting for boot completion"
A=$(adb shell getprop sys.boot_completed | tr -d '\r')
while [ "$A" != "1" ]; do
        echo "[WEIMINN] Waiting for boot completion"
        sleep .5
        A=$(adb shell getprop sys.boot_completed | tr -d '\r')
done
boot_end=`date +%s`
echo Boot time was `expr $boot_end - $boot_start` seconds.

adb root

echo "[WEIMINN] Enabling logging"
adb shell setprop debug.ld.all dlerror,dlopen

rm -f logcat.txt
echo "[WEIMINN] Logging with Logcat to logcat.txt"
adb logcat >> logcat.txt
```

And now the code changes are detected by the build system and the new logic is reflected in the logcat!

7.1.2 Implement Zicheng Code inside AOSP13 Emulator

Insert the following code at the bottom of `build/make/target/board/emulator_x86_64/device.mk`:

```
DISABLE_ARTIFACT_PATH_REQUIREMENTS := true
PRODUCT_PACKAGES += MINIMAManager
```

And paste in the `MINIMAManager.apk` inside `packages/apps/MINIMAManager` directory.

But the app installed via `adbinstallsuccess_apps/60_com.atomic.apps.medical.drug.dictionary.apk` doesn't launch after preloading the MINIMAManager APK. If I remove the preload, then the app launches.

Pasted in the Customized Framework codes and now can succesfully `adb install` and launch the apps. The debloation also works!

7.2 May 07-14, 2024

7.2.1 Verify AOSP13 Debloating via ART Only

Get a list of APKs that can be successfully debloated and demoed.

```
adb install success_apps/60_com.atomic.apps.medical.drug.dictionary.apk
adb push success_schema/60_com.atomic.apps.medical.drug.dictionary_removed_methods
    .txt /sdcard

adb install success_apps/169_com.storiestime.apk
adb push success_schema/169_com.storiestime_removed_methods.txt /sdcard

adb install success_apps/471_com.mobilemirror.app2018.mirror.apk
adb push success_schema/471_com.mobilemirror.app2018.mirror_removed_methods.txt /
    sdcard

adb install success_apps/400_com.myprograms.glasgow.apk

adb install success_apps/382_com.diogines.pregnancy.apk
```

These APKs cannot be launched

```
adb install success_apps/363_com.BloodpressureHistoryDiary.healthRecordsAnalyze.
    apk
adb install success_apps/424_com.mdhelper.cardiojournal.apk
```

7.2.2 Which components are involved in Framework for Debloation?

Procedure	Description
services/core/java/com/android/server/pm/permission/PermissionManagerService.java	
onPackageInstalled	Modify to add READ Permission to the installed package's requested permissions.

Table 7.1: Framework Procedures

7.3 Isolate functionalities of ART Procedures

Procedure	Zicheng's Work
libartbase/base/os_linux.h	
CreateMINIMAFile	Not invoked
CreateDirectories2	Not invoked
libartbase/base/os_linux.cc	
CreateMINIMAFile	Not invoked
CreateDirectories2	Not invoked
libdexfile/dex/art_dex_file_loader.cc	

Procedure	Zicheng's Work
`ArtDexFileLoader::Open`	Only trivial logging
`libdexfile/dex/dex_file_loader.cc`	
`DexFileLoader::OpenCommon`	Only trivial logging
`libnativeloader/native_loader_namespace.cpp`	
`NativeLoaderNamespace::Load`	Only trivial logging
`libnativeloader/native_loader.cpp`	
`OpenNativeLibrary`	Only trivial logging
`OpenNativeLibraryInNamespace`	Only trivial logging
`oderefresh/oderefresh.cc`	
`AddDex2OatProfileAndCompilerFilter`	Change property `dalvik.vm.systemservercompilerfilter` for `speed` to `verify`.
`oderefresh/oderefresh_main.cc`	
`InitializeConfig`	Change argument `--compiler-filter` for `speed` to `verify`.
`runtime/entrypoints/quick/quick_trampoline_entry_points.cc`	
`artQuickToInterpreterBridge`	No change
`runtime/interpreter/interpreter_common.cc`	
`DoCallCommon`	Only trivial Logging
`runtime/interpreter/interpreter_switch_impl-inl.h`	

Additional header Macros	`#include"utils/Log.h"`
	`#include<jni.h>`
	`#include"runtime_globals.h"`
	`#include"jni/java_vm_ext.h"`
	`#include"jni/jni_env_ext.h"`

`ExecuteSwitchImplCpp`	Get `SwitchImplContext`'s `shadow_frame`'s `GetMethod`'s `PrettyMethod` and check `MYmatch_hook_method`. If the method's signature matches, create intent to switich to MINIMA app.
`runtime/interpreter/interpreter_switch_impl.h`	
`ExecuteSwitchImpl`	No change
`runtime/interpreter/interpreter.cc`	
`Execute`	No change
`EnterInterpreterFromEntryPoint`	No change
`runtime/jit/jit.cc`	

Procedure	Zicheng's Work
`MethodEntered`	No change
`runtime/jni/java_vm_ext.cc`	
Additional header Macros	`#include"utils/Log.h"`
`FindSymbol`	Compare `symbol_name` to `Java_edu_smu_imitatejumping_Simple_1JNI_1Class_duration`
`JavaVMExt::LoadNativeLibrary`	Only trivial logging
`runtime/jni/jni_internal.cc`	
`FindClass`	No change
`runtime/mirror/class.cc`	
`FindClassMethodWithSignature`	No change
`runtime/native/dalvik_system_DexFile.cc`	
`DexFile_openDexFileNative`	No change
`runtime/native/dalvik_system_ZygoteHooks.cc`	
`modifyFilePermissions1`	Procedure to modify a given file's permission; Not invoked
`ZygoteHooks_nativePostForkChild`	Remove tracing logic. Get the process' package name for trivial logging.
`runtime/app_info.cc`	
`GetPackageName` **(NO NEED)**	Get package name from AppInfo instance
`runtime/app_info.h`	
`GetPackageName` **(NO NEED)**	Add definition to retrieve package name of the app; Not invoked
`runtime/art_method-inl.h`	
`ArtMethod::CheckIncompatibleClassChange`	Trivial Logging
`ArtMethod::UpdateCounter`	Get `PrettyMethod` and log it with `hotness_count_`
`runtime/art_method.cc`	
Additional headers	`#include"utils/Log.h"`
`ArtMethod::Invoke` **(NO NEED)**	Log its PrettyMethod if the method name matches `Runtime::MYmatch_target_method` after having quick code.
`ArtMethod::PrettyMethod` **(NO NEED)**	Add additional information such as DEX method index, counter, and method index
`runtime/art_method.h`	

Procedure	Zicheng's Work
ArtMethod::UpdateCounter	Modify declaration to include REQUIRES_SHARED(Locks::mutator_lock_) at the end
runtime/class_linker.cc	
ClassLinker::FindClass	Only trivial logging
LinkCode	SetDontCompile for the method if Runtime::MYmatch_target_method or Runtime::MYmatch_hook_method, plus trivial logging
ClassLinker::LoadClass	Only trivial Logging
runtime/instrumentation.cc	
CanUseNterp	If Runtime::MYmatch_target_method or Runtime::MYmatch_hook_method then return false to exit instead of proceeding.
Instrumentation::InitializeMethodsCode	Check for empty_Hook() in the method signature and then logs. Add logging during the check if method is native.
runtime/oat_file_manager.cc	
OatFileManager::OpenDexFilesFromOat_Impl	Only trivial logging
runtime/runtime_globals.h	
Added headers	#include"utils/Log.h" #include<iostream> #include<sstream> #include<fstream> #include<stdio.h> #include<dirent.h> #include"base/os.h" #include<vector> #include<string>
runtime/runtime.h	
NativeLibFunc	Add declaration
MYmatch_hook_method	Add declaration
MYmatch_target_method	Add declaration
MYreadFile	Add declaration
MYmake_file	Add declaration
read_content	Add declaration
getLoadingSchema	Add definition
getLoadedSchema	Add definition

Procedure	Zicheng's Work
`getShouldReadSchema`	Add definition
`setLoadingSchema`	Add definition
`setLoadedSchema`	Add definition
`setShouldReadSchema`	Add definition; not invoked
`getDebugging`	Add definition
`getTarget_method_string_vector`	Add definition for accessor to `target_method_string_vector`
`setTarget_method_string_vector`	Add definition
`getMINIMA_file_path`	Add definition for accessor to `MINIMA_file_path`
`getMINIMA_folder_path`	Not invoked
`getHookMethodName`	Add definition for accessor to `hook_method_name`
`MINIMA_file_path`	Add private declaration
`hook_method_name`	Add private declaration
`target_method_string_vector`	Add private declaration
`target_native_func_string_vector`	Add private declaration
`debugging`	Add private declaration
`api_prefix_List`	Add private declaration
`loaded_schema_`	Add private declaration after `image_dex2oat_enabled_`
`loading_schema_`	Add private declaration after `image_dex2oat_enabled_`
`should_read_schema_`	Add private declaration after `image_dex2oat_enabled_`
`runtime/runtime.cc`	
`StringAppendV`	Called by `StringPrintf` and `StringAppendF` which are not invoked
`StringPrintf`	Not invoked
`StringAppendF`	Not invoked
`Runtime::MINIMA_file_path`	Hardcoded to `"/data/local/tmp/mySchema.txt"`
`Runtime::hook_method_name`	Hardcoded to `"voidedu.smu.minimaconfig.SettingsActivity.empty_Hook()"`
`Runtime::debugging`	Hardcoded to `false`
`Runtime::target_method_string_vector`	The vector that stores the schema
`Runtime::target_native_func_string_vector`	Empty schema of native functions. Not invoked
`api_prefix_List`	Not invoked

Procedure	Zicheng's Work
NativeLibFunc	Format to store native functions in schema target_native_func_string_vector
Runtime	Add initializers loaded_schema_(false), loading_schema_(false) and should_read_schema_(false).
Create	Checks if MINIMA file exists with OS::FileExists(Runtime::getMINIMA_file_path().c_str()) and does nothing with it
Start	Only trivial logging
Init	Remove trace_config_->trace_mode=Trace::TraceMode::kMethodTracing;
MYmatch_hook_method	Check if method is hook_method_name
java2cpp	Converts Java arraylist to C++ vector
is_within_JNImethod_list	Not invoked
Runtime::read_content	Loads the schema and stores it in Runtime::target_native_func_string_vector.
is_packageMethod	Not invoked
Runtime::MYmatch_target_method	Returns false if still loading schema (getLoadingSchema), runtime not started or is system server. If preinstalled pacakge, should not read schema. Otherwise, call read_content to load the schema. Access the schema via getTarget_method_string_vector and iterate through to see if the method matches any of the signature in the schema.
Runtime::MYmake_file	Not invoked
Runtime::MYreadFile	Not invoked
runtime/trace.cc	
modifyFilePermissions	Modify permission of given file
Trace::Start	Calls modifyFilePermissions to modify trace_filename
Trace::Trace	Change initialization of trace_mode_ from trace_mode to to TraceMode::kMethodTracing
Trace::MethodEntered	No change
Trace::MethodExited	No change

Table 7.2: ART Procedures involved in Debloation

In frameworks/base/services/core/java/com/android/server/pm/parsing/pkg/

PackageImpl.java, comment out this line in method void makeImmutable:

```
1 requestedPermissions = Collections.unmodifiableList(requestedPermissions);
```

7.4 May 15, 2024

7.4.1 Verify debloater in several android apps

```
1 05-15 21:44:13.512     0     0 E SELinux : avc:  denied  { find } for pid=2247 uid
      =99007 name=content_capture scontext=u:r:isolated_app:s0:c512,c768 tcontext=u:
      object_r:content_capture_service:s0 tclass=service_manager permissive=0
2 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517] No pending
      exception expected: java.lang.SecurityException: Isolated process not allowed
      to call getContentProvider
3 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at java.lang.
      Exception android.os.Parcel.createExceptionOrNull(int, java.lang.String) (
      Parcel.java:3057)
4 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at java.lang.
      Exception android.os.Parcel.createException(int, java.lang.String) (Parcel.
      java:3041)
5 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at void
      android.os.Parcel.readException(int, java.lang.String) (Parcel.java:3024)
6 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at void
      android.os.Parcel.readException() (Parcel.java:2966)
7 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at android.app
      .ContentProviderHolder android.app.IActivityManager$Stub$Proxy.
      getContentProvider(android.app.IApplicationThread, java.lang.String, java.lang
      .String, int, boolean) (IActivityManager.java:5935)
8 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at android.
      content.IContentProvider android.app.ActivityThread.acquireProvider(android.
      content.Context, java.lang.String, int, boolean) (ActivityThread.java:7381)
9 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at android.
      content.IContentProvider android.app.ContextImpl$ApplicationContentResolver.
      acquireUnstableProvider(android.content.Context, java.lang.String) (
      ContextImpl.java:3668)
10 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at android.
      content.IContentProvider android.content.ContentResolver.
      acquireUnstableProvider(android.net.Uri) (ContentResolver.java:2542)
11 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at android.
      database.Cursor android.content.ContentResolver.query(android.net.Uri, java.
      lang.String[], android.os.Bundle, android.os.CancellationSignal) (
      ContentResolver.java:1213)
12 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at android.
      database.Cursor android.content.ContentResolver.query(android.net.Uri, java.
      lang.String[], java.lang.String, java.lang.String[], java.lang.String, android
      .os.CancellationSignal) (ContentResolver.java:1161)
13 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at android.
      database.Cursor android.content.ContentResolver.query(android.net.Uri, java.
      lang.String[], java.lang.String, java.lang.String[], java.lang.String) (
      ContentResolver.java:1117)
14 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at java.lang.
      Class java.lang.VMClassLoader.findLoadedClass(java.lang.ClassLoader, java.lang
      .String) (VMClassLoader.java:-2)
15 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at java.lang.
      Class java.lang.ClassLoader.findLoadedClass(java.lang.String) (ClassLoader.
      java:738)
```

```
16 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at java.lang.
       Class java.lang.ClassLoader.loadClass(java.lang.String, boolean) (ClassLoader.
       java:363)
17 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at java.lang.
       Class java.lang.ClassLoader.loadClass(java.lang.String) (ClassLoader.java:312)
18 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at android.app
       .Service android.app.AppComponentFactory.instantiateService(java.lang.
       ClassLoader, java.lang.String, android.content.Intent) (AppComponentFactory.
       java:129)
19 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at void
       android.app.ActivityThread.handleCreateService(android.app.
       ActivityThread$CreateServiceData) (ActivityThread.java:4667)
20 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at void
       android.app.ActivityThread.-$$Nest$mhandleCreateService(android.app.
       ActivityThread, android.app.ActivityThread$CreateServiceData) (ActivityThread.
       java:-1)
21 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at void
       android.app.ActivityThread$H.handleMessage(android.os.Message) (ActivityThread
       .java:2289)
22 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at void
       android.os.Handler.dispatchMessage(android.os.Message) (Handler.java:106)
23 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at boolean
       android.os.Looper.loopOnce(android.os.Looper, long, int) (Looper.java:205)
24 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at void
       android.os.Looper.loop() (Looper.java:294)
25 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at void
       android.app.ActivityThread.main(java.lang.String[]) (ActivityThread.java:8248)
26 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at java.lang.
       Object java.lang.reflect.Method.invoke(java.lang.Object, java.lang.Object[]) (
       Method.java:-2)
27 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at void com.
       android.internal.os.RuntimeInit$MethodAndArgsCaller.run() (RuntimeInit.java
       :552)
28 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at void com.
       android.internal.os.ChildZygoteInit.runZygoteServer(com.android.internal.os.
       ZygoteServer, java.lang.String[]) (ChildZygoteInit.java:136)
29 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at void com.
       android.internal.os.WebViewZygoteInit.main(java.lang.String[]) (
       WebViewZygoteInit.java:147)
30 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at java.lang.
       Object java.lang.reflect.Method.invoke(java.lang.Object, java.lang.Object[]) (
       Method.java:-2)
31 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at void com.
       android.internal.os.RuntimeInit$MethodAndArgsCaller.run() (RuntimeInit.java
       :552)
32 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at void com.
       android.internal.os.ZygoteInit.main(java.lang.String[]) (ZygoteInit.java:971)
33 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517] Caused by:
       android.os.RemoteException: Remote stack trace:
34 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at com.android
       .server.am.ActivityManagerService.enforceNotIsolatedCaller(
       ActivityManagerService.java:3079)
35 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at com.android
       .server.am.ContentProviderHelper.getContentProvider(ContentProviderHelper.java
       :130)
36 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at com.android
       .server.am.ActivityManagerService.getContentProvider(ActivityManagerService.
       java:6782)
37 05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at android.app
```

```
    .IActivityManager$Stub.onTransact(IActivityManager.java:2776)
38  05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]   at com.android
    .server.am.ActivityManagerService.onTransact(ActivityManagerService.java:2763)
39  05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517]
40  05-15 21:44:13.493  2247  2247 F ocessService1:0: thread.cc:2517] (Throwable with
    no stack trace)
```

In AOSP 13, the runtime responses to the changes in the schema by the Management App instantly, whereas in AOSOP 14, the response is not consistent. Now trying to go into `MY_match_target_method` of `art/runtime/runtime.cc` and see the flow up close.

The debloating works perfectly when:

```
1  adb uninstall com.atomic.apps.medical.drug.dictionary && adb install success_apps
   /60_com.atomic.apps.medical.drug.dictionary.apk
```

But after closing the app and relaunch, the debloating doesn't work for some methods anymore. Need to see what happens to the runtime when the app is closed and relaunched.

This sandbox related exception has nothing to do with this error as it still shows when the debloating was working perfectly after reinstalling:

```
1  05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517] No pending
   exception expected: java.lang.SecurityException: Isolated process not allowed
   to call getContentProvider
2  05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at java.lang.
   Exception android.os.Parcel.createExceptionOrNull(int, java.lang.String) (
   Parcel.java:3057)
3  05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at java.lang.
   Exception android.os.Parcel.createException(int, java.lang.String) (Parcel.
   java:3041)
4  05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at void
   android.os.Parcel.readException(int, java.lang.String) (Parcel.java:3024)
5  05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at void
   android.os.Parcel.readException() (Parcel.java:2966)
6  05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at android.app
   .ContentProviderHolder android.app.IActivityManager$Stub$Proxy.
   getContentProvider(android.app.IApplicationThread, java.lang.String, java.lang
   .String, int, boolean) (IActivityManager.java:5935)
7  05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at android.
   content.IContentProvider android.app.ActivityThread.acquireProvider(android.
   content.Context, java.lang.String, int, boolean) (ActivityThread.java:7381)
8  05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at android.
   content.IContentProvider android.app.ContextImpl$ApplicationContentResolver.
   acquireUnstableProvider(android.content.Context, java.lang.String) (
   ContextImpl.java:3668)
9  05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at android.
   content.IContentProvider android.content.ContentResolver.
   acquireUnstableProvider(android.net.Uri) (ContentResolver.java:2542)
10 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at android.
   database.Cursor android.content.ContentResolver.query(android.net.Uri, java.
   lang.String[], android.os.Bundle, android.os.CancellationSignal) (
   ContentResolver.java:1213)
11 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at android.
   database.Cursor android.content.ContentResolver.query(android.net.Uri, java.
   lang.String[], java.lang.String, java.lang.String[], java.lang.String, android
   .os.CancellationSignal) (ContentResolver.java:1161)
```

```
12 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at android.
       database.Cursor android.content.ContentResolver.query(android.net.Uri, java.
       lang.String[], java.lang.String, java.lang.String[], java.lang.String) (
       ContentResolver.java:1117)
13 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at java.lang.
       Class java.lang.VMClassLoader.findLoadedClass(java.lang.ClassLoader, java.lang
       .String) (VMClassLoader.java:-2)
14 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at java.lang.
       Class java.lang.ClassLoader.findLoadedClass(java.lang.String) (ClassLoader.
       java:738)
15 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at java.lang.
       Class java.lang.ClassLoader.loadClass(java.lang.String, boolean) (ClassLoader.
       java:363)
16 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at java.lang.
       Class java.lang.ClassLoader.loadClass(java.lang.String) (ClassLoader.java:312)
17 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at android.app
       .Service android.app.AppComponentFactory.instantiateService(java.lang.
       ClassLoader, java.lang.String, android.content.Intent) (AppComponentFactory.
       java:129)
18 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at void
       android.app.ActivityThread.handleCreateService(android.app.
       ActivityThread$CreateServiceData) (ActivityThread.java:4667)
19 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at void
       android.app.ActivityThread.-$$Nest$mhandleCreateService(android.app.
       ActivityThread, android.app.ActivityThread$CreateServiceData) (ActivityThread.
       java:-1)
20 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at void
       android.app.ActivityThread$H.handleMessage(android.os.Message) (ActivityThread
       .java:2289)
21 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at void
       android.os.Handler.dispatchMessage(android.os.Message) (Handler.java:106)
22 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at boolean
       android.os.Looper.loopOnce(android.os.Looper, long, int) (Looper.java:205)
23 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at void
       android.os.Looper.loop() (Looper.java:294)
24 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at void
       android.app.ActivityThread.main(java.lang.String[]) (ActivityThread.java:8248)
25 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at java.lang.
       Object java.lang.reflect.Method.invoke(java.lang.Object, java.lang.Object[]) (
       Method.java:-2)
26 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at void com.
       android.internal.os.RuntimeInit$MethodAndArgsCaller.run() (RuntimeInit.java
       :552)
27 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at void com.
       android.internal.os.ChildZygoteInit.runZygoteServer(com.android.internal.os.
       ZygoteServer, java.lang.String[]) (ChildZygoteInit.java:136)
28 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at void com.
       android.internal.os.WebViewZygoteInit.main(java.lang.String[]) (
       WebViewZygoteInit.java:147)
29 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at java.lang.
       Object java.lang.reflect.Method.invoke(java.lang.Object, java.lang.Object[]) (
       Method.java:-2)
30 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at void com.
       android.internal.os.RuntimeInit$MethodAndArgsCaller.run() (RuntimeInit.java
       :552)
31 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at void com.
       android.internal.os.ZygoteInit.main(java.lang.String[]) (ZygoteInit.java:971)
32 05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517] Caused by:
       android.os.RemoteException: Remote stack trace:
```

```
05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at com.android
    .server.am.ActivityManagerService.enforceNotIsolatedCaller(
    ActivityManagerService.java:3079)
05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at com.android
    .server.am.ContentProviderHelper.getContentProvider(ContentProviderHelper.java
    :130)
05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at com.android
    .server.am.ActivityManagerService.getContentProvider(ActivityManagerService.
    java:6782)
05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at android.app
    .IActivityManager$Stub.onTransact(IActivityManager.java:2776)
05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]   at com.android
    .server.am.ActivityManagerService.onTransact(ActivityManagerService.java:2763)
05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517]
05-16 01:06:34.222  2319  2319 F ocessService1:0: thread.cc:2517] (Throwable with
    no stack trace)
```

7.5 May 19, 2024

7.5.1 What makes up FjordPhantom exactly?

Hooking

Hook into APIs that is used to determine if Accessibility services are turned on, and return false information to bypass screenreader and rooting detection. Can also hook to UI functionalities such as dialog boxes to close them immediately if they contain certain strings.

Usage of hooking in Malware analysis

Paper	Hook Logic
Without System Modification	
Boxify, USENIX2015[3]	Secure sandboxing by dynmaically loading and executing within its own process. No firmware or application modification, or rooting needed.
Malton, USENIX2017[4]	Non-invasive Multi-layer (Java, C++ and ARM) Taint Analysis and Path Exploration. Taint propagation at Instruction (ARM) layer using Valgrind[5] because both app and framework code are compiled to native code in the ART runtime.
ARTDroid, IMPS2016[6]	No modification needed for app and Android system. Find target methods in virtual memory, hijack `vtable`, and set native hooks.
RetroSkeleton, MobiSys'13[7]	App re-writing framework by hooking apps using static instrumentation, for unmodifiable Android devices. Uses *transformation policies* to replace *target* methods with *handler* methods.

[3] https://www.usenix.org/system/files/conference/usenixsecurity15/sec15-paper-backes.pdf

[4] https://www.usenix.org/system/files/conference/usenixsecurity17/sec17-xue.pdf

[5] https://valgrind.org/docs/valgrind2007.pdf

[6] https://ceur-ws.org/Vol-1575/paper_10.pdf

[7] https://www.cs.ucdavis.edu/~hchen/paper/mobisys2013rs.pdf

Paper	Hook Logic
AppGuard, TACAS2013[8]	Hooking apps by static instrumentation to invoke inline reference monitoring and enforcing security and privacy policies. No need for firmware modification, or root access.
With System Modification	
Ronin, DASC2018[9]	Hook Main activity to call Ronin Ronin overwrites PLT tables[10] for hooking native functions in the memory
StaDynA, CODASPY'15[11]	Hooking framework APIs to log classes and methods (path to code file and stack trace) loaded dynamically and via reflection that cannot be inferred by static analysis.
TaintDroid, USENIX2010[12]	Hooking taint sources such as sensor manager, information databases and device identifers. Also hooking taint sinks (native socket library for network connections)
DroidScope, USENIX2012[13]	Runtime and kernel instrumentation for dynamic taint analysis on Java- and OS-level
Andrubis, Technical Report[14]	Runtime instrumentation

Table 7.3: Permission Denied Syntax

[8] https://link.springer.com/content/pdf/10.1007/978-3-642-36742-7_39.pdf

[9] https://www.researchgate.net/publication/328611051_Android_Hooking_Revisited

[10] https://www.technovelty.org/linux/plt-and-got-the-key-to-code-sharing-and-dynamic-libraries.html

[11] https://lilicoding.github.io/SA3Repo/papers/2015_zhauniarovich2015stadyna.pdf

[12] https://static.usenix.org/event/osdi10/tech/full_papers/Enck.pdf

[13] https://www.usenix.org/system/files/conference/usenixsecurity12/sec12-final107.pdf

[14] https://www.vvdveen.com/publications/TR0414001.pdf

7.6 May 22-27, 2024

7.6.1 Repackaging

Apps with malicious payloads added to apps on non-official app markets. Most popular code injection method is to repackage with additional code. But can be easily detected.

Name	Description
Repackaging Attack on Android Banking Applications and Its Countermeasures, WPC'13[15]	Example of repackaging attack by getting rid of antivirus instance-checking and modifying integrity-checking logic to send hash of original APK instead of the modified APK Countermeasures: Self-signing restriction, Code obfuscation, and Code attestation
Detecting Repackaged Android Apps: Lit. Review and Benchmark, TSE2021[16]	Detection approaches: **Similarity computation** (Code fuzzy hash, layout tree, resource files, layout group graph, method statements, control flow graph, identifiers, APIs, Intents, Permissions, Sensors, method signature, inputs/outputs of methods, control flow pattern, user interfaces, ICC-based view graph, data-dependency graph, abstract syntactic gree, API call sequenes, etc...), **Runtime monitoring** (execution trace, virtualization-based protection, watermarking, and package name), **Supervised learning** (user interactions, sensitive APIs, permissions, system call sequences, distance of sensitive subgraphs), **Unsupervised learning** (program dependency graph, permissions, intents, components, API calls, ICC, etc...), and **Sympton discovery** (string offset order)
Active Warden Attack: On the (In)Effectiveness of Android App Repackage-Proofing, DSC2022[17]	By passing repackaging-proofings using Active Warden Attacks which is basically MITM (via customized cached local binder proxy) that intercepts and relay integrity verification messages between the victim app and the Android Framework APIs Existing repackaging-proofing works have flawed assumption of trusting ICCs

[15] https://link.springer.com/article/10.1007/s11277-013-1258-x
[16] https://ieeexplore.ieee.org/document/8653409
[17] https://ink.library.smu.edu.sg/cgi/viewcontent.cgi?article=7706&context=sis_research

Name	Description
Repack Me If You Can, ACSAC'21[18]	Existing anti-repacking and anti-virtualization solutions don't work. Virtualization eliminates the need to modify and repack the original APK. The container can execute any external app without modifying it, intercept all the API invocations to the Android OS and tamper the responses. Protects the apps using **code splitting** (removing portion of code from the original app to split the original APK into multiple DEXes), and **IAT** (injection of controls which are evaluated during the interaction between the container and the plugin).

Table 7.4: Papers concerining Repackaging Attacks

7.6.2 Virtualization and Containers

Allows installation of the same app multiple times to be used with different accounts[19]. Those different apps run in the same sandbox to allow them to access each other's files and memory to debug each other. Allows breaking of sandbox without rooting. Loads additional code (logic of malware and invocations of hooking framework) into the process of hosted app.

Name	Description
VAHunt: Warding Off New Repackaged Android Malware in App-Virtualization's Clothing, CCS'20[20]	App-level virtualization where the host app creates virtual environment by dynamic proxy, and uses API hooking (so that the system thinks that all requests come from the host app) and binder proxy to bypass system service restrictions Stateful detection model using FSM and hooking intent APIs to detect app-level virtualization Data flow analysis to extract self-hiding loading strategies to differentiate between malicious and benign app-level virtualization-based apps

[18] https://dl.acm.org/doi/pdf/10.1145/3485832.3488021
[19] https://promon.co/security-news/fjordphantom-android-malware/
[20] https://par.nsf.gov/servlets/purl/10220267

Name	Description
Seamless In-App Ad Blocking on Stock Android, SPW'2017[21]	App-level virtualization for deploying security solutions (stripping advertising related-code without breaking app) No modification to both system or app (apart from removing)
HideMyApp: Hiding the Presence of Sensitive Apps on Android, USENIX'2019[22]	Built on top of app-level virtualization, the container app launches the APK file of the sensitive app within its context so that the sensitive app is not registered with the OS to protect the app from nosy apps. No modification to firmware; few modification to the app
Anti-Plugin, Blackhat'2017[23]	Inspection of plugin technology (app-level virtualization) abuse by malware Malware can update itself without rooting the phoneor having to repackage; they only need to be downloaded and installed by the user the first time Malware can evade static analysis as the code is updated only after the installation
App in the Middle, MACS'2019[24]	App-level virtualization threat analysis Can detect virtualization by detecting instrumentation and verifying file system structure
Parallel Space Travelling, SACMAT'20[25]	App-level virtualization consists of Virtual Framework (for emulation of core system services like PackageManager and ActivityManager) and Hook module (for intercepting the interaction between the guest apps and the system services). Either GuestApp (privilege escalation, code injection, ransomware, phishing, cloning) or HostApp (hijacking, antivirus evasion) can be malicious. Can detect by inspecting private directory info, call stack, and memory maps

[21] https://svenbugiel.de/publication/wissfeld-17-most/wissfeld-17-most.pdf

[22] https://www.usenix.org/system/files/sec19-pham.pdf

[23] https://paper.bobylive.com/Meeting_Papers/BlackHat/Asia-2017/asia-17-Luo-Anti-Plugin-Don%27t-Let-Your-App-Play-As-An-Android-Plugin-wp.pdf

[24] https://dl.acm.org/doi/pdf/10.1145/3322205.3311088

[25] https://www.cs.ucr.edu/~heng/pubs/sacmat2020.pdf

Name	Description
VPBox, CCS'21[26]	Modify Android Framework for sandboxing via container-based virtualization which uses Linux container tools transplanted to Android or runs another Android OS as guest OS by mounting virtual file system and runtime. Different from app-level virtualization where host app provides virtualization on top of the Android framework and create system service proxies to intercept messages. The host app has to hook the API invocations of the guest app so that the Android system thinks that all API requests are from the host apps, leaving host app's signatures in the guest app's call stack and memory.
Condroid, MobileCloud2015[27]	OS-level virtualization using containers by modifying Android Framework (virtual Binder IPC mechanisms) Runs containers which are virtual machines running an isolated Android system with pre-installed apps. Android framework inside the Android systems inside the containers are modified. Linux kernel reconfigured to enable cgroups, namespace features, creating virtual devices and virtual device drivers. Android Framework of host Android system modified to cooperate with the containers. LXC tools transplanted from Linux to Android runtime environment for creating and managing containers.

Table 7.5: Papers concerning App-virtualization

[26] https://par.nsf.gov/servlets/purl/10327186

[27] http://arc.zju.edu.cn/_upload/article/files/d9/bd/a5f57e3a4143b907382976333a87/d086a9aa-13c0-4261-9109-b63686c62c97.pdf

Chapter 8

June

8.1 June 10, 2024

8.1.1 Decompile APKs

JADX

First Decompiler to try is JADX[1].

Need to install JDK11:

```
sudo apt install openjdk-11-jdk
update-java-alternatives --list
sudo update-alternatives --config java
```

Do not install JRE `sudo apt install openjdk-11-jre-headless`, as it is not JDK and lack some development library.

APK Tool[2]

Dex2Jar[3]

8.1.2 Repackaging Attack

Extract APK from Installed App

Download and install Screen Logger APK[4]:

```
adb install Screen\ Logger_1.1_APKPure.apk
```

After installation, grant requested permissions to the Screen Logger app for it to run properly.

Install DBS mobile banking application from Google Playstore, and extract its APK:

[1] https://github.com/skylot/jadx

[2] https://github.com/iBotPeaches/Apktool

[3] https://github.com/pxb1988/dex2jar

[4] https://apkpure.com/screen-logger/com.wultra.app.screenlogger/download

```
adb shell pm list packages -f -3
adb pull /data/app/~~VDIXkSOBT9AdrdsivBoitg==/com.dbs.sg.dbsmbanking-
    b3QDPSklmc7YrFj8nO2hHA==/base.apk
```

Safeguards

Emulator Detection logic[5] in OCBC app:

```
public class Validation {
    public static boolean isEmulator() {
        String str = Build.FINGERPRINT;
        if (!str.startsWith("generic") && !str.startsWith("unknown")) {
            String str2 = Build.MODEL;
            if (!str2.contains("google_sdk") && !str2.contains("Emulator") && !
                str2.contains("Android␣SDK␣built␣for␣x86") && !Build.MANUFACTURER.
                contains("Genymotion") && ((!Build.BRAND.startsWith("generic") ||
                !Build.DEVICE.startsWith("generic")) && !"google_sdk".equals(Build
                .PRODUCT))) {
                return false;
            }
        }
        return true;
    }
```

Root check when loading OneTouchActivity:

```
public boolean isRooted() {
    if (!Validation.isRooted(this)) {
        return false;
    }
    new AlertDialog.Builder(this).setTitle("").setMessage(getString(R.string.
        message_no_root_support)).setCancelable(false).setPositiveButton("OK", new
         DialogInterface.OnClickListener() { // from class: com.ocbc.mdt.onetouch.
        activity.OneTouchActivity.3
        @Override // android.content.DialogInterface.OnClickListener
        public void onClick(DialogInterface dialogInterface, int i11) {
            OneTouchActivity.this.finish();
            Process.killProcess(Process.myPid());
        }
    }).show();
    return true;
}
```

`String` constant that stores the warning message:

```
public static final String DEFAULT_ROOT_MSG_SG = "We␣cannot␣proceed␣with␣OCBC␣
    mobile␣banking␣as␣we␣suspect␣your␣device␣is␣'jail␣broken',␣'rooted'␣or␣running
    ␣a␣non-compatible␣operating␣system.␣This␣leaves␣you␣vulnerable␣to␣fraud␣
    attacks.␣Please␣login␣to␣www.ocbc.com␣to␣continue␣banking.";
```

Root detection checks for multiple condtions to be true:

```
public boolean n() {
    return j() || h() || b("su") || c() || e() || l() || g() || f() || d();
}
```

One of the Root detection logic uses RootBeer[6]:

[5] https://ray-chong.medium.com/android-emulator-detection-4d0f994aab5e
[6] https://github.com/scottyab/rootbeer

```
public boolean f() {
    if (!a()) {
        n50.a.a("We␣could␣not␣load␣the␣native␣library␣to␣test␣for␣root");
        return false;
    }
    int length = a.f55724d.length;
    String[] strArr = new String[length];
    for (int i11 = 0; i11 < length; i11++) {
        strArr[i11] = a.f55724d[i11] + "su";
    }
    RootBeerNative rootBeerNative = new RootBeerNative();
    try {
        rootBeerNative.setLogDebugMessages(this.f55727b);
        return rootBeerNative.checkForRoot(strArr) > 0;
    } catch (UnsatisfiedLinkError unused) {
        return false;
    }
}
```

8.2 June 17, 2024

8.2.1 Virtualization-based Attack

How to hook an API?

Dynamic Proxy API in Java for creating dynamic proxy of a class of instance using Proxy Design Pattern. Use reflection to hook them.

Using Parallel Space? Request wrappers collect virtualized app's requests and send it to the framework. UID, PID all encapsulated, thus circumventing sandboxing. Malware can be installed in the virtualization framework together with the target app and can access the app data without violating Android security policy.

All the virtualized apps inherit the same permissions as the virtualization platform. Thus, the framework need to implement the Android security model as well.

Penetration Test:

- **Permission Access:** Access dangerous permissions such as `ACCESS_FINE_GRAINED_LOCATION`, `SEND_SMS`, `CONTENT_PROVIDER_ACCESS` that are inherited from the virtualization platform.
- **Internal Storage:** Access directory `/data/data/Parallel_Space/victim_app`
- **Private App Component:** Content providers that uses databases to store
- **System Services:**
- **Shell Command:**
- **Socket:**

- **Privilege Escalation:**
- **Code injection:**
- **Randsomeware:**
- **Phishing:**
- **Clone:**
- **Antivirus evasion:**
- **Hijacking:**

Host app (Parallel space) has launcher, hook module (communicates with Host app through IPC calls to intercept interactions between guest apps and system services) and virtualization framework (emulates core system services by implementing virtual system serices that relays communication to actual system services).

What API to hook?

8.2.2 Why does debloating doesn't work anymore after relaunching?

Hyptothesis 1: Some thing is enabling JIT/AOT

Find anything that's enabling compilation, like setting filter/profile to `speed` or `speed-profile` using:

```
clear && find ./frameworks/ ./art/ ./bionic/ ./device/ ./build/ ./libnativehelper
    \( -iname '*.java' -o -iname '*.cpp' -o -iname '*.cc' -o -iname '*.hpp' -o -
    iname '*.h' -o -iname '*.S' -o -iname '*.mk' \) -a ! -iname '*test*' -a ! -
    iname '*out*' | xargs grep --color -sin 'speed-profile'
```

Hypothesis 2: Understand the change in AOT/JIT process from AOSP 13 to 14

Find anything changes related to JIT/AOT using:

```
cd AOSP13\ vs\ AOSP14/
clear && find ./frameworks/ ./art/ ./bionic/ ./device/ ./build/ | xargs grep --
    color -sin 'jit'
```

I know that these files are only the files that have been touched by Zicheng. But we can start from here which has a relatively small search space.

Check JIT Code Caching

All procedures assocated with JIT:

Procedure	Description
runtime/interpreter/interpreter.cc	
Execute	
runtime/entrypoints/quick/quick_trampoline_entrypoints.cc	
artQuickGenericJniTrampoline	
runtime/jit/jit.cc	
Jit::MethodEntered	
Jit::CompileMethod	
Jit::CompileMethodFromProfile	
JitCompileTask::Run	
Jit::CompileMethodInternal	
compiler/jit/jit_compiler.cc	
JitCompiler::CompileMethod	
compiler/optimizing/optimizing_compiler.cc	
OptimizingCompiler::JitCompile	
runtime/jit/jit.cc	
JIT::MethodEntered	
runtime/jit/jit-inl.h	
JIT::AddSamples	
runtime/instrumentation.cc	
Instrumentation::BranchImpl	Inform listeners that a branch has been taken (only supported by the interpreter)
runtime/instrumentation.h	
Branch	Inform listeners that a branch has been taken (only supported by the interpreter)

Table 8.1: JIT Procedures

Found out that there's an entry from quick everytime the ontextchange is called:

```
1 06-25 18:56:05.997  1373  2207 I putmethod.latin: [WEIMINN]
      quick_trampoline_entrypoints.cc::artQuickGenericJniTrampoline | Entered: void
      com.android.inputmethod.latin.BinaryDictionary.getSuggestionsNative(long, long
      , long, int[], int[], int[], int[], int[], int, int[], int[][], boolean[], int
      , int[], int[], int[], int[], int[], int[], float[])
2 06-25 18:56:05.998  1373  2207 I putmethod.latin: [WEIMINN]
      quick_trampoline_entrypoints.cc::artQuickGenericJniTrampoline | Entered: void
      com.android.inputmethod.latin.BinaryDictionary.getSuggestionsNative(long, long
      , long, int[], int[], int[], int[], int[], int, int[], int[][], boolean[], int
      , int[], int[], int[], int[], int[], int[], float[])
3 06-25 18:56:05.998  1373  2207 I putmethod.latin: [WEIMINN]
      quick_trampoline_entrypoints.cc::artQuickGenericJniTrampoline | Entered:
      boolean com.android.inputmethod.latin.BinaryDictionary.isCorruptedNative(long)
4 06-25 18:56:05.998  1373  2207 I putmethod.latin: [WEIMINN]
      quick_trampoline_entrypoints.cc::artQuickGenericJniTrampoline | Entered: void
      com.android.inputmethod.latin.BinaryDictionary.getSuggestionsNative(long, long
```

```
    , long, int[], int[], int[], int[], int[], int, int[], int[][], boolean[], int
    , int[], int[], int[], int[], int[], int[], float[])
06-25 18:56:05.998  1373  2207 I putmethod.latin: [WEIMINN]
    quick_trampoline_entrypoints.cc::artQuickGenericJniTrampoline | Entered:
    boolean com.android.inputmethod.latin.BinaryDictionary.isCorruptedNative(long)
```

Need to find the entry point of JIT and AOT invocations

8.2.3 Comprehensive Method Invocation Flow in AOSP 14

8.2.4 Comprehensive Code Compilation Flow in AOSP 14

8.2.5 Bionic Flow

8.2.6 Prepare Technical Document on Debloating

8.2.7 Learn Binder IPC Flow

8.2.8 Learn Package Manager Flow

8.2.9 Learn Permission Manager Flow