



Jailbreak detection mechanisms and how to bypass them

Pass The Salt 2021

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Whoami

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- Eloi Benoist-Vanderbeken
- @elvanderb on twitter

- Working for Synacktiv
 - Offensive security company
 - 90 ninjas
 - 3 departments: pentest, reverse engineering, development
 - Pass The Salt sponsor!

- Reverse engineering technical leader
 - 30 reversers
 - Focus on low level dev, reverse, vulnerability research/exploitation
 - If there is software in it, we can own it :)
 - We are hiring!



Introduction



JailBreak detection



- iOS
 - Closed operating system
 - No easy way to get root
 - JailBreaks bypass iOS security to get (almost) full access
- JailBreak detection
 - Used by banking applications and games
 - To make sure that the environment is “safe”...
 - ...or to block cheats/cracks
- Security researchers need to
 - Assess / reverse protected applications

iOS specificities



- Signature
 - All the code must be signed by Apple (enforced by the system)
 - All the data is also signed (enforced by the App Store)
- Memory protection
 - W^X
 - Only WebContent process can use JiT pages
- No side loading
 - “Apps may not [...] download, install, or execute code which introduces or changes features or functionality of the app”
- Public API
 - “Apps may only use public APIs”
 - Theoretically enforced by the App Store review process
 - Actually only used to block malicious tracking methods or deprecated/buggy APIs

Frida



- <https://frida.re>
- “Dynamic instrumentation toolkit for developers, reverse-engineers, and security researchers”
- Allows you to inject JavaScript to instrument any process
 - iOS / Android / Windows / macOS / Linux / QNX...
- Lots of features
- Lots of bindings (.NET, Python, Node.js, Swift...)
- Low level C API
- Well known by Pass The Salt aficionados
 - PTS 2020 - Why are Frida and QBDI a Great Blend on Android?
 - PTS 2018 - Radare2 + Frida: Better Together

Debugging an iOS app

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■ Without a JailBreak

- With ptrace (lldb / frida) → app needs the get-task-allow entitlement
- By injecting code (frida) → app needs to be repackaged

And you can only do data only instrumentation

- In both case, you need to resign the application...
- ... but it has a lot of side effect

Different Team ID

File are modified

■ With a JailBreak

- No entitlements are required
- Frida is able to attach to any process

Except system ones on post A12 iPhones because of PPL

Case study

The background features a dark, almost black, field with vibrant, wavy lines in shades of red and purple. A large, bright red circle is positioned on the left side, partially overlapping the wavy lines. The overall aesthetic is modern and abstract.

The target



- **A banking app**
- **Immediately crash when launched on a jailbroken device**
 - Exception Type: EXC_BAD_ACCESS (SIGSEGV)
 - Exception Subtype: KERN_INVALID_ADDRESS at 0x0000000000000200
- **Executable is quite large**
 - 31MB
- **Nothing special at first sight**
 - Methods name are not obfuscated
 - Strings are in cleartext
- **We tried a few scripts¹**
 - But without luck

Around the crash...

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```
if ( all_is_all_right != 1 )  
    ++*(_BYTE *) ((unsigned __int64)&unk_101C767D0 & 0x20C);  
return result;
```

Around the crash...

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```
if ( all_is_all_right != 1 )  
    ++*(_BYTE *) ((unsigned __int64)&unk_101C767D0 & 0x20C);  
return result;
```

Around the crash...

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```
if ( all_is_all_right != 1 )  
    ++*(_BYTE *) ((unsigned __int64)&unk_101C767D0 & 0x20C);  
return result;
```

```
do  
{  
    v31 = v102;  
    v32 = (unsigned __int8)v101 + 1;  
    v33 = (unsigned __int8)(v101 + 1);  
    v34 = (unsigned __int8)v138[v33];  
    v35 = v34 + (unsigned __int8)v103;  
    v36 = (unsigned __int8)(v34 + v103);  
    v138[v33] = v138[v36];  
    v138[v36] = v34;  
    encrypted_path[v31] ^= v138[v33] + (_BYTE)v34;  
    v22 = (unsigned __int64)(v31 + 1) >= 0x11;  
    v101 = v32;  
    v102 = v31 + 1;  
    v103 = v35;  
    v100 = v31 - 16;  
}  
while ( v31 != 16 );  
path_is_decrypted = 1;  
}  
  
atomic_store(0, &dword_101CDDA8C);  
v99 = encrypted_path;  
v98 = 1LL;  
v37 = mac_syscall(SYS_utimes, encrypted_path, (const timeval *)1);
```

Around the crash...

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```
if ( all_is_all_right != 1 )  
    ++*(_BYTE *) ((unsigned __int64)&unk_101C767D0 & 0x20C);  
return result;
```

```
do  
{  
    v31 = v102;  
    v32 = (unsigned __int8)v101 + 1;  
    v33 = (unsigned __int8)(v101 + 1);  
    v34 = (unsigned __int8)v138[v33];  
    v35 = v34 + (unsigned __int8)v103;  
    v36 = (unsigned __int8)(v34 + v103);  
    v138[v33] = v138[v36];  
    v138[v36] = v34;  
    encrypted_path[v31] ^= v138[v33] + (_BYTE)v34;  
    v22 = (unsigned __int64)(v31 + 1) >= 0x11;  
    v101 = v32;  
    v102 = v31 + 1;  
    v103 = v35;  
    v100 = v31 - 16;  
}  
while ( v31 != 16 );  
path_is_decrypted = 1;  
}  
atomic_store(0, &dword_101CDDA8C);  
v99 = encrypted_path;  
v99 = 111;  
v37 = mac_syscall(SYS_utimes, encrypted_path, (const timeval *)1);
```


Around the crash...

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```
ADRL      X8, encrypted_path
MOV       W9, #1
MOV       X10, X9
STR       X8, [X19, #0x108]
STR       X10, [X19, #0x100]
LDR       X20, [X19, #0x108]
LDR       X21, [X19, #0x100]
MOV       X16, #0x8A
MOV       X0, X20
MOV       W1, W21
SVC       0x80
CSET      X23, CS
MOV       X22, X0
SUBS      W23, W23, #0
CSET      W24, EQ
SUBS      W22, W22, #0xE
CSET      W25, NE
ORR       W24, W24, W25
```

Syscalls

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- **Syscalls are directly executed**
 - 400+ syscalls
 - Hooking APIs is not sufficient
 - Not very compliant with the “Apps may only use public APIs” policy...
- **Strings are decrypted on the fly**
 - Integrity checks
 - Impossible to just find and replace blacklisted paths
- **What we would like to do**
 - Intercept all the syscall with Frida
 - Manipulate the arguments
 - Replace the return value

Interception with Frida

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Examples are from the doc: <https://frida.re/docs/javascript-api/>



- Classically used to intercept function arguments or return values

```
Interceptor.attach(Module.getExportByName('libc.so', 'read'), {
  onEnter(args) {
    this.fileDescriptor = args[0].toInt32();
  },
  onLeave(retval) {
    if (retval.toInt32() > 0) {
      /* do something with this.fileDescriptor */
    }
  }
});
```

- Or to completely replace its implementation

```
const openPtr = Module.getExportByName('libc.so', 'open');
const open = new NativeFunction(openPtr, 'int', ['pointer', 'int']);
Interceptor.replace(openPtr, new NativeCallback((pathPtr, flags) => {
  const path = pathPtr.readUtf8String();
  log('Opening "' + path + '"');
  const fd = open(pathPtr, flags);
  log('Got fd: ' + fd);
  return fd;
}, 'int', ['pointer', 'int']));
```

Interception with Frida

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- But can also be used to intercept arbitrary instructions

```
let mainModule = Process.enumerateModules()[0];
let instructionAddress = mainModule.base.add(0x1247)
Interceptor.attach(instructionAddress, (args) => {
  console.log(`R0 = ${this.context.r0}`)
});
```

- Useful to dump process state in the middle of a function...
- But not magic nor perfect
 - May have to patch multiple instructions to redirect execution flow
 - May trash registers (an issue is open)

Using breakpoints

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- Frida also allows to intercept exceptions!

```
Process.setExceptionHandler(function (exp) {  
  console.log(`Exception ${exp.type} @ ${exp.address}`);  
  Thread.sleep(1);  
  return false;  
});
```

- Replace all the syscall with breakpoints
 - Ensure that we only patch one instruction
- Catch the exception to intercept all the syscalls
- Modify the context to emulate them

Patch all the syscalls

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```
function replaceSyscall(address, size){
    let count = 0
    let syscallIns = "01 10 00 d4"

    Memory.scanSync(address, size, syscallIns).forEach((match) => {
        let address = match.address;
        if (address.and(3).toInt32() !== 0)
            return;
        count += 1
        Memory.patchCode(address, 4, (address) => {
            let instructionWriter = new Arm64Writer(address);
            instructionWriter.putBrkImm(0);
        });
    });
    console.log(`[+] Found ${count} svc 0x80`);
}
```

The nasty crash...

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- After a few tries we implemented several syscalls
- In parallel we found that normal function are also used
- Process always crashed just after the checks
 - Invalid deref, exit(0), objc_msgSend with invalid pointers etc.
 - Easy to find the check
- But then the process started to crash...
- ... this time with trashed PC / LR
 - No easy way to find the underlying test

Stalker

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- **Frida has a Dynamic Binary Instrumentation engine**
 - Stalker
- **Can be used to log all the basic blocks executed**
- **Idea**
 - Run the app until the last successfully bypassed check
 - Trace all the basic blocks
 - Wait for the program to crash
- **Make sure to use sync method**
 - Frida loses the buffered messages when the app crashes
- **This quickly gave us the culprit**
 - An API that we weren't hooking yet

Stalker

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```
function trace() {
  let tid = Process.getCurrentThreadId();
  console.warn('[+] attaching stalker on thread '+tid);
  Stalker.follow(tid, {
    events: {call: false, ret: false, exec: false, block: false, compile: true},
    transform(iterator) {
      let instruction = iterator.next();

      const startAddress = instruction.address;
      if ((startAddress.compare(mainModule.base) >= 0) &&
          (startAddress.compare(mainModule.base.add(mainModule.size)) < 0)) {
        function callback (context) {
          console.log('executing ' + context.pc.sub(mainModule.base));
        }
        iterator.putCallout(callback);
      }
      do {
        iterator.keep();
      } while ((instruction = iterator.next()) !== null);
    }
  });
}
```

Protections

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- **Try to find JailBreak files**
 - open, utimes, stat, pathconf, stat64, fopen
 - Both syscalls and functions
- **Try to block/detect debuggers**
 - ptrace(PT_DENY_ATTACH);
- **Check if the parent pid is launchd**
 - getppid() == 1
- **Try to detect if the rootfs is writable**
 - getfsstat64, statvfs

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Solution



A generic API

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- A generic interface to hook both functions and syscalls

```
}, {  
  name: "ptrace",  
  syscall: 26,  
  hook(arg){  
    if (arg == 0x1f) { // PT_DENY_ATTACH  
      console.log("[+] ptrace(PT_DENY_ATTACH) -> NOK");  
      return {retv: 0};  
    }  
    console.log("[+] ptrace(???) -> OK");  
  }  
}, {  
  name: "utimes",  
  syscall: 138,  
  hook(arg){  
    let path = arg.readUtf8String()  
    if (!iswhite(path)) {  
      console.log(`[+] utimes(${path}) -> NOK`);  
      return {errno: 2}  
    }  
    console.log(`[+] utimes(${path}) -> OK`);  
  }  
}, {
```

A generic API

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■ Handle special cases

```
name: "open",
syscall: 5,
hook(arg) {
  let path = arg.readUtf8String()
  if (!iswhite(path)) {
    console.log(`[+] open(${path}) -> NOK`);
    return {
      errno: 2,
      onLeave(state) {
        let fd = state.context.x0.toInt32();
        console.log(`fd: ${fd}`);
        if (fd !== -1) {
          console.log(`closing fd ${fd}`);
          close(fd);
        }
      }
    }
  }
  console.log(`[+] open(${path}) -> OK`);
}
```



Future



Other techniques

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- **Try to load an invalid signature**
 - `fcntl(F_ADDSIGS);`
- **Check if some JailBreak libraries are loaded in your process**
 - `/usr/lib/substitute-inserter.dylib` for example
 - Can use `dlopen` / memory scanning / `dyld` internal structures etc.
- **Check if your process is instrumented**
 - Check code integrity
 - CRC, derive constants from the code, check API entries, etc.
 - Time code execution
 - Try to detect Frida
- **Check signature state**
 - Via `csops(CS_OPS_MARKKILL)`
- **Crash later**
 - Use a global context
 - Put the crash long after the detection
 - Complicate the backtracing

 SYNACKTIV



?

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Bonus



Future of iOS instrumentation

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■ Harder and harder to attack iOS devices

■ Pointer signature (PAC)

Per process and per Team ID keys

A lot of kernel data pointers are now signed

■ API hardening

Impossible to manipulate a system process even with its task port

■ Sandboxing

More and more kernel API are sandboxed

- ioctl, fcntl, syscalls, necp etc.

More and more services are sandboxed

■ Isolation

Kernel allocations segregation

■ Apple not only kills bugs but also exploit techniques

■ JailBreaks are more and more precious



- **All the memory management is done in a special CPU state**
 - Impossible to patch the page tables with an arbitrary kernel write
- **PPL also protect userland services**
 - PPL knows all the system services
 - Hashes are hardcoded in its data
 - Forbid to inject third party executable code in a system process
- **Could be deployed for all the processes**
 - If they don't have a special entitlement
- **Still possible to manipulate the process...**
 - With data only manipulation
 - Or by using hardware breakpoints
- **...but not that easy nor handy**
 - Needs to sign pointers with the distant process key
 - Not an infinite number of hardware breakpoint
 - All the tool will have to be recoded