TLS Session Key Extraction from Memory on iOS Devices

Research Project 2

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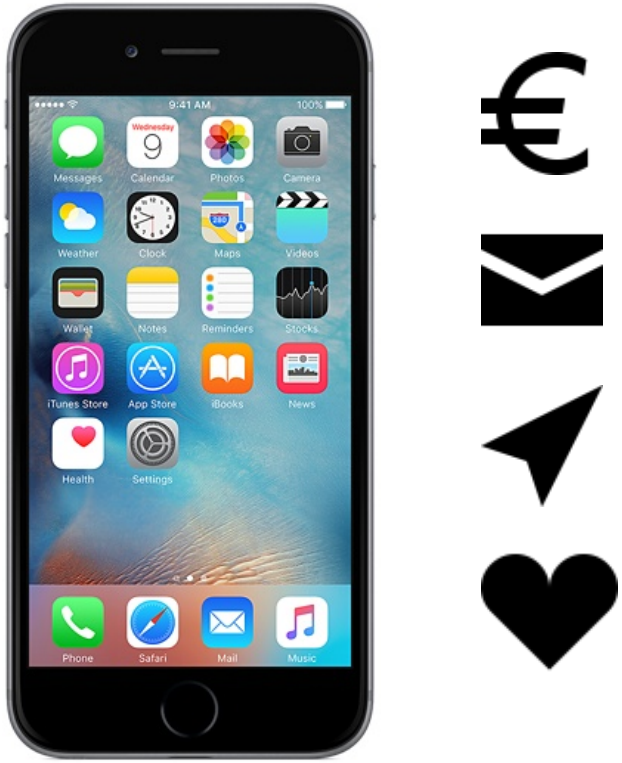

9:41 AM
100%
Messages
Calendar
Photos
Camera
Weather
Clock
Maps
Videos
Wallet
Notes
Reminders
Stocks
iTunes Store
App Store
iBooks
News
Health
Settings
Phone
Safari
Mail
Music

Motivation

- Increase in TLS encryption on iOS devices
- Prevents blackbox testing
- Existing tools *disable* TLS and *rely on jailbreak*
- Is there an alternative approach?

Research Question

Is it possible to extract TLS session keys from the process memory of a device running iOS 9.0 or greater?

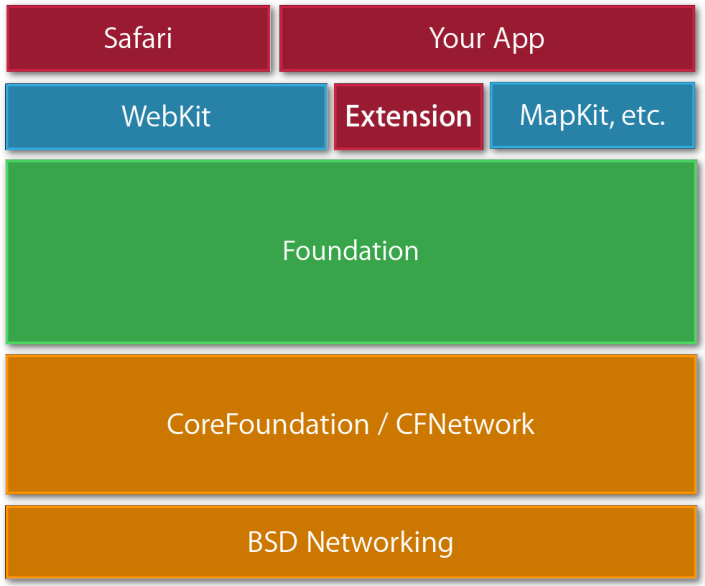
- How is TLS handled in iOS?
- Can it be done with jailbroken *and* non-jailbroken devices?

TLS

- Cryptographic protocol, successor of SSL
- Provides *confidentiality and authentication*
- Uses the *Record* protocol
- Sub-protocols
    1. Handshake
    2. ChangeCipherSpec
    3. Application Data
    4. Alert

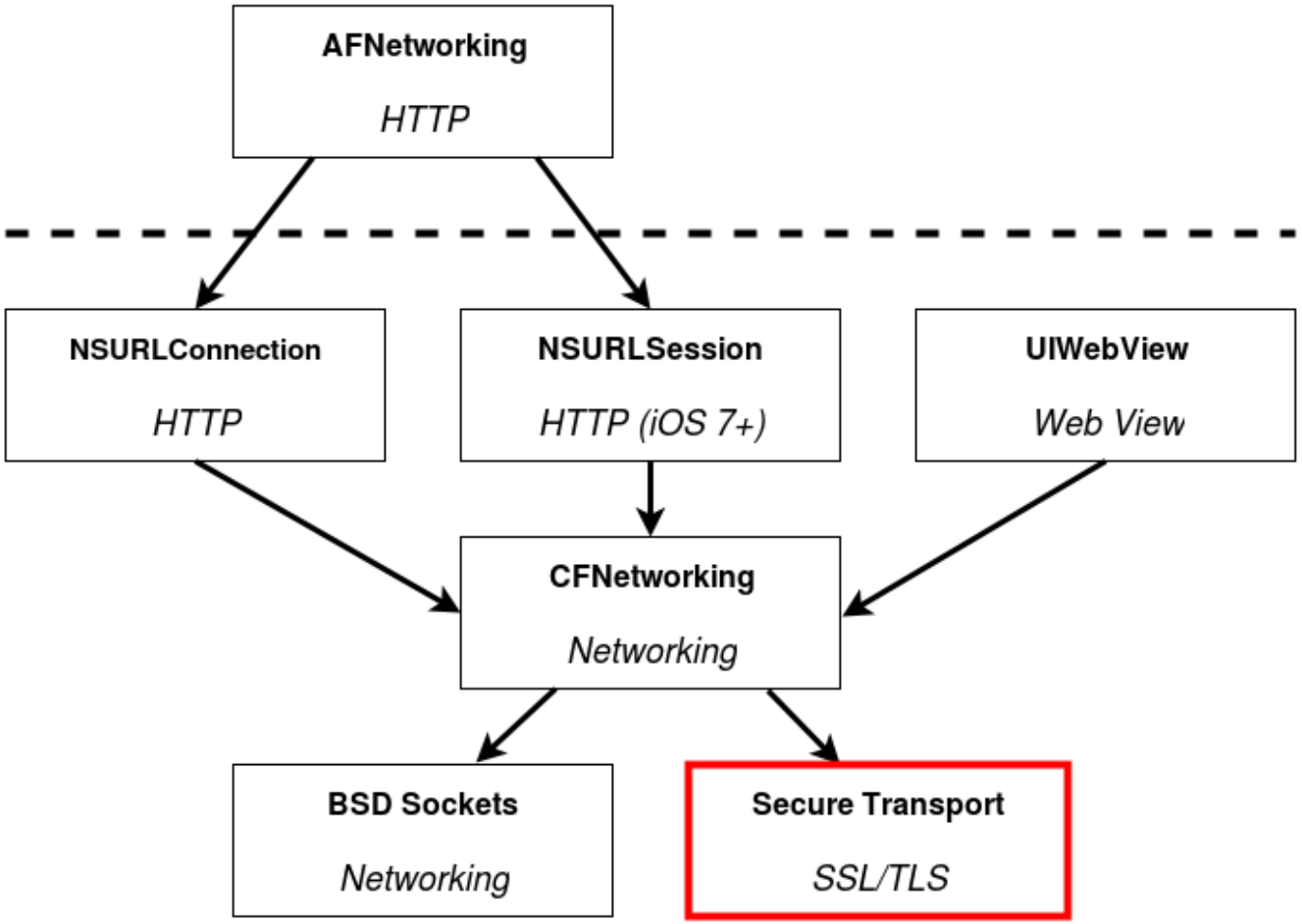
TLS in iOS

- Foundation Networking APIs
- TLS handled via *Secure Transport API*
- App Transport Security (ATS) (9.0+)
  - TLS 1.2
  - Forward secrecy
  - Key Exchange - ECDHE
  - Authentication - ECDSA or RSA
  - Mandatory on App Store from 2017



Source: Apple.com

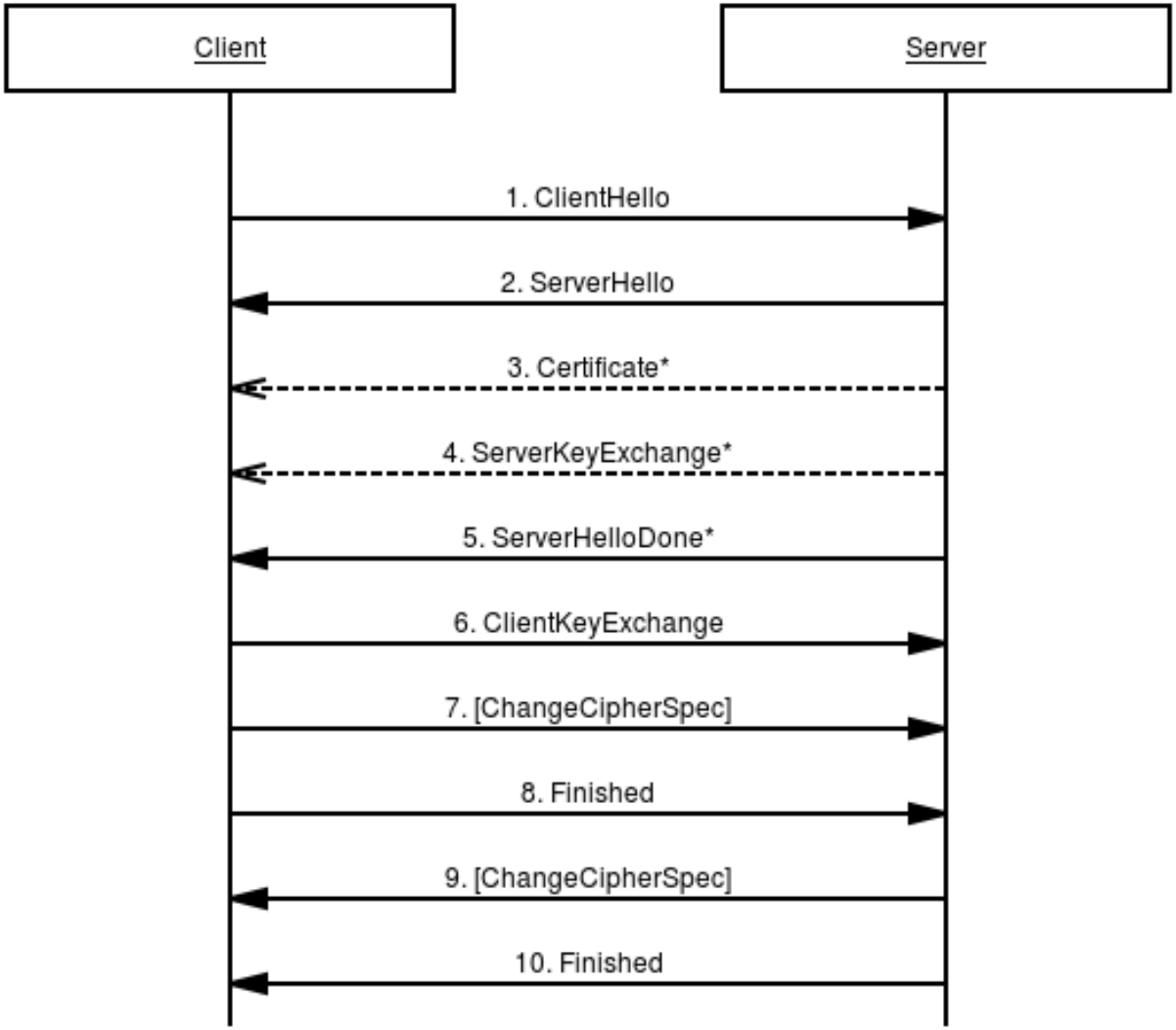
iOS Network Stack



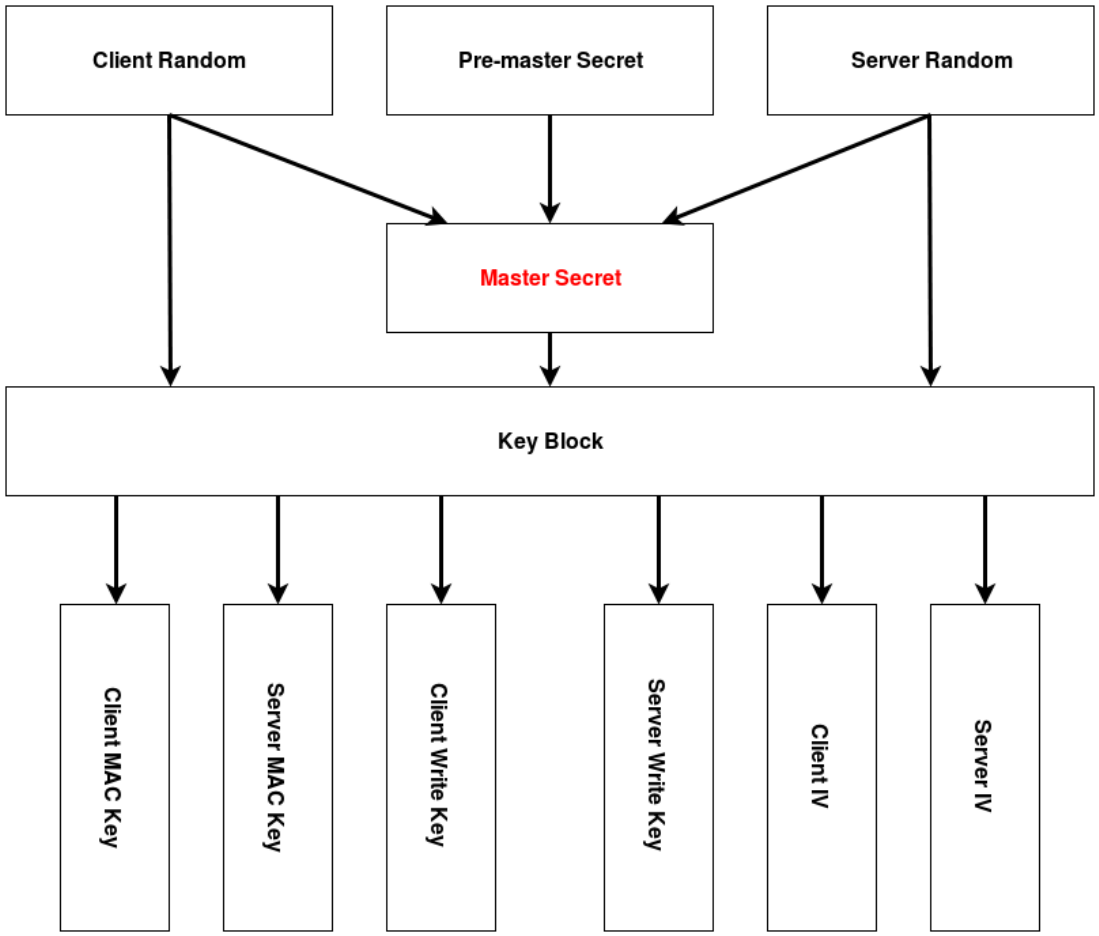
TLS Handshake

- Establish shared secret
- Four phases:
  1. Exchange capabilities and agree on connection parameters
  2. Authentication
  3. Agree on shared secret
  4. Verify handshake messages

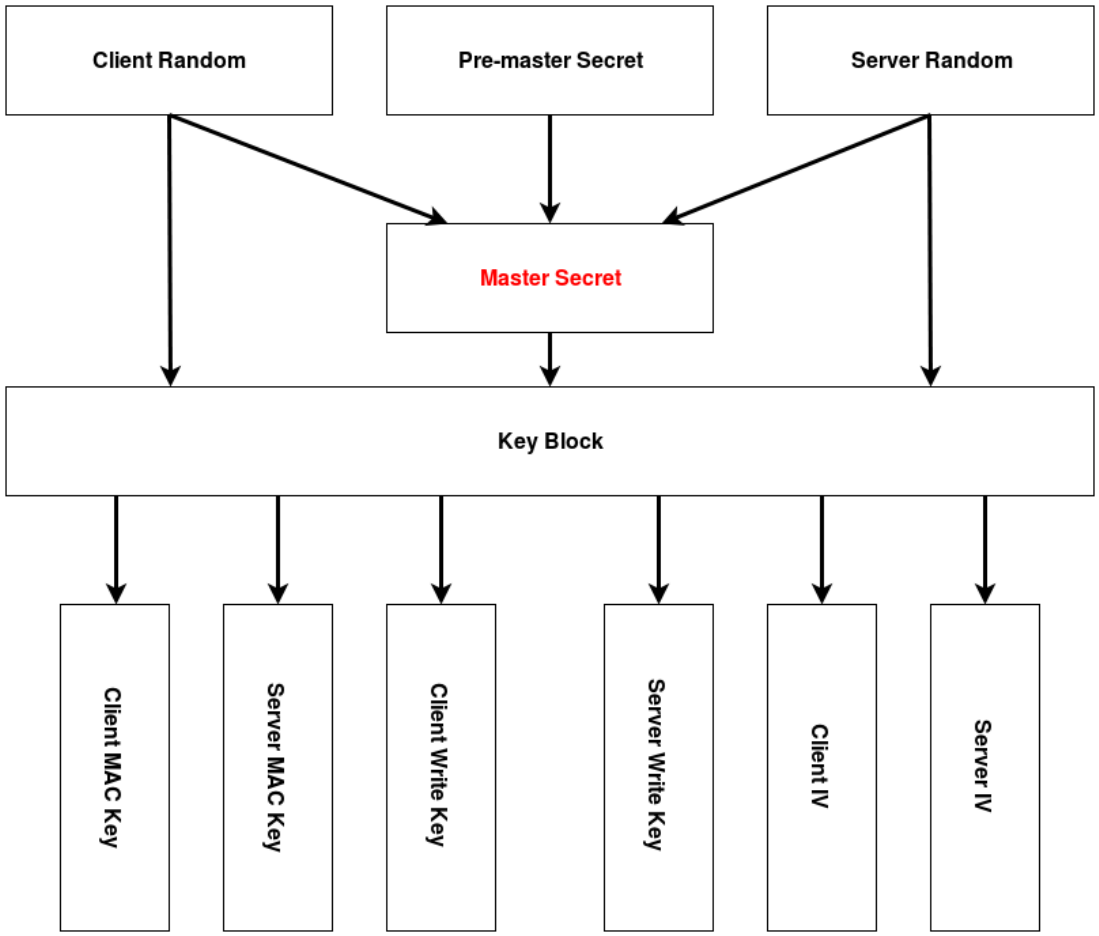
TLS Handshake



Key Material



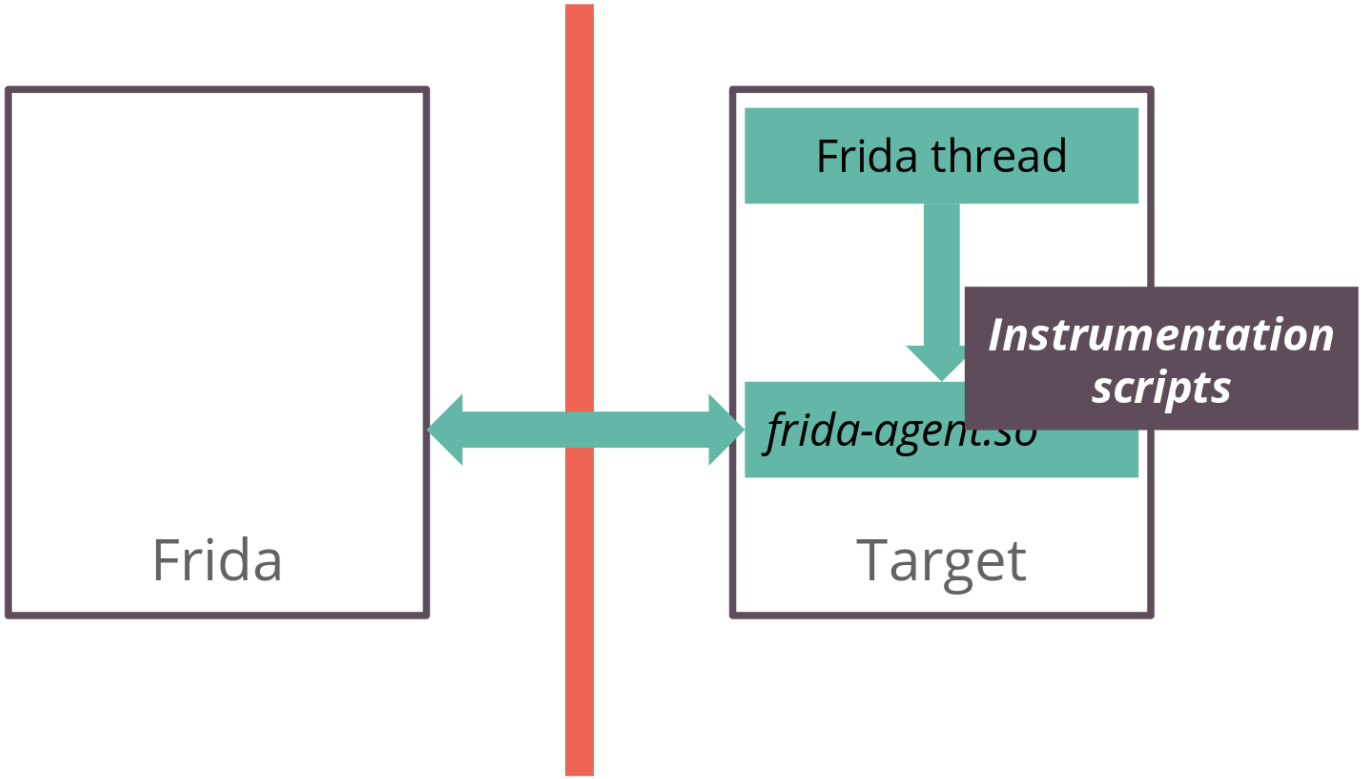
What do we need?


Client Random
Pre-master Secret
Server Random
Master Secret
Key Block
Client MAC Key
Server MAC Key
Client Write Key
Server Write Key
Client IV
Server IV

Tools

FRIDA

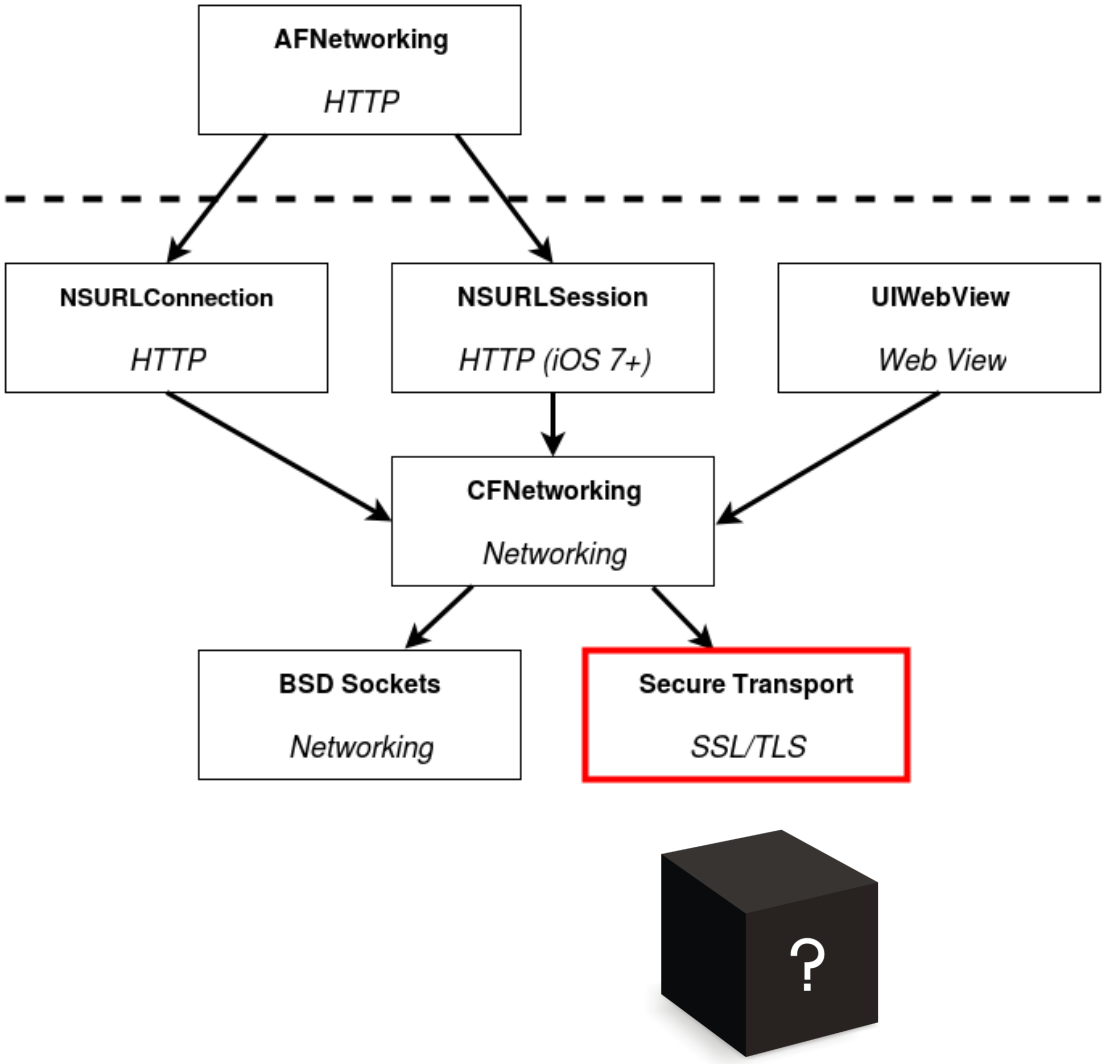
- Dynamic instrumentation toolkit
- Live inspection of processes
- Scriptable
  - Execute own debug scripts *inside* another process
- Used for
    - Attaching to processes
    - Hooking functions
    - *Inspecting memory*



Source: frida.re

Finding the secret

Targeting iOS Secure Transport



Targeting iOS Secure Transport

- Secure Transport API hides internal handshake operations
- Encryption *actually* handled by coreTLS library
- Source code for older versions available online

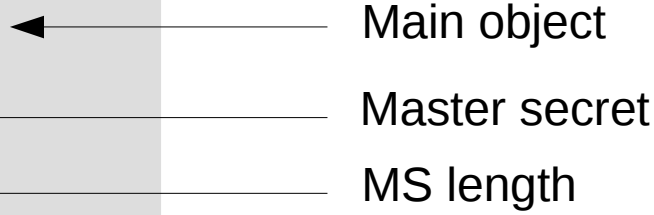
CoreTLS source

```
struct  _tls_handshake_s {

        tls_protocol_version  negProtocolVersion;
        tls_protocol_version  clientReqProtocol;
        tls_protocol_version  minProtocolVersion;
        tls_protocol_version  maxProtocolVersion;
        …

        uint8_t         clientRandom[SSL_CLIENT_SRVR_RAND_SIZE];
        uint8_t         serverRandom[SSL_CLIENT_SRVR_RAND_SIZE];
        tls_buffer              preMasterSecret;
        uint8_t         masterSecret[SSL_MASTER_SECRET_SIZE];
        …
}


typedef struct _tls_handshake_s *tls_handshake_t;
```

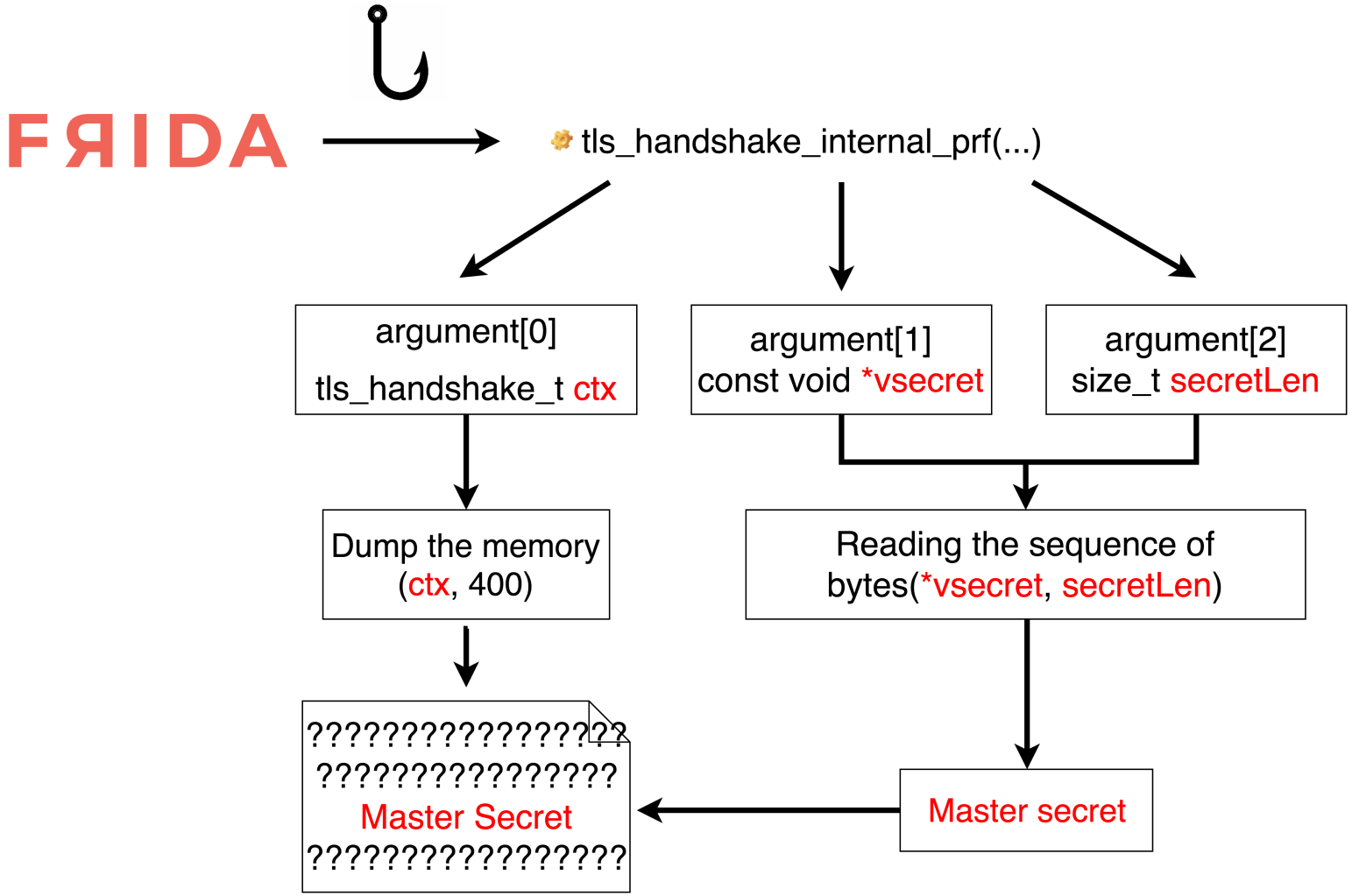
CoreTLS source

tls_handshake.h

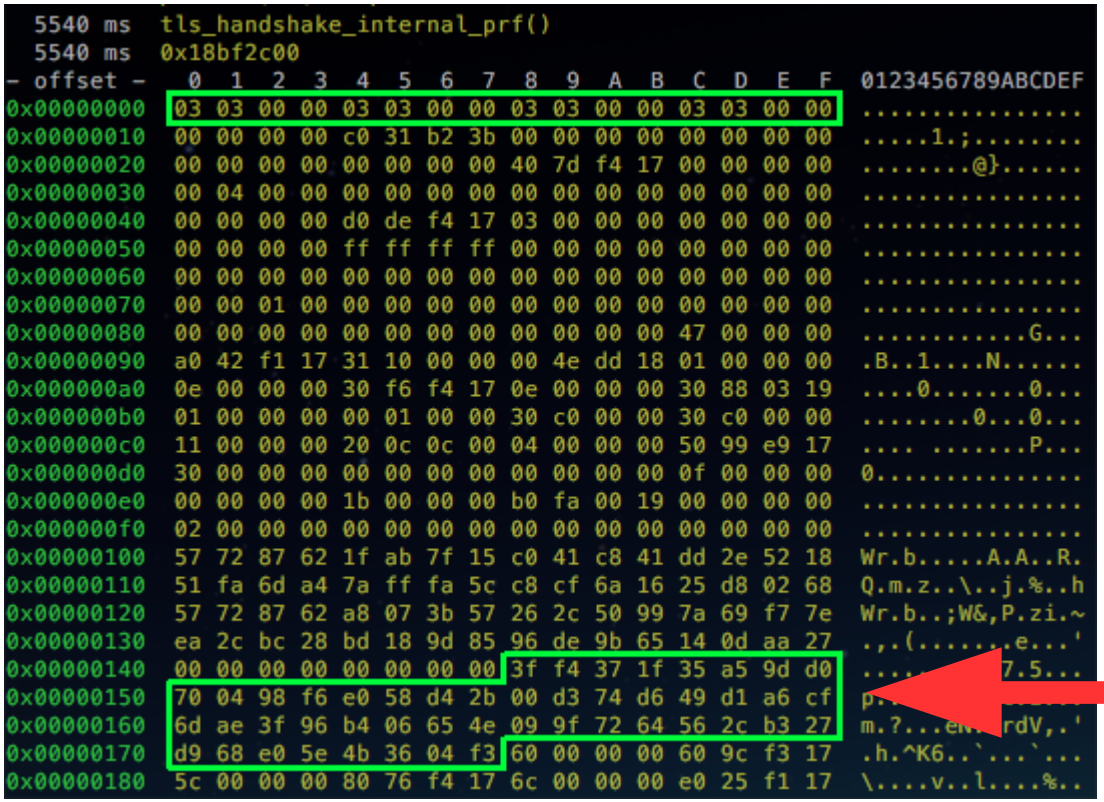
```
int tls_handshake_internal_prf(tls_handshake_t ctx,
                               const void *vsecret,
                               size_t secretLen,
                               const void *label,
                               size_t labelLen,
                               const void *seed,
                               size_t seedLen,
                               void *vout,
                               size_t outLen);
```



Using Frida


FRIDA
tls_handshake_internal_prf(...)
argument[0]
tls_handshake_t ctx
argument[1]
const void *vsecret
argument[2]
size_t secretLen
Dump the memory
(ctx, 400)
Reading the sequence of
bytes(*vsecret, secretLen)
????????????????
????????????????
Master Secret
????????????????
Master secret

Memory dump with Frida



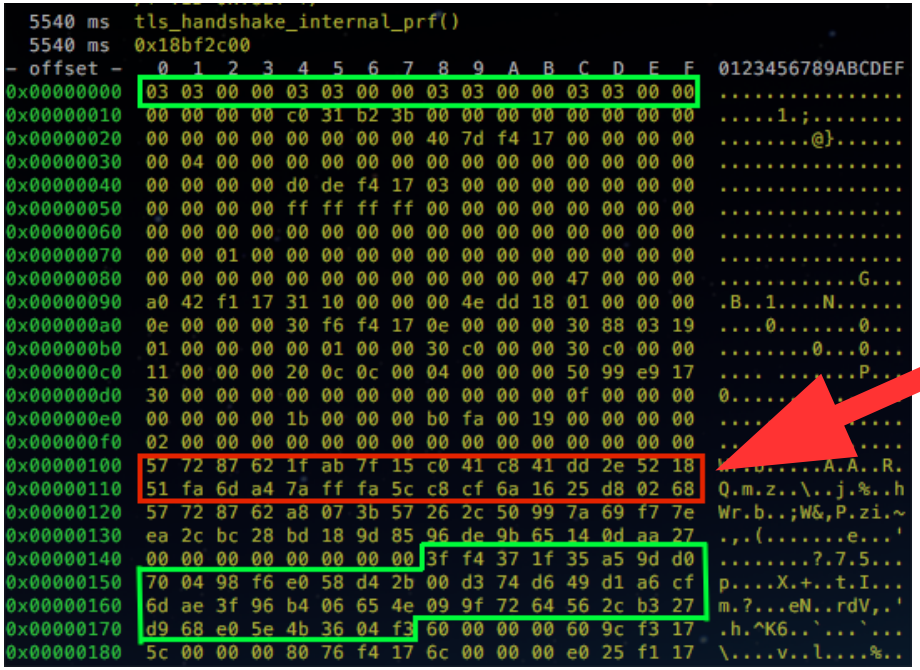
tls_types.h

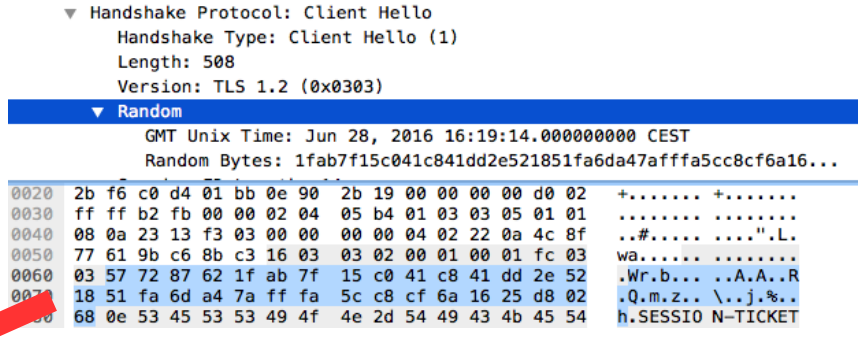
```
...
TLS_1_0 = 0x0301
TLS_1_1 = 0x0302
TLS_1_2 = 0x0303
...
```

Master secret

Finding the Identifiers

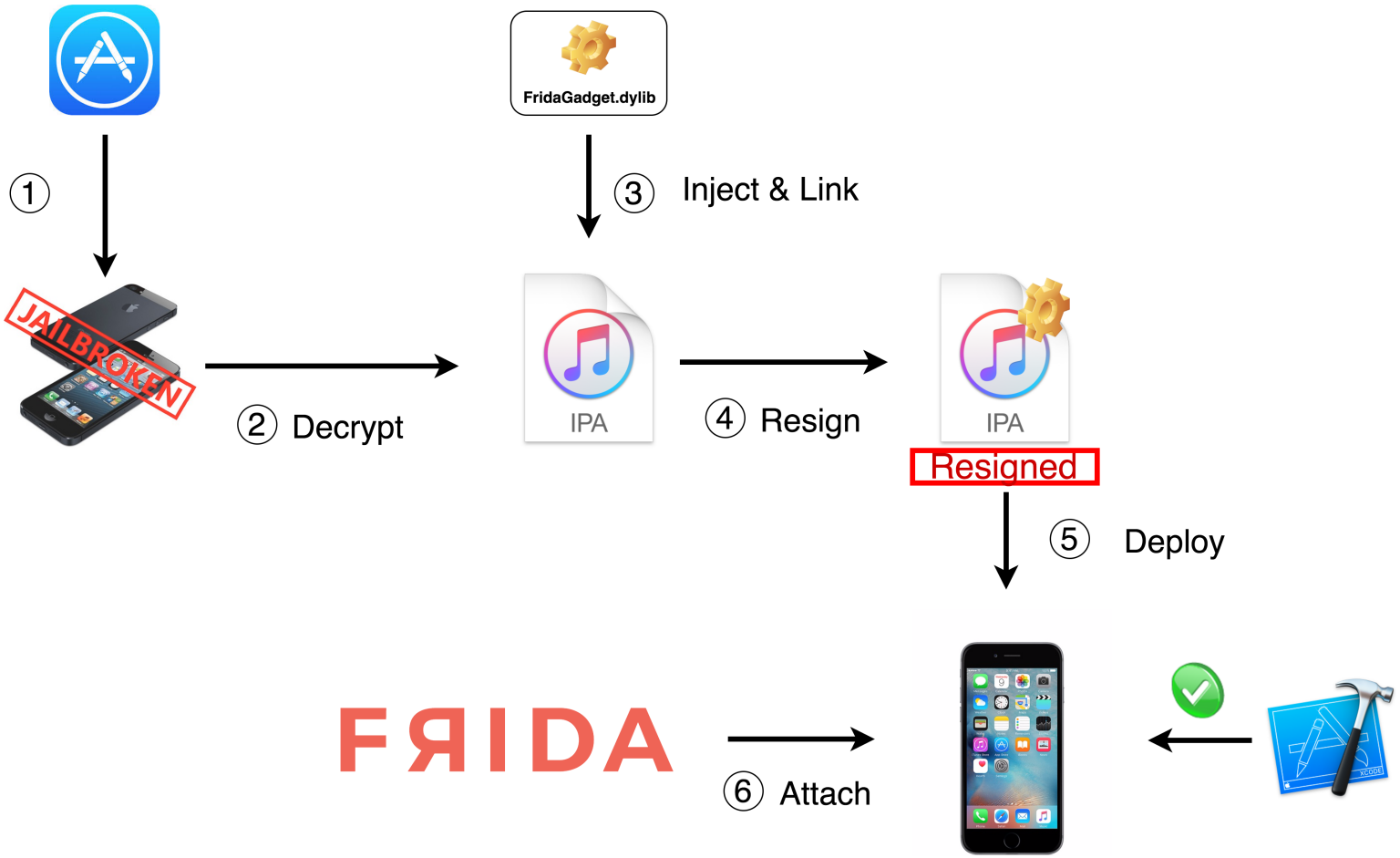
- Captured packets with Wireshark whilst running Frida
- Compared hex outputs to match identifiers





Non-jailbroken devices

Compiling Frida into an Application



Demo

Concluding Remarks

Is it possible to extract TLS session keys from the process memory of a device running iOS 9.0 or greater?

- Yes, both with jailbroken and non-jailbroken
- TLS APIs in iOS rely on coreTLS library
- Relies on Frida, also possible with lldb

Future Work

- iOS 10
- Support for OpenSSL in iOS?
- TLS 1.3 in Draft

With special thanks to

Cedric van Bockhaven @ Deloitte

Thank you for your attention!

Questions?