B(l)utter

Reversing Flutter Application by using Dart Runtime

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Agenda

- What is Flutter Application?
- Reverse Engineering Challenges
- Building Dart (AOT) Runtime for Reversing
- Getting Information from Dart Snapshot
- Intro to Dart Internal (ARM64)
- Dumping Objects at Runtime with Frida

whoami

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- Security Researcher
- Working for Datafarm Co., Ltd.
- Public exploits and tools on
  - https://github.com/worawit

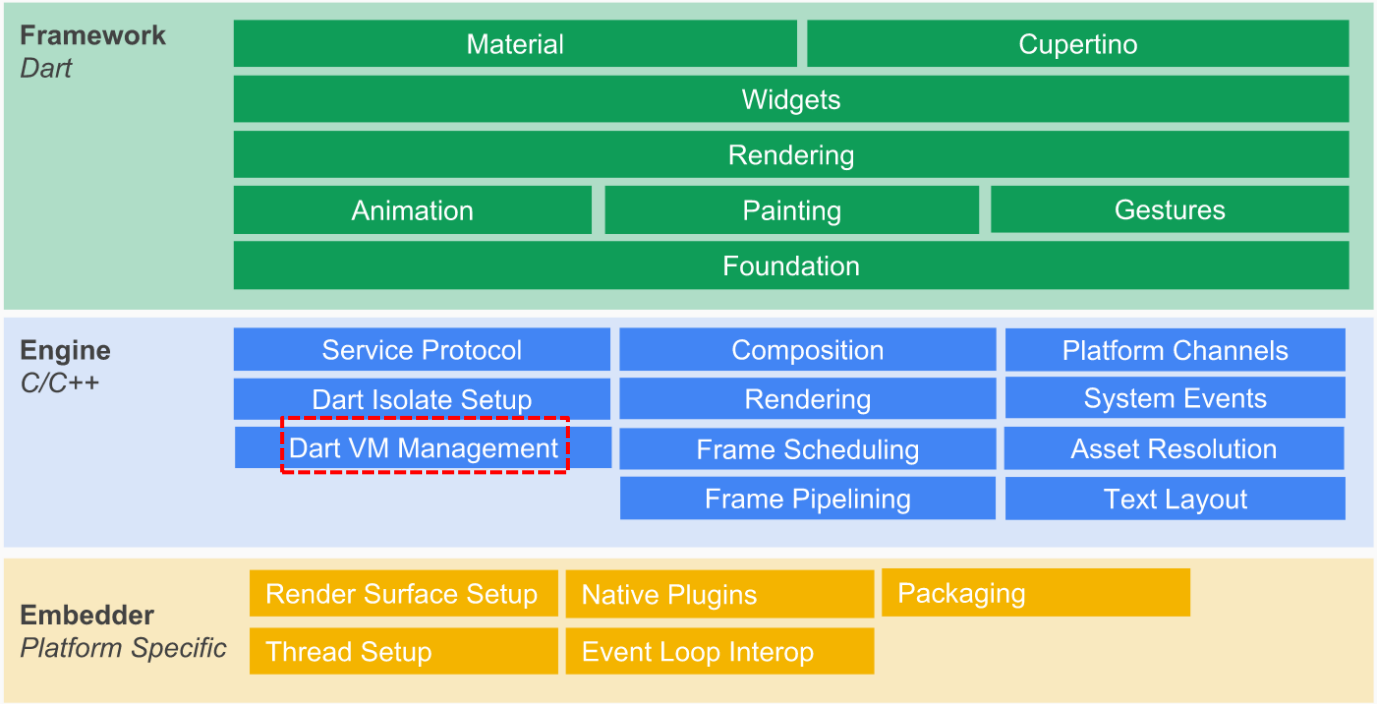
What is Flutter Application?

What is Flutter?

- Flutter is an open source framework by Google
  - For building beautiful, natively compiled, multi-platform applications from a single codebase
- Flutter code is powered by Dart platform
- Flutter app developers write code in Dart Language

```
void main() {
  if (Random().nextInt(1) == 1) print(devConfig.url);
  final config = kReleaseMode ? prodConfig : devConfig;
  print(URLController._endpoint);
  print(URLController.login);
  print(config.url);
}
```

Flutter Architectural Overview

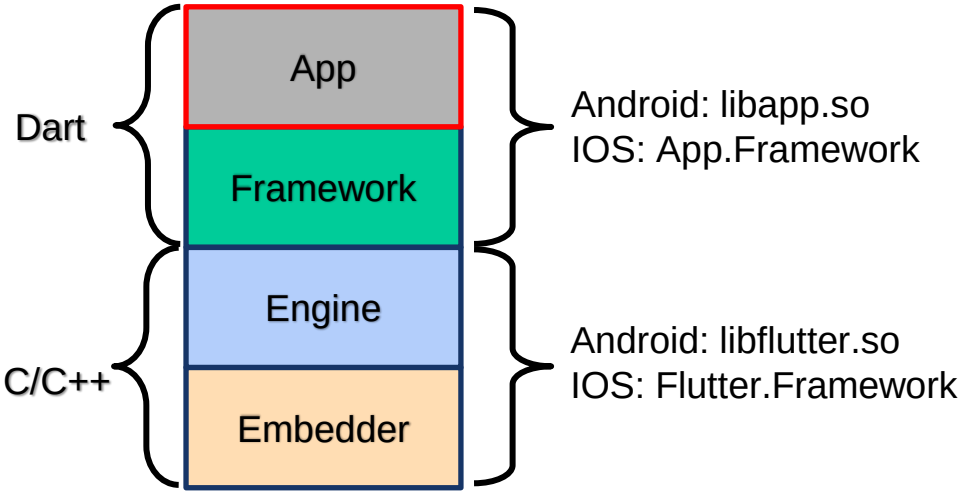


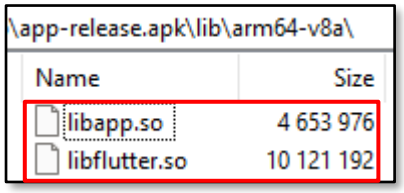
Ref: https://raw.githubusercontent.com/flutter/engine/main/docs/flutter_overview.svg

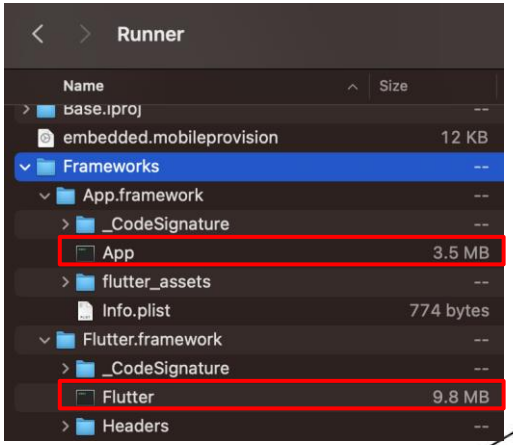
Scope of This Talk

- Target only Mobile Application (Android, iOS)
- ARM64 architecture only
- Release build only
  - Symbols are stripped
  - Full optimization

Flutter Mobile App in Installer Package







Flutter Mobile Application

- Use Dart Ahead-Of-Time (AOT) compiler
  - for producing machine code (in release build)
- The AOT-compiled code still runs inside a Dart VM
  - Precompiled runtime (a stripped version of Dart VM)
- The code and data are serialized into a binary snapshot

```
sub_26EFF8                              ; CODE XREF: sub_26DB54+48↑p
                STP             X29, X30, [X15,#-0x10]!
                MOV             X29, X15
                SUB             X15, X15, #0x28 ; '('
                STUR            X22, [X29,#-8]
                LDR             X16, [X26,#0x38]
                CMP             X15, X16
                B.LS            loc_26F0E8

loc_26F014                              ; CODE XREF: sub_26EFF8+F4↓j
                ADD             X0, X27, #0xE,LSL#12
                LDR             X0, [X0,#0x530]
                BL              sub_19FAEC
                LDR             X0, [X26,#0x68]
                LDR             X0, [X0,#0x1650]
                LDR             X16, [X27,#0x28]
                CMP             W0, W16
                B.NE            loc_26F03C
                LDR             X2, [X27,#0x43E8]
                BL              sub_44BB44
```

Dart Snapshot

- Serialized state of the Dart VM at a specific point in its execution
- A Dart snapshot is taken just before calling main

```
$ objdump -T libapp.so

libapp.so:     file format elf64-little

DYNAMIC SYMBOL TABLE:
0000000000180000 g    DO .text  0000000000005ce0 _kDartVmSnapshotInstructions
0000000000185d00 g    DO .text  00000000002e6500 _kDartIsolateSnapshotInstructions
0000000000000200 g    DO .rodata        0000000000003b30 _kDartVmSnapshotData
0000000000003d40 g    DO .rodata        0000000000017b720 _kDartIsolateSnapshotData
00000000000001c8 g    DO .note.gnu.build-id     0000000000000020 _kDartSnapshotBuildId
```

```
$ llvm-objdump-15 --macho -t App
App:

SYMBOL TABLE:
00000000001de740 g     O __TEXT,__const _kDartIsolateSnapshotData
000000000000d500 g     F __TEXT,__text _kDartIsolateSnapshotInstructions
00000000001d6200 g     O __TEXT,__const _kDartVmSnapshotData
0000000000007a00 g     F __TEXT,__text _kDartVmSnapshotInstructions
```

Problems

Problem 1: Parsing Dart Snapshots

- Universal parser for Dart snapshots cannot be written
  - Dart is constantly evolving
  - The format of snapshots keeps changing
- The snapshot deserialization code is in Dart VM
  - Always included in an installer package
  - Check if the deserializing snapshot is a same version (from hash)
- Known public Dart snapshot parsers
  - Doldrums - https://github.com/rscloura/Doldrums
  - darter - https://github.com/mildsunrise/darter
- Both tools do not work with new Dart versions
  - Updating parser take times

Problem 2: Analyzing Dart (ABI) Code

- Use general purpose registers as special purpose
  - ARM64 R15 -> Dart VM stack pointer
  - ARM64 R27 -> Object pool pointer
  - ...
- Use pool pointer to access object pool
  - No direct references to static data
- Custom calling convention
- Utilize Dart VM functions by calling Dart Stubs
  - Dart stubs are entry points for entering Dart VM from compiled code
- Inline Dart Stubs

Register Usages on ARM64

```
// Register aliases.
const Register TMP = R16;  // Used as scratch register by assembler.
const Register TMP2 = R17;
const Register PP = R27;  // Caches object pool pointer in generated code.
const Register DISPATCH_TABLE_REG = R21;  // Dispatch table register.
const Register CODE_REG = R24;
// Set when calling Dart functions in JIT mode, used by LazyCompileStub.
const Register FUNCTION_REG = R0;
const Register FPREG = FP;          // Frame pointer register.
const Register SPREG = R15;         // Stack pointer register.
const Register IC_DATA_REG = R5;    // ICData/MegamorphicCache register.
const Register ARGS_DESC_REG = R4;  // Arguments descriptor register.
const Register THR = R26;           // Caches current thread in generated code.
const Register CALLEE_SAVED_TEMP = R19;
const Register CALLEE_SAVED_TEMP2 = R20;
const Register HEAP_BITS = R28;  // write_barrier_mask << 32 | heap_base >> 32
const Register NULL_REG = R22;   // Caches NullObject() value.
#define DART_ASSEMBLER_HAS_NULL_REG 1

// ABI for catch-clause entry point.
const Register kExceptionObjectReg = R0;
const Register kStackTraceObjectReg = R1;
```

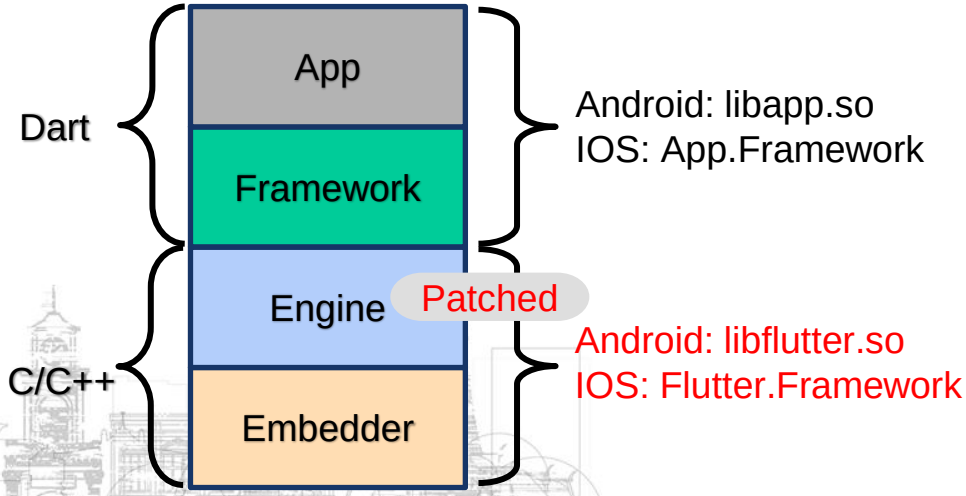
From <dart_v3.0.3>/runtime/vm/constants_arm64.h

Previous Public Works

- reFlutter
  - https://github.com/Impact-I/reFlutter
  - https://swarm.ptsecurity.com/fork-bomb-for-flutter/
- flutter-re-demo
  - https://github.com/Guardsquare/flutter-re-demo
  - https://www.guardsquare.com/blog/current-state-and-future-of-reversing-flutter-apps
- Andre Lipke's Blog
  - https://blog.tst.sh/reverse-engineering-flutter-apps-part-1/
- Introduction to Dart VM
  - https://mrale.ph/dartvm/

reFlutter Approach

- Patch the Dart Runtime source code to dump a snapshot information while launching an application
  - To avoid writing snapshots parser
- Recompile the flutter engine



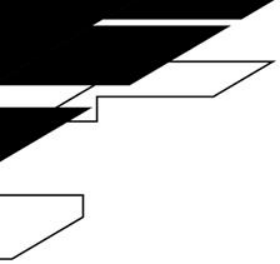
reFlutter Limitation

- Very difficult to develop and debug patched code
  - Hinder the further code analysis development
- Recompiling consumes a lot of resources
  - Disk, CPU
  - Time
- An application must be repackaged and executed

The Idea

- We only want snapshot deserialization functions
- The functions are only in Dart Runtime

- Can we build Dart SDK as library?



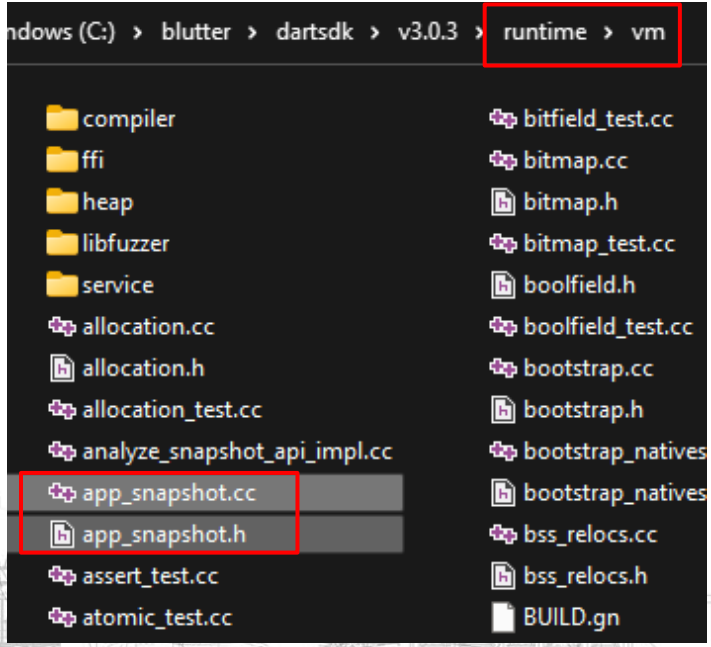
Building Dart Runtime

First Attempt: Building Dart SDK (Failed)

- Following the steps in the Dart wiki page
- Building Dart SDK requires Google's depot tools
- The tools will fetch all dependencies
  - fetch dart
- The final source code size is >10GB
  - Not good if we have to build multiple versions of Dart Runtime
- The built command builds too many binaries
  - Take times and disk space

Minimize Build to Dart Runtime Only

- Focus on files only in runtime/vm directory




```
c:\blutter\dartsdk\v3.0.3\runtime\vm>rg -v "^#" vm_sources.gni
4:
7:vm_sources = [
8:  "allocation.cc",
9:  "allocation.h",
10:  "app_snapshot.cc",
11:  "app_snapshot.h",
12:  "base64.cc",
13:  "base64.h",
14:  "base_isolate.h",
15:  "bit_vector.cc",
16:  "bit_vector.h",
17:  "bitfield.h",
18:  "bitmap.cc",
19:  "bitmap.h",
20:  "boolfield.h",
21:  "bootstrap.h",
22:  "bootstrap_natives.cc",
```

Minimize Build to Dart Runtime Only

- Create our own CMakeLists.txt
- The defined macros from
  - Generated build files of previous failed attempt
- The source and header files from
  - Parsing the Google's build script
  - Listing all source file in a subdirectory
  - Adding the missing source files manually (after compiling errors)
- The 3rd party library from
  - Linking error message (only ICU)
  - Use a precompiled one

The Build Result

- Dart SDK clone directory with git sparse checkout
  - Size <100MB
- Building time
  - Less than 5 minutes on my laptop
- Dart Runtime as static library on Windows
  - Size ~20MB
- The target OS and architecture can be selected from
  - DART_TARGET_OS_ANDROID, DART_TARGET_OS_MACOS_IOS
  - TARGET_ARCH_ARM64, TARGET_ARCH_X64
- No source code patching

```
C:\blutter>prompt $d$t$_$P$G

Wed 08/16/2023 8:44:10.64
C:\blutter>python dartvm_fetch_build.py 3.0.6 android arm64
Cloning into 'C:\data\work\blutter\dartsdk\v3.0.6'...
remote: Enumerating objects: 2446, done.
remote: Counting objects: 100% (2446/2446), done.
remote: Compressing objects: 100% (2003/2003), done.
Receiving objects:  97% (2373/2446), 724.00 KiB | 1.19 MiB/sremote: Total 2446 (delta 78), reused 1332 (delta 47), pack-
Receiving objects:  99% (2422/2446), 724.00 KiB | 1.19 MiB/s
Receiving objects: 100% (2446/2446), 1.46 MiB | 2.03 MiB/s, done.
Resolving deltas: 100% (78/78), done.
remote: Enumerating objects: 23, done.
remote: Counting objects: 100% (23/23), done.
remote: Compressing objects: 100% (22/22), done.
Receiving objects:  86% (20/23)sed 7 (delta 0), pack-reused 0Receiving objects:  78% (18/23)
Receiving objects: 100% (23/23), 127.81 KiB | 1.29 MiB/s, done.
Updating files: 100% (23/23), done.
```

Start fetching and compiling Dart Runtime

```
-- Installing: C:/data/work/blutter/dartsdk/v3.0.6/../../packages/lib/cmake/dartvm3.0.6_android_arm64/dartvm3.0.6_androi
d_arm64Config.cmake
-- Installing: C:/data/work/blutter/dartsdk/v3.0.6/../../packages/lib/cmake/dartvm3.0.6_android_arm64/dartvm3.0.6_androi
d_arm64ConfigVersion.cmake

Wed 08/16/2023 8:46:16.77
C:\blutter>
Wed 08/16/2023 8:46:42.08
C:\blutter>dir packages\lib\*.lib
 Volume in drive C is Windows
 Volume Serial Number is 28E6-5A7D

 Directory of C:\blutter\packages\lib

08/14/2023  09:02 AM        21,276,052 dartvm3.0.3_android_arm64.lib
08/16/2023  08:46 AM        21,276,074 dartvm3.0.6_android_arm64.lib
```

Finished compiling Dart Runtime

Dart Runtime Static Library

Getting Information from Dart Snapshot

Using Dart Runtime Internal API

- To access all loaded information in detail
  - Then fill the information into machine code
- Read Dart SDK source code
  - To learn how to use Internal API
- Use only public class methods
  - Their interfaces should not be changed in a new Dart version

Loading Dart Snapshot

```
char* error = NULL;
Dart_InitializeParams init_params = { 0 };
init_params.version = DART_INITIALIZE_PARAMS_CURRENT_VERSION;
init_params.vm_snapshot_data = vm_snapshot_data;
init_params.vm_snapshot_instructions = vm_snapshot_instructions;
init_params.start_kernel_isolate = false;
// other params are no needed if snapshot is not run
error = Dart_Initialize(&init_params);

Dart_IsolateFlags flags;
Dart_IsolateFlagsInitialize(&flags);
flags.is_system_isolate = false;
flags.snapshot_is_dontneed_safe = true;
flags.null_safety = true;
auto isolate = Dart_CreateIsolateGroup(nullptr, nullptr,
  isolate_snapshot_data, isolate_snapshot_instructions,
  &flags, nullptr, nullptr, &error);
```

Getting Classes

```
auto table = dart::Isolate::Current()->group()->class_table();
auto& library = dart::Library::Handle();
auto& cls = dart::Class::Handle();

// load from class table
for (intptr_t i = 0; i < table->NumCids(); i++) {
    auto clsPtr = table->At(i);
    if (clsPtr == nullptr)
        continue;

    cls = clsPtr;
    library = cls.library();
    // ...
}
```

Getting Stubs

- Dart Runtime helper functions
- The symbol names are not in the Dart Snapshot
  - They are in Dart Runtime source code

```
#define OBJECT_STORE_STUB_CODE_LIST(DO)                                        \
  DO(dispatch_table_null_error_stub, DispatchTableNullError)                   \
  DO(late_initialization_error_stub_with_fpu_regs_stub,                        \
     LateInitializationErrorSharedWithFPURegs)                                 \
  DO(late_initialization_error_stub_without_fpu_regs_stub,                     \
     LateInitializationErrorSharedWithoutFPURegs)                              \
  DO(null_error_stub_with_fpu_regs_stub, NullErrorSharedWithFPURegs)           \
```

From <dart_v3.0.3>/runtime/vm/object_store.h

```
#define DO(member, name) \
  ptr = store->member(); \
  code = ptr; \
  ep_addr = code.EntryPoint(); \
  stub = new DartStub(ptr, DartStub::name ## Stub, ep_addr, code.Size(), #name); \
  stubs[ep_addr] = stub;
OBJECT_STORE_STUB_CODE_LIST(DO);
```

```
static _ globalContext(/* No info */) async {
  // ** addr: 0x26eff8, size: 0xf8
  // 0x26eff8: stp  x29, x30, [x15, #-0x10]!
  // 0x26effc: mov  x29, x15
  // 0x26f000: sub  x15, x15, #0x28
  // 0x26f004: stur  x22, [x29, #-8]
  // 0x26f008: ldr  x16, [x26, #0x38]
  // 0x26f00c: cmp  x15, x16
  // 0x26f010: b.ls  #0x26f0e8
  // 0x26f014: add  x0, x27, #0xe, lsl #12
  // 0x26f018: ldr  x0, [x0, #0x530]
  // 0x26f01c: bl  #0x19faec  ; InitAsyncStub
  // 0x26f020: ldr  x0, [x26, #0x68]
  // 0x26f024: ldr  x0, [x0, #0x1650]
  // 0x26f028: ldr  x16, [x27, #0x28]
  // 0x26f02c: cmp  w0, w16
  // 0x26f030: b.ne  #0x26f03c
  // 0x26f034: ldr  x2, [x27, #0x43e8]
  // 0x26f038: bl  #0x44bb44  ; InitLateFinalStaticFieldStub
  // 0x26f03c: stur  x0, [x29, #-0x10]
  // 0x26f040: add  x16, x27, #0xe, lsl #12
  // 0x26f044: ldr  x16, [x16, #0x538]
  // 0x26f048: stp  x16, x0, [x15]
  // 0x26f04c: bl  #0x26f198  ; [package:flutter/src/services/asset_bundle.dart] PlatformAssetBundle::load
```

Object Pool (PP)

- Global constant objects
  - Also includes immediates and addresses
- Strings are immutable (constants)

```
[pp+0x3a38] Null
[pp+0x3a40] String: " in type cast"
[pp+0x3a48] TypeArguments: <_TraversalSortNode>
[pp+0x3a50] Function: [dart:ui] Image::_image (0x40f384)
[pp+0x3a58] TypeArguments: <_BoxEdge>
[pp+0x3a60] IMM: double(0.1) from 0x3fb999999999999a
[pp+0x3a68] TypeArguments: <_SemanticsSortGroup>
[pp+0x3a70] AnonymousClosure: static (0x40fdec), in [package:flutter/src/semantics
[pp+0x3a78] Type: _BoxEdge
[pp+0x3a80] Null
[pp+0x3a88] String: " in type cast"
[pp+0x3a90] Obj!TextDirection@405381 : {
  Super!_Enum : {
    off_8: int(0x0),
    off_10: "rtl"
  }
}
```

```
static _ globalContext(/* No info */) async {
  // ** addr: 0x26eff8, size: 0xf8
  // 0x26eff8: stp  x29, x30, [x15, #-0x10]!
  // 0x26effc: mov  x29, x15
  // 0x26f000: sub  x15, x15, #0x28
  // 0x26f004: stur  x22, [x29, #-8]
  // 0x26f008: ldr  x16, [x26, #0x38]
  // 0x26f00c: cmp  x15, x16
  // 0x26f010: b.ls  #0x26f0e8
  // 0x26f014: add  x0, x27, #0xe, lsl #12  ; [pp+0xe530] TypeArguments: <SecurityContext>
  // 0x26f018: ldr  x0, [x0, #0x530]
  // 0x26f01c: bl  #0x19faec  ; InitAsyncStub
  // 0x26f020: ldr  x0, [x26, #0x68]
  // 0x26f024: ldr  x0, [x0, #0x1650]
  // 0x26f028: ldr  x16, [x27, #0x28]  ; [pp+0x28] Sentinel
  // 0x26f02c: cmp  w0, w16
  // 0x26f030: b.ne  #0x26f03c
  // 0x26f034: ldr  x2, [x27, #0x43e8]  ; [pp+0x43e8] Field <::.rootBundle>: static late final (offset: 0x
  // 0x26f038: bl  #0x44bb44  ; InitLateFinalStaticFieldStub
  // 0x26f03c: stur  x0, [x29, #-0x10]
  // 0x26f040: add  x16, x27, #0xe, lsl #12  ; [pp+0xe538] "assets/certs/server.pem"
  // 0x26f044: ldr  x16, [x16, #0x538]
  // 0x26f048: stp  x16, x0, [x15]
  // 0x26f04c: bl  #0x26f198  ; [package:flutter/src/services/asset_bundle.dart] PlatformAssetBundle::load
```

Dart Thread Offsets

- List of VM-global objects/addresses cached in each Dart Thread object
- Many objects are accessed through Dart Thread object
- The names are not in the Dart Snapshot

```
#define DEFINE_OFFSET_INIT(type_name, member_name, expr, default_init_value) \
  threadOffsetNames[dart::Thread::member_name##offset()] = #member_name;
  CACHED_CONSTANTS_LIST(DEFINE_OFFSET_INIT);
#undef DEFINE_OFFSET_INIT

#define DEFINE_OFFSET_INIT(name) \
  threadOffsetNames[dart::Thread::name##_entry_point_offset()] = #name;
  RUNTIME_ENTRY_LIST(DEFINE_OFFSET_INIT);
#undef DEFINE_OFFSET_INIT
```

```
static _ globalContext(/* No info */) async {
  // ** addr: 0x26eff8, size: 0xf8
  // 0x26eff8: stp  x29, x30, [x15, #-0x10]!
  // 0x26effc: mov  x29, x15
  // 0x26f000: sub  x15, x15, #0x28
  // 0x26f004: stur  x22, [x29, #-8]
  // 0x26f008: ldr  x16, [x26, #0x38]  ; THR::stack_limit
  // 0x26f00c: cmp  x15, x16
  // 0x26f010: b.ls  #0x26f0e8
  // 0x26f014: add  x0, x27, #0xe, lsl #12  ; [pp+0xe530] TypeArguments: <SecurityContext>
  // 0x26f018: ldr  x0, [x0, #0x530]
  // 0x26f01c: bl  #0x19faec  ; InitAsyncStub
  // 0x26f020: ldr  x0, [x26, #0x68]  ; THR::field_table_values
  // 0x26f024: ldr  x0, [x0, #0x1650]
  // 0x26f028: ldr  x16, [x27, #0x28]  ; [pp+0x28] Sentinel
  // 0x26f02c: cmp  w0, w16
  // 0x26f030: b.ne  #0x26f03c
  // 0x26f034: ldr  x2, [x27, #0x43e8]  ; [pp+0x43e8] Field <::.rootBundle>: static late final (offset: 0x
  // 0x26f038: bl  #0x44bb44  ; InitLateFinalStaticFieldStub
  // 0x26f03c: stur  x0, [x29, #-0x10]
  // 0x26f040: add  x16, x27, #0xe, lsl #12  ; [pp+0xe538] "assets/certs/server.pem"
  // 0x26f044: ldr  x16, [x16, #0x538]
  // 0x26f048: stp  x16, x0, [x15]
  // 0x26f04c: bl  #0x26f198  ; [package:flutter/src/services/asset_bundle.dart] PlatformAssetBundle::load
```

Before

```
sub_26EFF8                              ; CODE XREF: sub_26
                STP             X29, X30, [X15,#-0x10]!
                MOV             X29, X15
                SUB             X15, X15, #0x28 ; '('
                STUR            X22, [X29,#-8]
                LDR             X16, [X26,#0x38]
                CMP             X15, X16
                B.LS            loc_26F0E8

loc_26F014                              ; CODE XREF: sub_26
                ADD             X0, X27, #0xE,LSL#12
                LDR             X0, [X0,#0x530]
                BL              sub_19FAEC
                LDR             X0, [X26,#0x68]
                LDR             X0, [X0,#0x1650]
                LDR             X16, [X27,#0x28]
                CMP             W0, W16
                B.NE            loc_26F03C
                LDR             X2, [X27,#0x43E8]
                BL              sub_44BB44
```

After

```
static _ globalContext(/* No info */) async {
  // ** addr: 0x26eff8, size: 0xf8
  // 0x26eff8: stp  x29, x30, [x15, #-0x10]!
  // 0x26effc: mov  x29, x15
  // 0x26f000: sub  x15, x15, #0x28
  // 0x26f004: stur  x22, [x29, #-8]
  // 0x26f008: ldr  x16, [x26, #0x38]  ; THR::stack_limit
  // 0x26f00c: cmp  x15, x16
  // 0x26f010: b.ls  #0x26f0e8
  // 0x26f014: add  x0, x27, #0xe, lsl #12  ; [pp+0xe530] TypeArguments: <SecurityCo
  // 0x26f018: ldr  x0, [x0, #0x530]
  // 0x26f01c: bl  #0x19faec  ; InitAsyncStub
  // 0x26f020: ldr  x0, [x26, #0x68]  ; THR::field_table_values
  // 0x26f024: ldr  x0, [x0, #0x1650]
  // 0x26f028: ldr  x16, [x27, #0x28]  ; [pp+0x28] Sentinel
  // 0x26f02c: cmp  w0, w16
  // 0x26f030: b.ne  #0x26f03c
  // 0x26f034: ldr  x2, [x27, #0x43e8]  ; [pp+0x43e8] Field <::.rootBundle>: static
  // 0x26f038: bl  #0x44bb44  ; InitLateFinalStaticFieldStub
  // 0x26f03c: stur  x0, [x29, #-0x10]
  // 0x26f040: add  x16, x27, #0xe, lsl #12  ; [pp+0xe538] "assets/certs/server.pem"
  // 0x26f044: ldr  x16, [x16, #0x538]
  // 0x26f048: stp  x16, x0, [x15]
  // 0x26f04c: bl  #0x26f198  ; [package:flutter/src/services/asset_bundle.dart] Pla
```

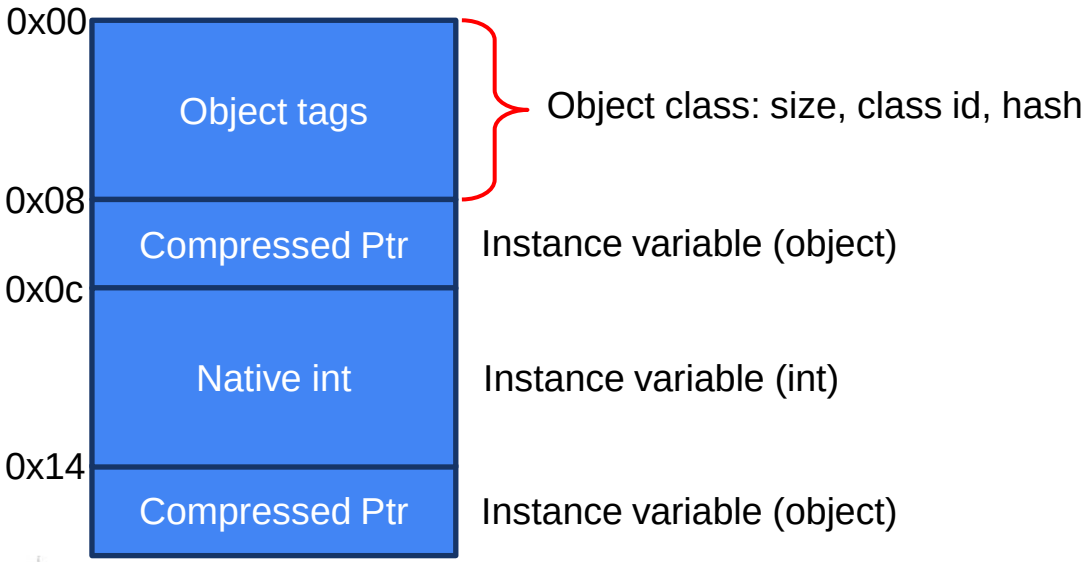
Intro to Dart Internal (ARM64)

Pointer Compression

- Allocate an aligned 4GB region of address space as heap
  - Only lower 32 bits of object pointer is stored in memory
  - Lower memory usage with smaller pointer
  - Not enabled on iOS because it requires an additional application entitlement
- The decompress pointer instruction always be after the loading object instruction

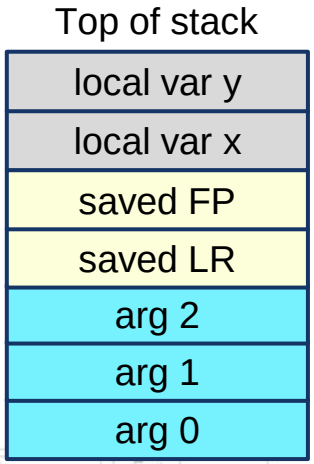
```
ldur  w1, [x0, #7]
add  x1, x1, x28, lsl #32
```

Dart Object Memory Layout (64 bit)



Dart Calling Convention

- Use R15 register as Dart VM Stack Pointer
- All call arguments are stored in Stack
- Store arguments in reversed order from a typical one



Example for stack frame of function with 3 arguments

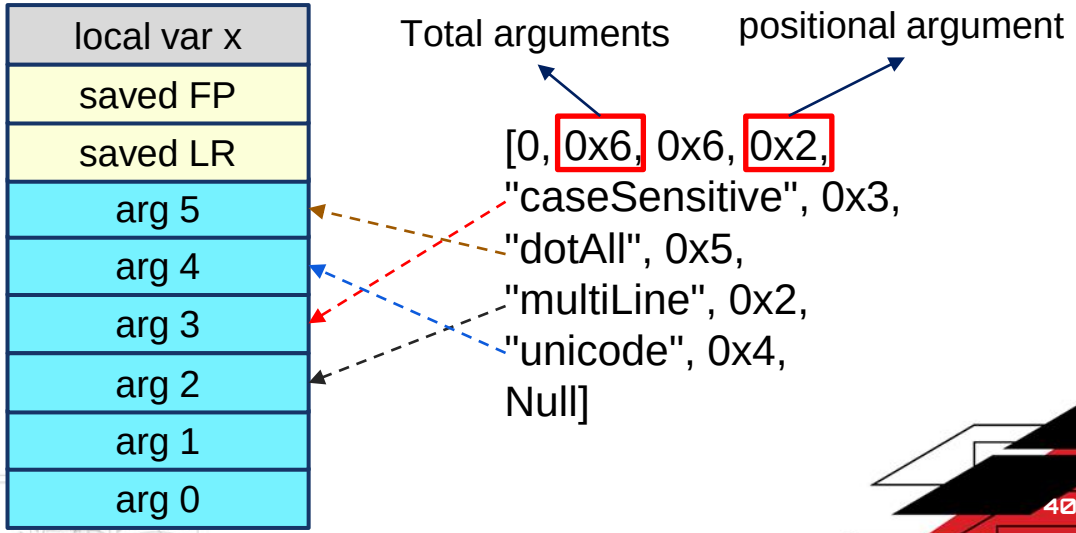
Dart Calling with Named Parameters

- Use R4 register as Arguments Descriptor

```
ldr  x4, [x27, #0x13c8]  ; [pp+0x13c8]
```

RegExp constructor

```
RegExp(
    String source,
    {bool multiLine = false,
    bool caseSensitive = true,
    @Since("2.4") bool unicode = false,
    @Since("2.4") bool dotAll = false}
)
```



Calling Dart Stub

- Use selected registers as Stub arguments
- Most of them are defined in **constants_<arch>.h**
- Some of them is fixed in compiler

```
struct InitStaticFieldABI {
  static const Register kFieldReg = R2;
  static const Register kResultReg = R0;
};

struct AllocateObjectABI {
  static const Register kResultReg = R0;
  static const Register kTypeArgumentsReg = R1;
  static const Register kTagsReg = R2;
};

struct AllocateClosureABI {
  static const Register kResultReg = AllocateObjectABI::kResultReg;
  static const Register kFunctionReg = R1;
  static const Register kContextReg = R2;
  static const Register kScratchReg = R4;
};
```

From <dart_v3.0.3>/runtime/vm/constants_arm64.h

Dump Object with Frida

Frida Hooking

- Auto generating script for accessing Dart objects
  - Target application information such as classes
  - Functions for accessing Dart object in memory
- Current support only dumping an Dart object

```
const ShowNullField = false;
const MaxDepth = 5;

function onLibappLoaded() {
    xxx("remove this line and correct the hook value");
    const fn_addr = 0xdeadbeef;
    Interceptor.attach(libapp.add(fn_addr), {
        onEnter: function () {
            init(this.context);
            let objPtr = getArg(this.context, 0);
            const [tptr, cls, values] = getTaggedObjectValue(objPtr);
            console.log(`${cls.name}@${tptr.toString().slice(2)} =`, JSON.stringify(values, null, 2));
        }
    });
}
```

```
// class id: 183, size: 0x10, field offset: 0x8
class Client extends Object {

  late HttpClient client; // offset: 0x8

  _ post1(/* No info */) async {
    // ** addr: 0x223d24, size: 0x1f4
    // 0x223d24: stp  x29, x30, [x15, #-0x10]!
```

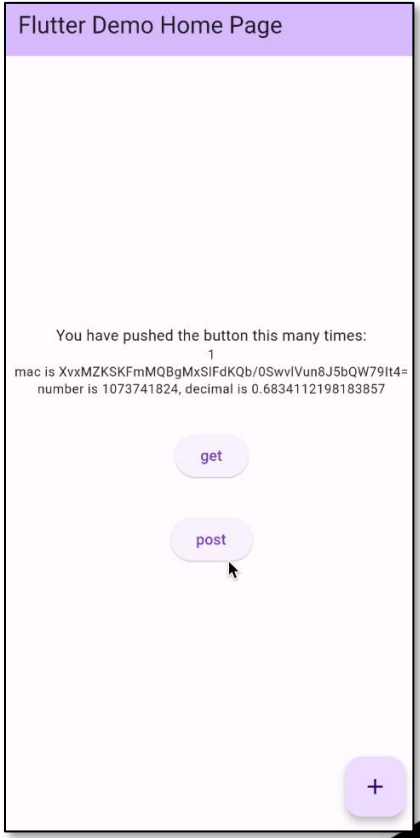
Disassembled code from libapp.so

```
const Client_post1 = 0x223d24;
Interceptor.attach(libapp.add(Client_post1), {
    onEnter: function () {
        init(this.context);
        let objPtr = getArg(this.context, 0);
        const [tptr, cls, values] = getTaggedObjectValue(objPtr);
        console.log(`${cls.name}@${tptr.toString().slice(2)} =`, I
    }
});
```

Frida script for dumping Client.post1 argument

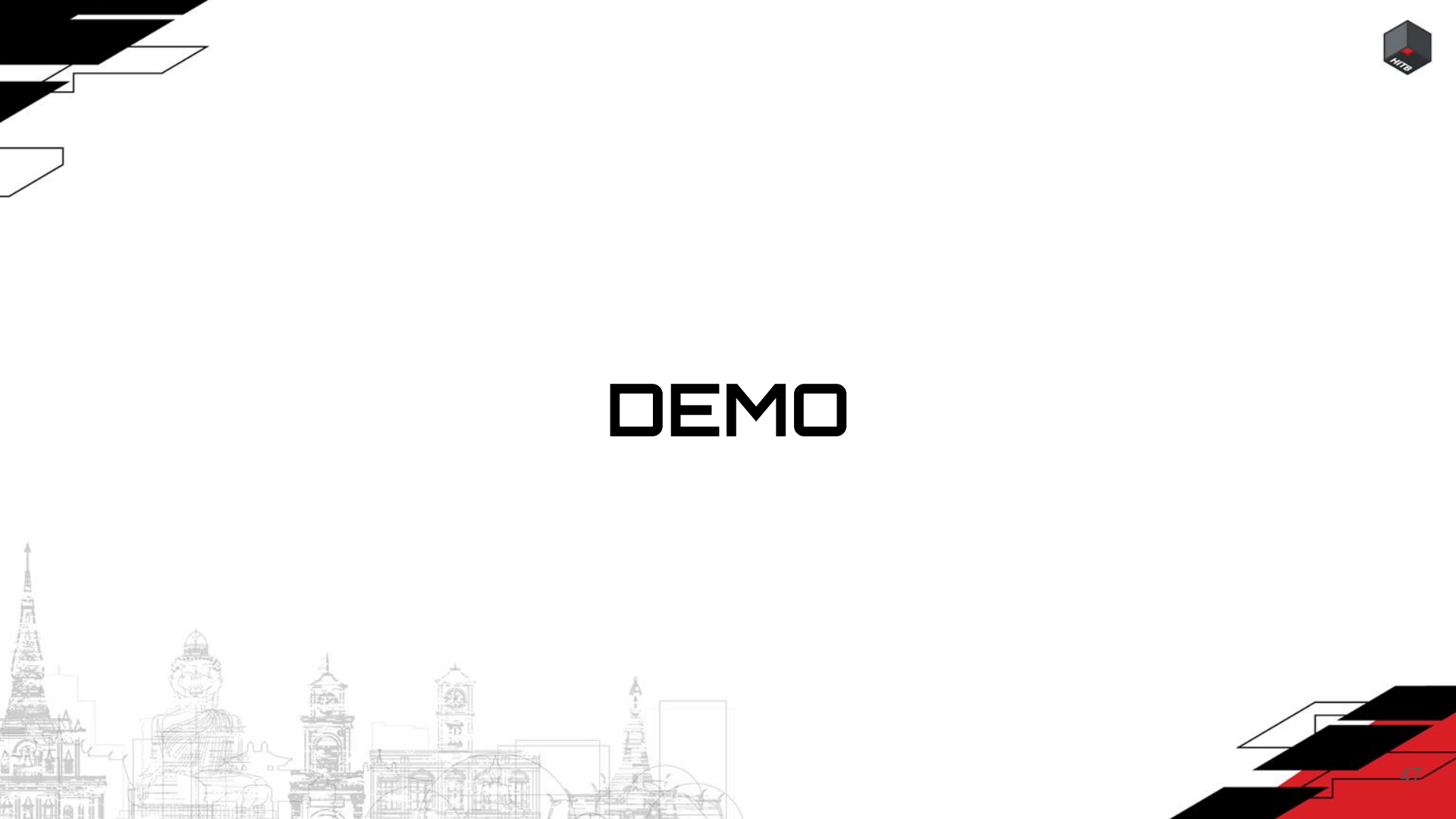
```
static final webKey = Key(Uint8List.fromList(<int>[
  11, 22, 33, 44, 55, 66, 77, 88, 99, 255, 0, 128, 64, 32, 16, 8]));
```

```
Spawned `re.reflut.reflut`. Resuming main thread!
[Android Emulator 5554::re.reflut.reflut ]-> CommentData@72006e3f69 = {
  "off_8!String@72006e3e29": "tnIgr/raWadgxGiXJA4fGiHku9mRYud1D64y3Fxyeh4=",
  "off_c!Key@72006e3f59": {
    "parent!Encrypted": {
      "off_8!_Uint8List@72006e3ed9": [
        11,
        22,
        33,
        44,
        55,
        66,
        77,
        88,
        99,
        255,
        0,
        128,
        64,
        32,
        16,
        8
      ]
    }
  },
  "off_10!DateTime@72006e3f89": {
    "off_c": "1692689213403087",
    "off_14!bool@72000080b1": false
  }
}
```



Conclusion

- Using Dart Runtime is allowed us to get a lot of information from a Flutter application
  - All symbol names in a Dart Snapshot
  - Names of fixed value/constants that only used in Runtime code
    - Stub names
    - Thread offset names
- These information make further analysis easier
  - This part requires studying Dart internals
- The Blutter tool will be released at
  - https://github.com/worawit/Blutter


DEMO

THANK YOU!