Make iOS App more Robust and Security through Fuzzing

Wei Wang & Zhaowei Wang

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About us

- ID: Proteas, Shrek_wzw
- Working at: Qihoo 360 Nirvan Team
- Focused on: iOS and OS X Security Research
- Twitter: @ProteasWang, @Shrek_wzw

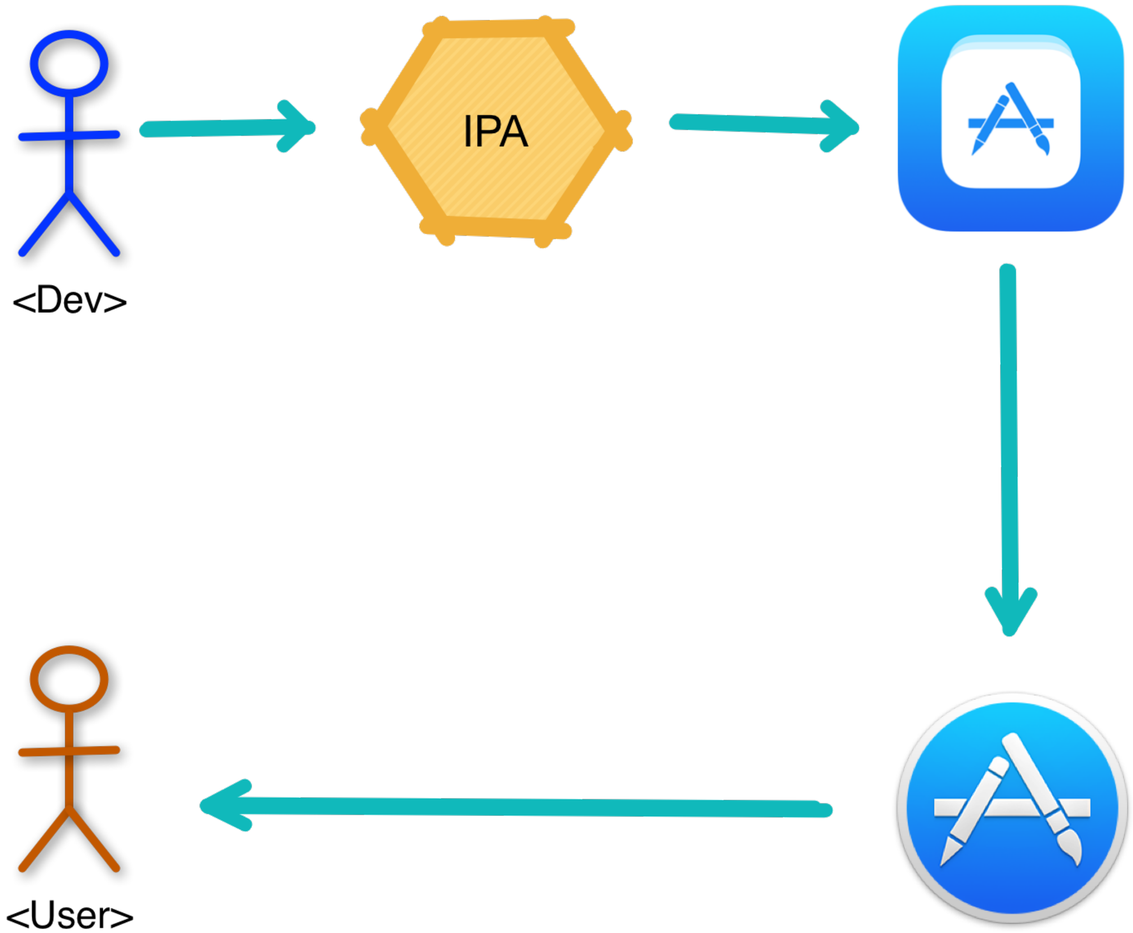
Agenda

- Status of iOS App Security Development Lifecycle
- Why Using AFL to Fuzz App during Development
- Port AFL to iOS
- Characteristics and Attacking Surfaces of iOS App
- Fuzz iOS App
- Fuzz 3rd Party Libraries

Status of iOS App Security Development Lifecycle

- There are about 2 million Apps on Apple AppStore as of June 2016
- Most developed by individual developers or small companies
- For most of those developers or companies, there is no security engineer to protect the Apps
- So the SDL may be like this:

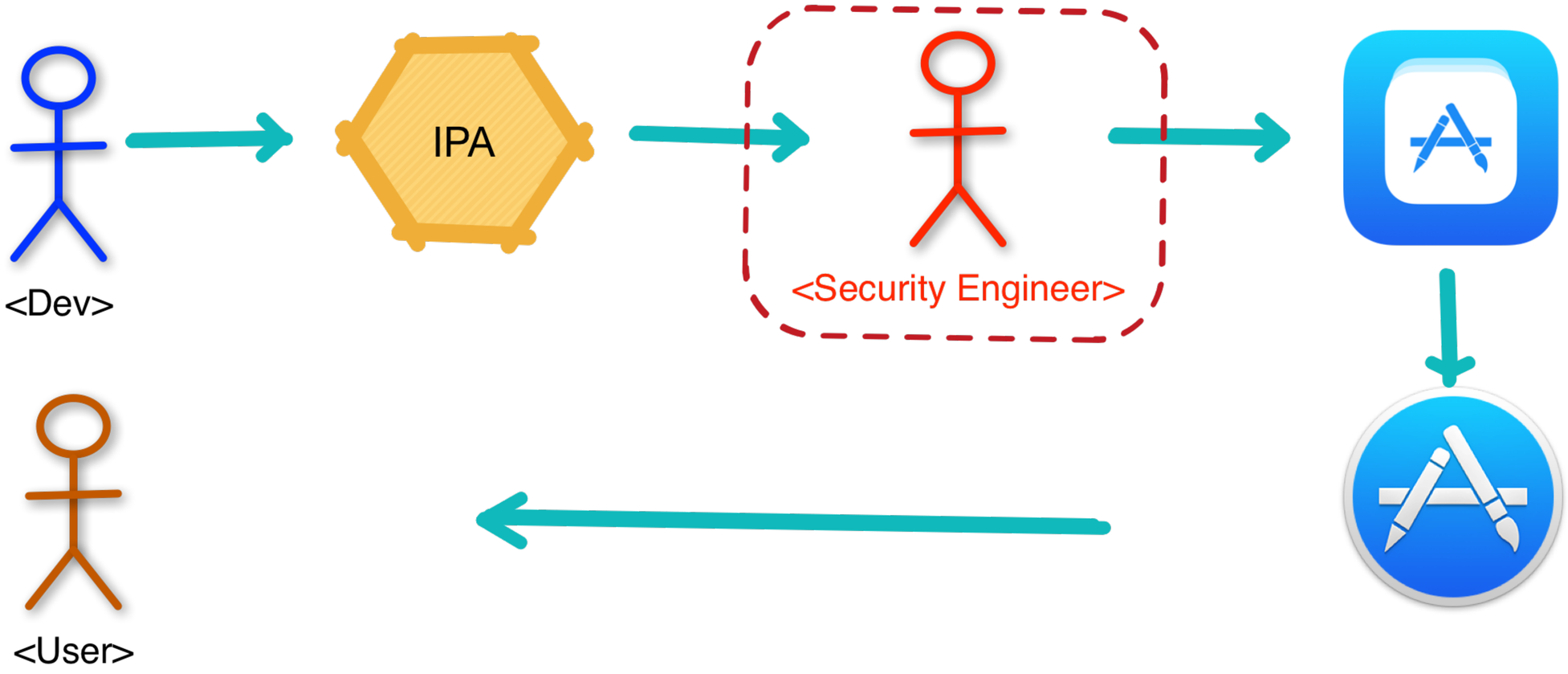
Status of iOS App Security Development Lifecycle



Status of iOS App Security Development Lifecycle

- For companies with iOS security engineers
- Developers submit the App to security engineers first
- Security engineers assess the App using the blackbox way
- After security assessment, the App is submitted to iTunes Connect

Status of iOS App Security Development Lifecycle

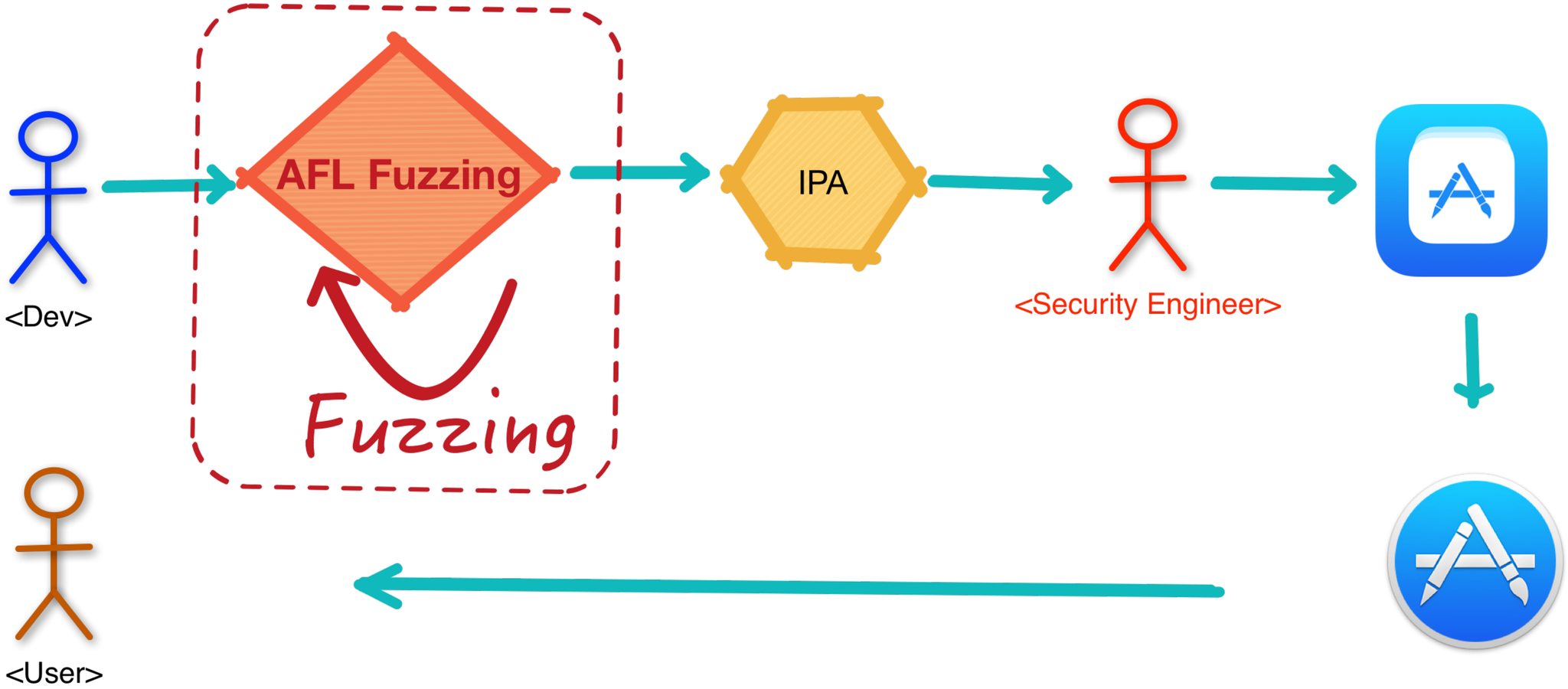


Why Using AFL to Fuzz App during Development

- Bugs should be found as earlier as possible
- We have the source code of our App, this is import for using AFL
- AFL is easy to config and easy to use
- Can be integrated with CI(Continuous Integration)
- When run unit tests with CI, should also run AFL fuzzing

Why Using AFL to Fuzz App during Development

- SDL with AFL



Port AFL to iOS - Port Codes

- Change the API used to create shared memory: shmget() —> shm_open()
- All other changes are for this
- Get the code from my repo: https://github.com/Proteas/afl/tree/ios-afl-clang-fast
- This method is also compatible with AFL 2.35b(currently latest version)

Port AFL to iOS - Build Clang

- Before building AFL, should first build clang
- Get code from: http://opensource.apple.com/
- Using Apple's clang is for compatibility when building Xcode projects
- After building clang, add the result bin dir to PATH
- `export PATH="${CLANG_DIST_DIR}/bin:${PATH}"`

Port AFL to iOS - Build AFL

- Set Env param: `export AFL_NO_X86=1`
- Cross-compile targets:
  - `afl-fuzz, afl-showmap, afl-tmin, afl-gotcpu, afl-analyze`
  - `./llvm_mode/afl-llvm-rt.o`
- Native compile: `afl-clang-fast`
- Use `lipo` to merge the build results, then can fuzz macOS and iOS App using the same toolchain

Port AFL to iOS - Tips and Tricks

- Currently AFL-iOS can only fuzz arm64 binary
- Because AFL using C++11's thread local storage, the App deployment target should be >= 9.0
- Because of Jetsam, should limit the memory usage
- `./afl-fuzz -i ${TEST_CASES} -o ${RESULT_DIR} -m 80M ${TARGET_APP} @@`

Port AFL to iOS

Characteristics and Attacking Surfaces of iOS App

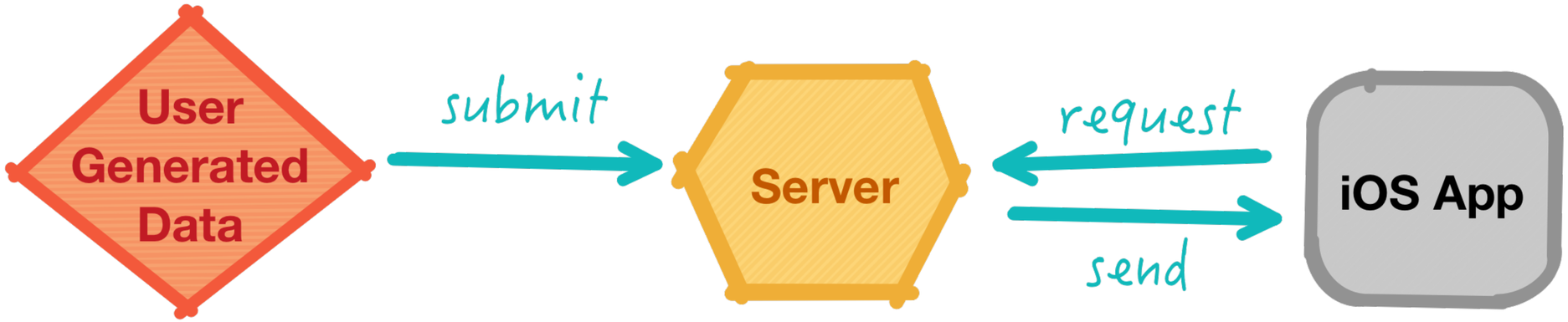
- Most of the Apps only communicate with their own server
- Requires HTTPS connections for iOS Apps by the end of this year
- The remote attacking surface is narrow relatively after using HTTPS
- If there are certificate validation vulnerabilities or config mistakes in iOS App
- Traditional remote attacking surfaces will be back

Characteristics and Attacking Surfaces of iOS App

- Most of the communication protocol of iOS App based on:
    - JSON
    - XML
    - Protocol Buffers
- If can be hijacked, the type-confusion is a kind of issue
- We should validate the input data immediately after receiving it:
    - JSON Schema
    - XML Schema
- Not allow any malformed data come into our App

Characteristics and Attacking Surfaces of iOS App

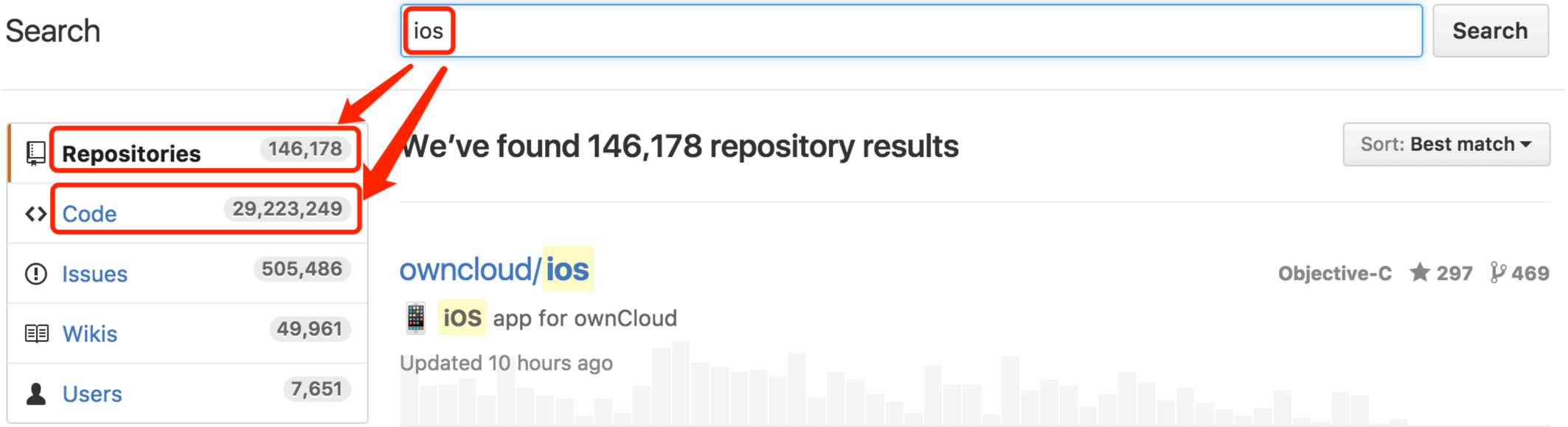
- If there are no certificate validation issues
- We should pay more attention to this kind of Apps:



- Apps like: iMessage, Twitter, Facebook, Dropbox, etc
- Different Apps have different attack surfaces depends on how it processing the user generated data

Characteristics and Attacking Surfaces of iOS App

- There are lots of iOS libraries on Github
- Writing iOS App is more and more like “stacking wood”
- Search “ios” on Github(1476435790):



Characteristics and Attacking Surfaces of iOS App

- Sharing is great
- There are so many codes on Github
- Some are shared by companies with fully testing or security assessment
- Some are written by individual developers
- Some are just demos
- We should do something to make the code more security
- Using AFL is a practical choice

Characteristics and Attacking Surfaces of iOS App

- What libraries are more suitable for fuzzing with AFL ?
    - Parsers: JSON Parser, XML Parser, DSLs Parser
    - Video & Audio Encoder and Decoder
    - Image Encoder and Decoder
    - Archive related libraries
    - …

Fuzz iOS App

- Introduce practical steps about how to fuzz our own codes
- We will use an open source app to demonstrate all the process
- The key point here is: the target function to be fuzzed is coupled seriously
- So the target function can’t be fuzzed on macOS
- We need to do fuzzing on iDevice

Fuzz iOS App

- The demo App: https://github.com/songfei/ArchiveALL
- Function of ArchiveALL is unarchiving rar, lzma, zip on iOS
- Function code is seriously coupled with the demo app
- It is not easy to extract the specific function(for example: unrar)

Fuzz iOS App

- clone the repository, and create a new branch: `AFL-Fuzz`
- check out the newly created branch
- copy `main.m` to `main-normal.m`
- create file: `main-afl.m`
- add following contents to `main-afl.m`:

Fuzz iOS App

main-afl.m

```objc
#import "SFArchiveFileItem.h"
#import "SF7zArchive.h"
#import "SFRarArchive.h"
#import "SFZipArchive.h"

int DoFuzzing(int argc, char * argv[]);
int FuzzArchive(SFBaseArchive *archive);
int FuzzUnzip(NSString *fileName);
int FuzzUnrar(NSString *fileName);
int FuzzUn7z(NSString *fileName);

int main(int argc, char * argv[])
{
    @autoreleasepool {
        return DoFuzzing(argc, argv);
    }
}
```

```objc
int DoFuzzing(int argc, char * argv[])
{
    if (argc != 3) {
        NSLog(@"Usage: ./ArchiveAll 0|1|2 ./test.zip");
        return -1;
    }

    NSFileManager *fileManager = [NSFileManager defaultManager];
    NSString *inputFileName = [NSString stringWithUTF8String:argv[2]];
    if (![fileManager fileExistsAtPath:inputFileName]) {
        NSLog(@"%s: file not exist", __FUNCTION__);
        return -1;
    }

    // Fuzz Type
    int type = 0;

    NSString *inputType = [NSString stringWithUTF8String:argv[1]];
    type = (int)[inputType integerValue];

    if (type == 0) {
        return FuzzUnzip(inputFileName);
    }
    else if (type == 1) {
        return FuzzUnrar(inputFileName);
    }
    else if (type == 2) {
        return FuzzUn7z(inputFileName);
    }
    else {
        NSLog(@"error fuzz type");
        return -1;
    }
}
```

Fuzz iOS App

- Edit `main.m`:

```
#ifdef AFL_FUZZ
    #include "./main-afl.m"
#else
    #include "./main-normal.m"
#endif
```

- Key point of above code is using macro to control the entry of the App

Fuzz iOS App

- Create `afl-ios.xcconfig` to config build params for AFL building

```
ONLY_ACTIVE_ARCH = NO
ARCHS = arm64
VALID_ARCHS = arm64
ENABLE_BITCODE = NO
OTHER_CFLAGS = "-DAFL_FUZZ=1"
OTHER_CPLUSPLUSFLAGS = "-DAFL_FUZZ=1"
OTHER_LDFLAGS = $(PATH_TO_AFL_DIST)/afl/afl-llvm-rt.o
```

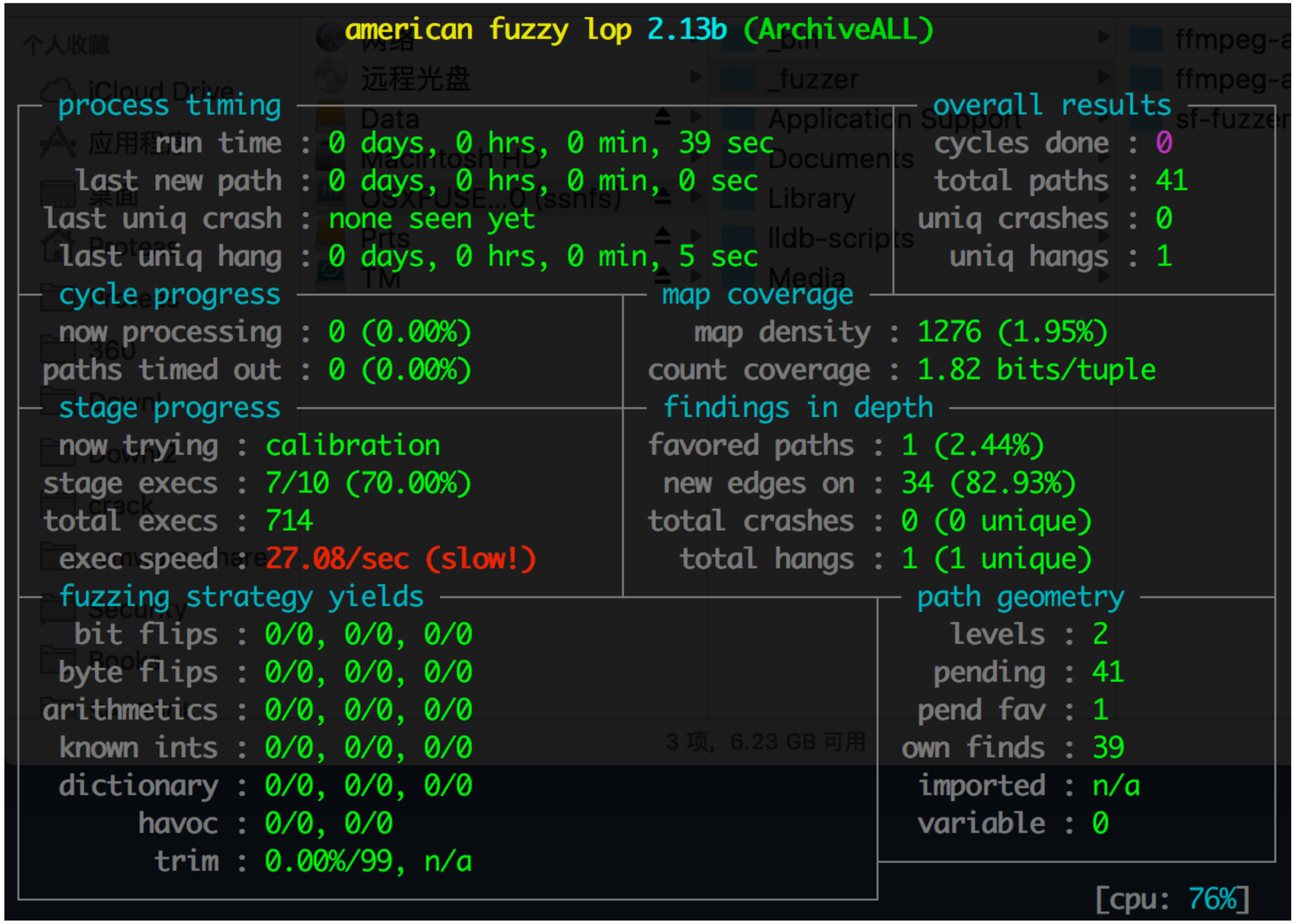
Fuzz iOS App

- Build

```
AFL_ROOT_DIR="TODO"

export AFL_PATH="${AFL_ROOT_DIR}"
export PATH="${AFL_ROOT_DIR}:${PATH}"

rm -rf "./Build"

xcodebuild \
    CC="${AFL_ROOT_DIR}/afl-clang-fast" \
    CXX="${AFL_ROOT_DIR}/afl-clang-fast++" \
    -project "ArchiveALL.xcodeproj" \
    -target "ArchiveALL" \
    -xcconfig "./afl-ios.xcconfig" \
    -configuration "Debug"
```

Fuzz iOS App

- Run it on iDevice
- Fuzzing Unrar



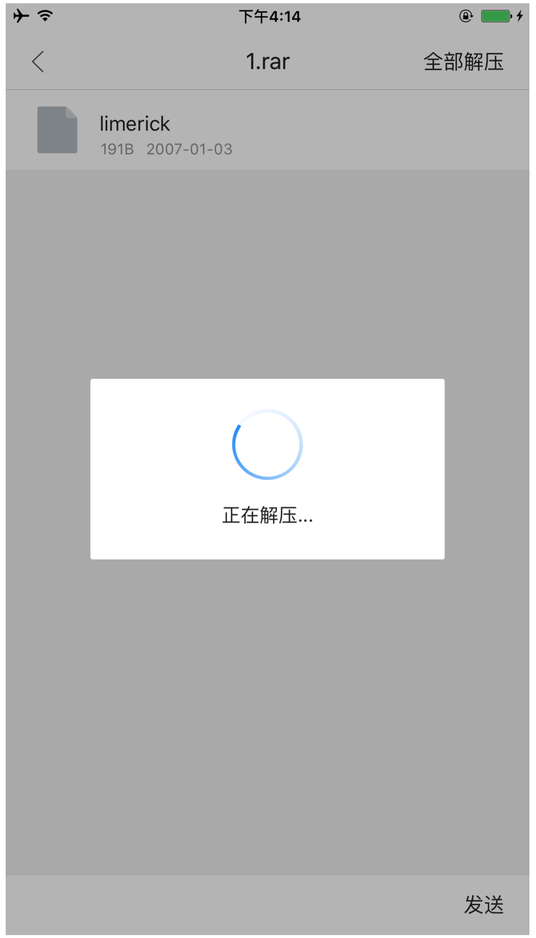
Fuzz iOS App

- As the image shows: In less than 1 minute, we got a DoS
- It can also DoS the App used this library.
- QQ Browser v6.7.2.2345
- All the following fuzzers and fuzzing results can be downloaded from:
- https://github.com/Proteas/fuzzers_based_on_afl

Fuzz iOS App

- QQ Browser v6.7.2.2345
- unrar DoS
- CPU Usage: 99.4%
- The GUI is freezing
- Need to kill the app

34,148	com.apple.dt.ins	root	0	2	1.14 MiB	664.89 MiB	arm64	00.56069
34,156	mttlite	mobile	99.4	11	65.02 MiB	899.41 MiB	arm64	1:35.719...
34,158	com.apple.dt.ins	root	4.1	5	2.32 MiB	666.88 MiB	arm64	04.752408



Fuzz 3rd Party Libraries

- With the doc of AFL and the previous information
- You can build your own fuzzers based on AFL
- Although we can fuzz on iOS, we prefer to do fuzzing on OS X
- The following will show some fuzzers and analysis some of the fuzzing results

Fuzz 3rd Party Libraries

- **ZXingObjC - v3.1.0**
- An Objective-C Port of ZXing
- Out-of-Bounds Read
- 140+ hangs(infinite loop)

```
SUMMARY: AddressSanitizer: heap-buffer-overflow ZXBitMatrix.m:140 -[ZXBitMatrix getX:y:]
Shadow bytes around the buggy address:
  0x1c06000033b0: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x1c06000033c0: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x1c06000033d0: fa fa fa fa 00 00 00 00 fa fa 00 00 00 fa fa fa
  0x1c06000033e0: 00 00 00 fa fa fa fd fd fd fa fa fa 00 00 00 fa
  0x1c06000033f0: fa fa fd fd fd fa fa fa fd fd fd fa fa fa 00 00
=>0x1c0600003400: 00 fa[fa]fa 00 00 00 00 fa fa fd fd fd fa fa fa
  0x1c0600003410: fd fd fd fa fa fa fd fd fd fa fa fa fd fd fd fa
  0x1c0600003420: fa fa fd fd fd fa fa fa fd fd fd fa fa fa fd fd
  0x1c0600003430: fd fa fa fa fd fd fd fa fa fa fd fd fd fa fa fa
  0x1c0600003440: fd fd fd fa fa fa fd fd fd fa fa fa 00 00 00 00
  0x1c0600003450: fa fa fd fd fd fd fa fa fd fd fd fa fa fa fd fd
```

Fuzz 3rd Party Libraries

- **Unrar4iOS - 1.0.0 - 6c90561**
- heap overflow: -[Unrar4iOS extractStream:]
- heap overflow in C, but ObjC object may be overwritten
- `Unrar4iOS.mm`

```
// alloc buffer
NSLog(@"buffer size: %lu", length);
UInt8 *buffer = (UInt8 *)malloc(length * sizeof(UInt8));

……

// copy data to buffer
NSLog(@"memcpy size: %ld", P2);
memcpy(*buffer, (UInt8 *)P1, P2);
```

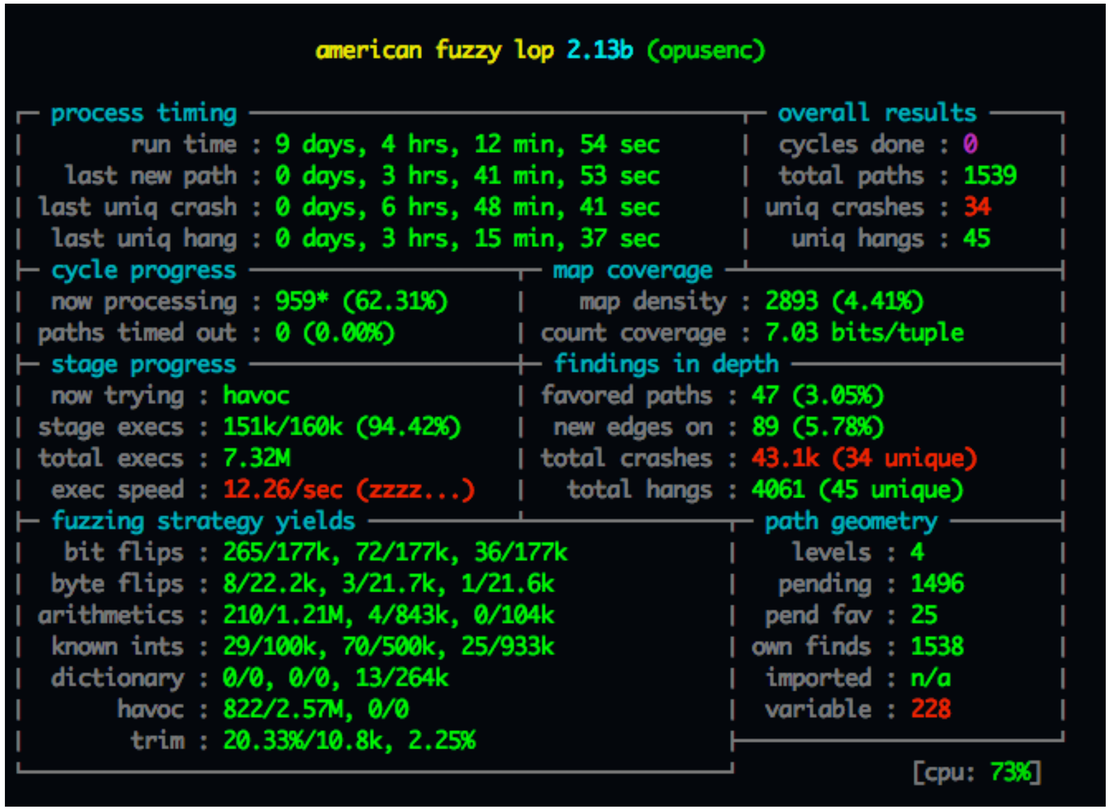
```
unrar[12069:2318258] buffer size: 191
unrar[12069:2318258] memcpy size: 214
```

Fuzz 3rd Party Libraries

- **opus codec**
- Audio Codecs
- Versions
  - `flac-1.3.0`
  - `libogg-1.3.2`
  - `opus-1.1`
  - `opus-tools-0.1.9`
- Analysis the fuzzing results, you will find: stack overflows, integer overflows, …

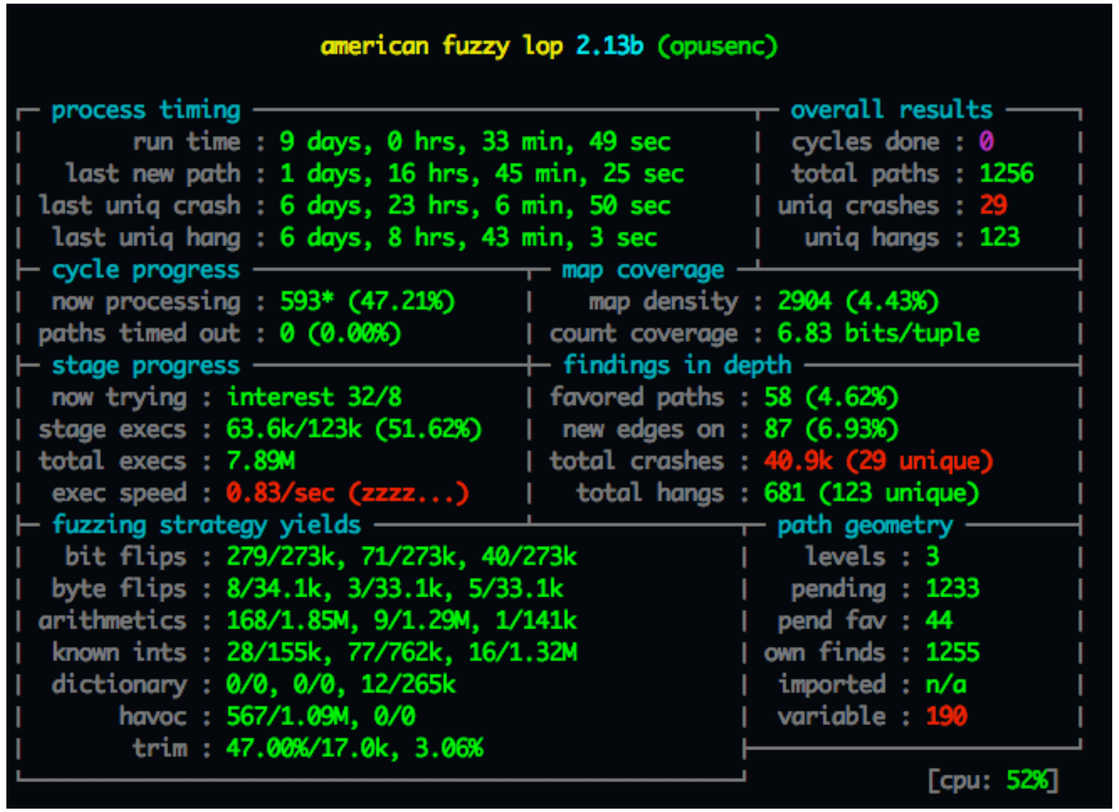
Fuzz 3rd Party Libraries

- **opus codec - encode - wav**
- **Some are exploitable**
- *Floating point exception: 8*
- *AddressSanitizer failed to allocate 0xfffffffffffe0004 bytes*
- *AddressSanitizer: **stack-overflow** on address 0x7fff5b3ceb88*
- *AddressSanitizer: **heap-buffer-overflow** on address 0x00014ad3c800*
- *……*



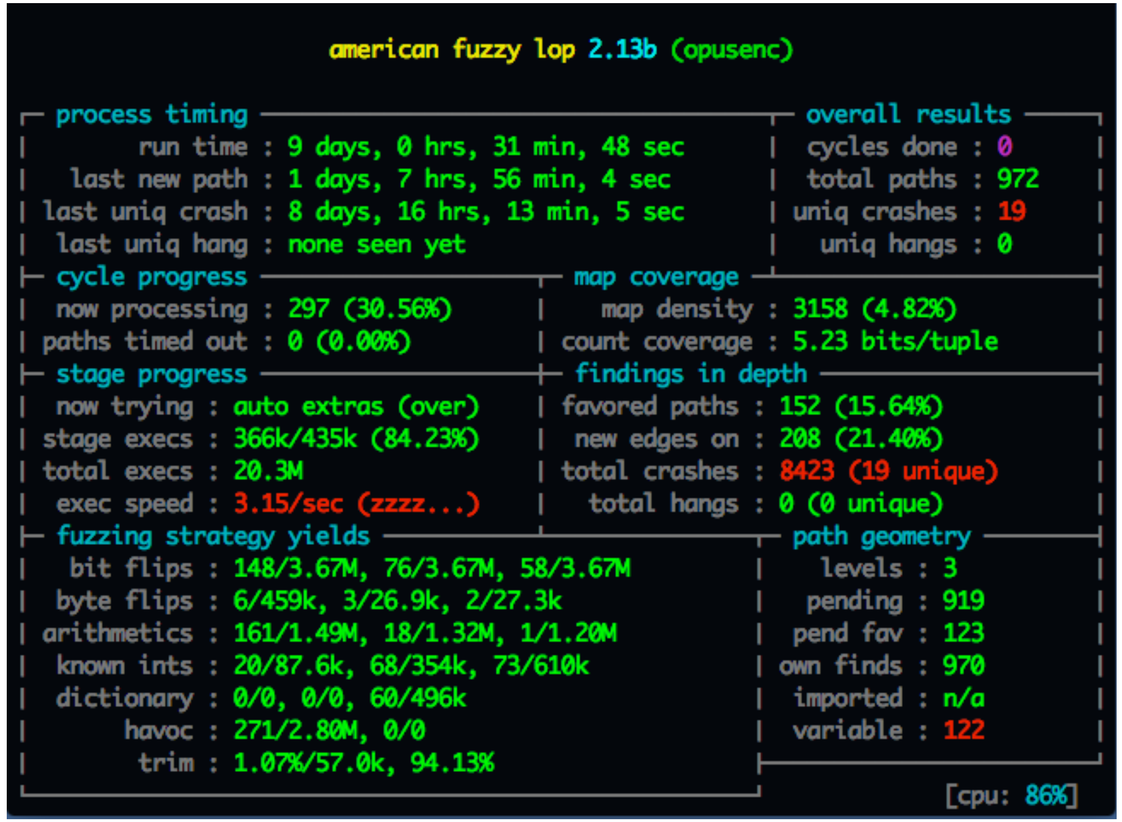
Fuzz 3rd Party Libraries

- **opus codec - encode - aif**
- **Some are exploitable**
- *AddressSanitizer: **stack-overflow** on address 0x7ffed2b175d8*
- *AddressSanitizer: **heap-buffer-overflow** on address 0x62e000000000*
- *AddressSanitizer failed to allocate 0xfffffffffffe0004 bytes*
- *AddressSanitizer: SEGV on unknown address 0x62de00001dac*
- *AddressSanitizer: unknown-crash on address 0xffffffff504c0d420*
- *……*



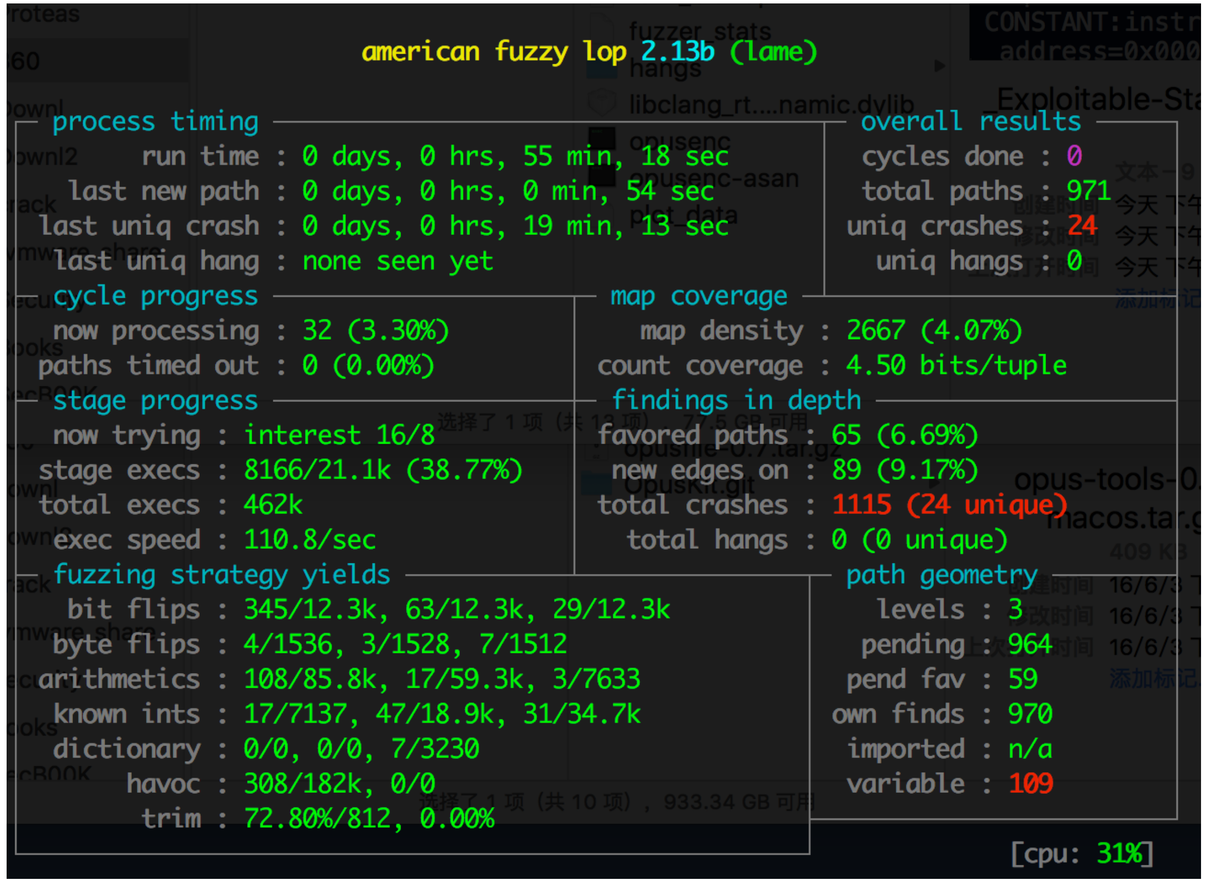
Fuzz 3rd Party Libraries

- **opus codec - encode - flac**
- *AddressSanitizer: SEGV on unknown address 0x000000000000*
- *Floating point exception: 8*
- *AddressSanitizer: SEGV ??:0 oi_strncasecmp*
- *……*



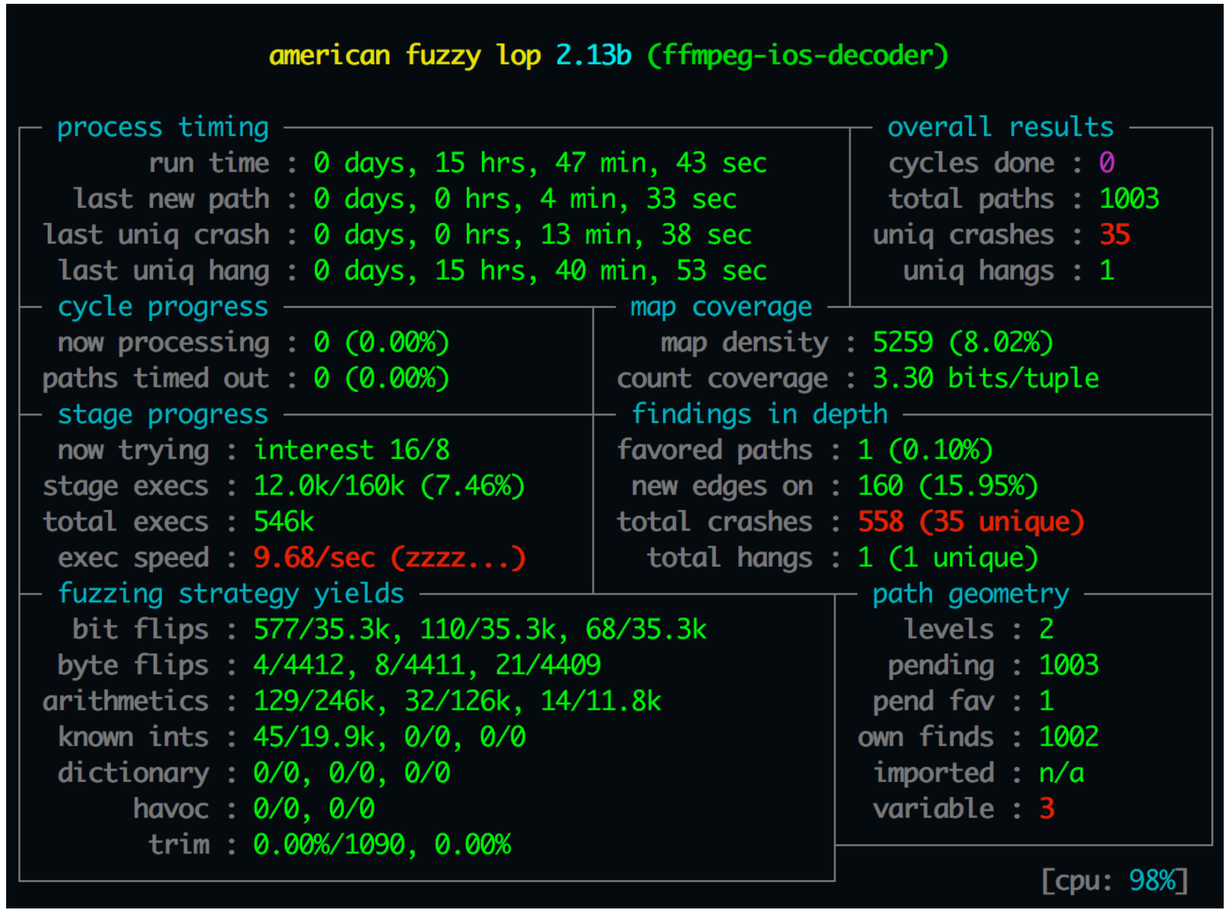
Fuzz 3rd Party Libraries

- **lame mp3 encoder - 3.99.5**
- *AddressSanitizer: SEGV on unknown address 0x60bffff05b38*
- *AddressSanitizer: SEGV ??:0 fill_buffer*
- *AddressSanitizer: SEGV on unknown address 0x000000000000*
- *AddressSanitizer: **heap-buffer-overflow** on address 0x60c00000bd3c*
- *AddressSanitizer: **heap-buffer-overflow** ??:0 fill_buffer*
- *……*



Fuzz 3rd Party Libraries

- **KxMovie(ffmpeg decoder) - 2c5324b0**
- iOS movie player based on ffmpeg
- Fuzz results: decode flv
- You could clone the fuzzer and continue to fuzz other formats



Thanks

- Thanks To Michal Zalewski <lcamtuf@google.com>
- For developing and sharing AFL

Reference

- Number of apps available in leading app stores as of June 2016
- American Fuzzy Lop: http://lcamtuf.coredump.cx/afl/
- ArchiveALL: https://github.com/songfei/ArchiveALL
- ZXingObjC: https://github.com/TheLevelUp/ZXingObjC
- Unrar4iOS: https://github.com/ararog/Unrar4iOS
- opus codec: https://www.opus-codec.org/
- KxMovie: https://github.com/kolyvan/kxmovie

Question ?