# LightSpy Malware Variant Targeting macOS

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On April 11, 2024, BlackBerry released a new blog detailing a new VirusTotal upload of the LightSpy mobile spyware framework. BlackBerry stated that this malware was an iOS implant, yet Huntress researchers discovered that, although the uploaded samples appear novel, they aren't actually targeting iOS at all. Instead, what was observed is a macOS variant of the LightSpy malware, which hasn't been previously reported. This new capability demonstrates that in addition to the iOS and Android, macOS users could've been targeted.

Based on BlackBerry's report, several large publications including Forbes, HackerNews, and Mashable, reported that the sample uploaded is an active and dangerous iOS threat. This is incorrect, as the sample BlackBerry analyzed will only run on Intel **macOS** devices, or Apple Silicon devices with Rosetta 2 enabled.

The publications also stated that this was a likely catalyst for Apple sending out "spyware attack alerts." We've assessed that, due to Apple's most recent support article, *About Apple threat notifications and protecting against mercenary spyware*, Apple is referring to the more recent and sophisticated Pegasus spyware from NSO Group.

It's also important to note that while we were able to find the Android version of this malware on the same C2 as the macOS version, it doesn't appear the iOS version is also present. In this article, we'll only be focusing on the macOS implant. For more information of the Android version (also known as WyrmSpy), please see this report by the ThreatFabric team.

In addition to our analysis, we're providing YARA and Sigma rules which can be used freely to detect potential usage of the macOS LightSpy variant. The text in all images or terminal screenshots are also available in the GitHub repository.

Thanks to researchers at TrendMicro, Kaspersky, and ThreatFabric for their prior work on the LightSpy framework, their contributions were incredibly helpful in our research.

## Technical Analysis

### Confirming macOS Targeting

While there is a variant of LightSpy that affects Apple's mobile devices like iPhone, this sample notably only targets the macOS platform. There are a number of factors which support this, but the largest is that these binaries are all compiled for the x86_64 architecture, ruling out iPhones based on the ARM architecture. This can be confirmed by running the **file** command against the macOS and iOS samples.

```
~/Malware/macos_lightspy_malware ❯ file *
macos_core_implant:     Mach-O 64-bit dynamically linked shared library x86_64
macos_loader:           Mach-O 64-bit executable x86_64
libAudioRecorder:       Mach-O 64-bit dynamically linked shared library x86_64
libBrowserHistory:      Mach-O 64-bit dynamically linked shared library x86_64
libCameraShot:          Mach-O 64-bit dynamically linked shared library x86_64
libFileManage:          Mach-O 64-bit dynamically linked shared library x86_64
libKeyChains:           Mach-O 64-bit dynamically linked shared library x86_64
libLanDevices:          Mach-O 64-bit dynamically linked shared library x86_64
libProcessAndApp:       Mach-O 64-bit dynamically linked shared library x86_64
libShellCommand:        Mach-O 64-bit dynamically linked shared library x86_64
libWifiList:            Mach-O 64-bit dynamically linked shared library x86_64

~/Malware/ios_lightspy_malware ❯ file *
payload:                Mach-O 64-bit dynamically linked shared library arm64
irc_loader:             Mach-O 64-bit executable arm64
BaseInfo:               Mach-O 64-bit dynamically linked shared library arm64
Browser:                Mach-O 64-bit dynamically linked shared library arm64
EnvironmentalRecording: Mach-O 64-bit executable arm64
FileManage:             Mach-O 64-bit dynamically linked shared library arm64
KeyChain:               Mach-O 64-bit dynamically linked shared library arm64
Location:               Mach-O 64-bit dynamically linked shared library arm64
Screen:                 Mach-O 64-bit dynamically linked shared library arm64
ShellCommand:           Mach-O 64-bit dynamically linked shared library arm64
SoftInfo:               Mach-O 64-bit dynamically linked shared library arm64
WifiList:               Mach-O 64-bit dynamically linked shared library arm64
```

In both cases, the structure of the implant is the same. A dropper, which loads a series of dynamically loaded modules (dylibs), similar to DLLs on Windows, that contain most of the malicious capabilities.

### Differences from iOS Version

What made LightSpy famous was an iOS version discovered in 2020, covered by both Kaspersky and TrendMicro. While there are a large number of similarities between the two, there are a few interesting differences that provide some new insight into the organization behind the framework as well as their targeting.

Generally, the macOS version seems to be more refined than the iOS version. The operational security (opsec) is significantly improved, the development practices seem more mature, and things are generally more organized. A quick example is that iOS version stores its C2 information in plain text:


*Figure 2: iOS LightSpy Downloading Plugins*

The macOS version solves this problem by using a plugin manifest, which provides more flexibility for updating plugins down the road in addition to lower static detections. Despite the various improvements, LightSpy still leaves plenty on the table when it comes to anti-analysis.

All of the binaries for both macOS and iOS contain plenty of developer artifacts. Looking specifically for file paths, we can extract a decent picture of how this malware was organized.

There are two hosts that seem to have been involved in development of LightSpy: **mac** and **air**. Obviously, there's no way to confirm that there weren't multiple development hosts with the same username, but this still helps in understanding the organization of the framework.

| | |
|---|---|
| | ├── Users |
| | │ ├── air |
| | │ │ ├── Library |
| | │ │ │ ├── |
| | │ │ │ │ └── |
| | │ │ ├── work |
| | │ │ │ ├── F_Warehouse |
| | │ │ │ │ ├── mac |
| | │ │ │ │ │ ├── |
| | │ │ │ │ │ │ └── |
| | │ │ │ │ │ ├── frame |

| | |
|---|---|
| | │ │ │ │ │ ├── framework |
| | │ │ │ │ │ │ ├── framework |
| | │ │ │ │ │ │ │ ├── A.m |
| | │ │ │ │ │ │ │ └── A.m |
| | │ │ │ │ │ │ │ ├── AsyncDataTask.m |
| | │ │ │ │ │ │ │ └── AsyncDataTask.m |
| | │ │ │ │ │ │ │ ├── AsyncFileTask.m |
| | │ │ │ │ │ │ │ └── AsyncFileTask.m |
| | │ │ │ │ │ │ │ ├── AsyncTextTask.m |
| | │ │ │ │ │ │ │ └── AsyncTextTask.m |
| | │ │ │ │ │ │ │ ├── CmdThread.m |
| | │ │ │ │ │ │ │ └── CmdThread.m |
| | │ │ │ │ │ │ │ ├── Common |
| | │ │ │ │ │ │ │ ├── DeviceID.m |
| | │ │ │ │ │ │ │ └── DeviceID.m |
| | │ │ │ │ │ │ │ ├── DeviceInformation.m |
| | │ │ │ │ │ │ │ └── DeviceInformation.m |
| | │ │ │ │ │ │ │ ├── LightLog.m |
| | │ │ │ │ │ │ │ └── LightLog.m |
| | │ │ │ │ │ │ │ ├── DormantControl.m |
| | │ │ │ │ │ │ │ └── DormantControl.m |
| | │ │ │ │ │ │ │ ├── NetWork |
| | │ │ │ │ │ │ │ ├── HttpManager.mm |
| | │ │ │ │ │ │ │ └── HttpManager.mm |
| | │ │ │ │ │ │ │ ├── SocketRocketUtility.m |
| | │ │ │ │ │ │ │ └── SocketRocketUtility.m |
| | │ │ │ │ │ │ │ ├── PermissionInfo.m |

| | |
|---|---|
| | │ │ │ │ │ │ │ │ └── PermissionInfo.m |
| | │ │ │ │ │ │ │ ├── Plugin |
| | │ │ │ │ │ │ │ ├── PluginAdapter.m |
| | │ │ │ │ │ │ │ └── PluginAdapter.m |
| | │ │ │ │ │ │ ├── SocketRocket |
| | │ │ │ │ │ │ ├── Internal |
| | │ │ │ │ │ │ │ ├── IOConsumer |
| | │ │ │ │ │ │ │ ├── SRIOConsumer.m |
| | │ │ │ │ │ │ │ └── SRIOConsumer.m |
| | │ │ │ │ │ │ ├── RunLoop |
| | │ │ │ │ │ │ │ ├── SRRunLoopThread.m |
| | │ │ │ │ │ │ │ └── SRRunLoopThread.m |
| | │ │ │ │ │ │ ├── SRWebSocket.m |
| | │ │ │ │ │ │ └── SRWebSocket.m |
| | │ │ │ │ │ ├── SyncTextTask.m |
| | │ │ │ │ │ └── SyncTextTask.m |
| | │ │ │ │ ├── database |
| | │ │ │ │ │ ├── Db.m |
| | │ │ │ │ │ └── Db.m |
| | │ │ │ │ │ ├── DbCommandPlan.m |
| | │ │ │ │ │ └── DbCommandPlan.m |
| | │ │ │ │ │ ├── DbCommandRecord.m |
| | │ │ │ │ │ └── DbCommandRecord.m |
| | │ │ │ │ │ ├── DbConfig.m |
| | │ │ │ │ │ └── DbConfig.m |
| | │ │ │ │ │ ├── DbDormantControl.m |
| | │ │ │ │ │ └── DbDormantControl.m |

```
        │ │ │ │ │ │ │ │ ├── DbPlugin.m
        │ │ │ │ │ │ │ │ └── DbPlugin.m
        │ │ │ │ │ │ │ │ ├── DbTransportControl.m
        │ │ │ │ │ │ │ │ └── DbTransportControl.m
        │ │ │ │ │ │ │ ├── fmdb
        │ │ │ │ │ │ │ │ ├── FMDatabase.m
        │ │ │ │ │ │ │ │ └── FMDatabase.m
        │ │ │ │ │ │ │ │ ├── FMDatabaseAdditions.m
        │ │ │ │ │ │ │ │ └── FMDatabaseAdditions.m
        │ │ │ │ │ │ │ │ ├── FMDatabaseQueue.m
        │ │ │ │ │ │ │ │ └── FMDatabaseQueue.m
        │ │ │ │ │ │ │ ├── framework.m
        │ │ │ │ │ │ │ └── framework.m
        │ │ │ │ │ │ │ ├── tool
        │ │ │ │ │ │ │ │ ├── NSArray+Service.m
        │ │ │ │ │ │ │ │ └── NSArray+Service.m
        │ │ │ │ │ │ │ │ ├── NSDictionary+Service.m
        │ │ │ │ │ │ │ │ └── NSDictionary+Service.m
        │ │ │ │ │ │ │ │ ├── NSString+Service.m
        │ │ │ │ │ │ │ │ └── NSString+Service.m
        │ │ │ │ │ ├── new_plugins
        │ │ │ │ │ │ ├── AudioRecorder
        │ │ │ │ │ │ ├── AudioRecorder
        │ │ │ │ │ │ │ ├── AudioRecorder.m
        │ │ │ │ │ │ │ └── AudioRecorder.m
        │ │ │ │ │ │ │ ├── utils
        │ │ │ │ │ │ │ │ ├── Utils.m
```

```
        │ │ │ │ │ │ │ │ │ └── Utils.m
        │ │ │ │ │ │ ├── BrowserHistory
        │ │ │ │ │ │ ├── BrowserHistory
        │ │ │ │ │ │ │ ├── BrowserHistory.m
        │ │ │ │ │ │ │ └── BrowserHistory.m
        │ │ │ │ │ │ │ ├── utils
        │ │ │ │ │ │ │ │ ├── Utils.m
        │ │ │ │ │ │ │ │ └── Utils.m
        │ │ │ │ │ │ ├── CameraShot
        │ │ │ │ │ │ ├── CameraShot
        │ │ │ │ │ │ │ ├── CameraShot.m
        │ │ │ │ │ │ │ └── CameraShot.m
        │ │ │ │ │ │ │ ├── utils
        │ │ │ │ │ │ │ │ ├── Utils.m
        │ │ │ │ │ │ │ │ └── Utils.m
        │ │ │ │ │ │ ├── FileManage
        │ │ │ │ │ │ ├── FileManage
        │ │ │ │ │ │ │ ├── FileManage.m
        │ │ │ │ │ │ │ └── FileManage.m
        │ │ │ │ │ │ ├── KeyChains
        │ │ │ │ │ │ ├── KeyChains
        │ │ │ │ │ │ │ ├── KeyChains.m
        │ │ │ │ │ │ │ └── KeyChains.m
        │ │ │ │ │ │ │ ├── utils
        │ │ │ │ │ │ │ │ ├── Utils.m
        │ │ │ │ │ │ │ │ └── Utils.m
        │ │ │ │ │ │ ├── LanDevices
```

```
        │ │ │ │ │ │ ├── LanDevices
        │ │ │ │ │ │ ├── LanDevices.m
        │ │ │ │ │ │ └── LanDevices.m
        │ │ │ │ │ │ ├── libs
        │ │ │ │ │ │ ├── SimplePing.m
        │ │ │ │ │ │ └── SimplePing.m
        │ │ │ │ │ │ ├── utils
        │ │ │ │ │ │ ├── Utils.m
        │ │ │ │ │ │ └── Utils.m
        │ │ │ │ │ ├── ProcessAndApp
        │ │ │ │ │ ├── ProcessAndApp
        │ │ │ │ │ ├── ProcessAndApp.m
        │ │ │ │ │ └── ProcessAndApp.m
        │ │ │ │ │ ├── utils
        │ │ │ │ │ ├── Utils.m
        │ │ │ │ │ └── Utils.m
        │ │ │ │ ├── ShellCommand
        │ │ │ │ ├── ShellCommand
        │ │ │ │ ├── ShellCommand.m
        │ │ │ │ └── ShellCommand.m
        │ │ │ │ ├── WifiList
        │ │ │ │ ├── WifiList
        │ │ │ │ ├── WifiList.m
        │ │ │ │ └── WifiList.m
        │ │ │ │ ├── utils
        │ │ │ │ ├── Utils.m
        │ │ │ │ └── Utils.m
```

```
    │ │ │ ├── znf_ios
    │ │ │ │ ├── mac
    │ │ │ │ │ ├── frame
    │ │ │ │ │ │ ├── macircloader
    │ │ │ │ │ │ │ ├── macircloader
    │ │ │ │ │ │ │ │ ├── Configuration.mm
    │ │ │ │ │ │ │ │ │ └── Configuration.mm
    │ │ │ │ │ │ │ │ ├── Downloader.mm
    │ │ │ │ │ │ │ │ │ └── Downloader.mm
    │ │ │ │ │ │ │ │ ├── FrameworkLoader.mm
    │ │ │ │ │ │ │ │ │ └── FrameworkLoader.mm
    │ │ │ │ │ │ │ │ ├── Utils.mm
    │ │ │ │ │ │ │ │ │ └── Utils.mm
    │ │ ├── mac
    │ │ │ ├── Downloads
    │ │ │ │ ├── jbreak
    │ │ │ │ │ ├── sock_port
    │ │ │ │ │ │ ├── iosurface.c
    │ │ │ │ │ │ │ └── iosurface.c
    │ │ │ │ │ │ ├── source
    │ │ │ │ │ │ │ ├── KernelUtilities.m
    │ │ │ │ │ │ │ │ └── KernelUtilities.m
    │ │ │ │ │ │ │ ├── diagnostics.m
    │ │ │ │ │ │ │ │ └── diagnostics.m
    │ │ │ │ │ │ │ ├── jailbreak.m
    │ │ │ │ │ │ │ │ └── jailbreak.m
    │ │ │ │ │ │ │ ├── kernel_alloc.c
```

```
        │ │ │ │ │ └── kernel_alloc.c
        │ │ │ │ ├── kernel_call.c
        │ │ │ │ │ └── kernel_call.c
        │ │ │ │ ├── kernel_slide.c
        │ │ │ │ │ └── kernel_slide.c
        │ │ │ │ ├── log.c
        │ │ │ │ │ └── log.c
        │ │ │ │ ├── platform.c
        │ │ │ │ │ └── platform.c
        │ │ │ │ ├── platform_match.c
        │ │ │ │ │ └── platform_match.c
        │ │ │ │ ├── prefs.m
        │ │ │ │ │ └── prefs.m
        │ │ │ │ ├── user_client.c
        │ │ │ │ │ └── user_client.c
        │ │ │ │ ├── utils.m
        │ │ │ │ │ └── utils.m
        │ │ │ │ ├── voucher_swap.c
        │ │ │ │ │ └── voucher_swap.c
        │ │ ├── framwork
        │ │ │ ├── CocoaLumberjack
        │ │ │ │ ├── Sources
        │ │ │ │ │ ├── CocoaLumberjack
        │ │ │ │ │ │ ├── DDFileLogger.m
        │ │ │ │ │ │ │ └── DDFileLogger.m
        │ │ │ │ │ │ ├── DDLog.m
        │ │ │ │ │ │ │ └── DDLog.m
```

| | |
|---|---|
| | │ │ │ │ │ ├── DDTTYLogger.m |
| | │ │ │ │ │ └── DDTTYLogger.m |
| | │ │ ├── hs |
| | │ │ │ ├── dev |
| | │ │ │ │ ├── iosmm |
| | │ │ │ │ │ ├── light |
| | │ │ │ │ │ │ ├── ShellCommand |
| | │ │ │ │ │ │ │ ├── ShellCommand |
| | │ │ │ │ │ │ │ │ ├── ShellCommand.m |
| | │ │ │ │ │ │ │ │ └── ShellCommand.m |
| | │ │ │ │ │ │ ├── SoftInfo |
| | │ │ │ │ │ │ │ ├── SoftInfo |
| | │ │ │ │ │ │ │ │ ├── SoftInfo.m |
| | │ │ │ │ │ │ │ │ └── SoftInfo.m |
| | │ │ │ │ │ │ ├── WifiList |
| | │ │ │ │ │ │ │ ├── WifiList |
| | │ │ │ │ │ │ │ │ ├── WifiList.m |
| | │ │ │ │ │ │ │ │ └── WifiList.m |
| | │ │ │ │ │ │ ├── browser |
| | │ │ │ │ │ │ │ ├── browser |
| | │ │ │ │ │ │ │ │ ├── browser.m |
| | │ │ │ │ │ │ │ │ └── browser.m |
| | │ │ ├── work |
| | │ │ │ ├── F_Warehouse |
| | │ │ │ │ ├── ios |
| | │ │ │ │ │ ├── landevices |
| | │ │ │ │ │ │ ├── landevices |

```
    │ │ │ │ │ │ ├── Libraries
    │ │ │ │ │ │ ├── External Libs
    │ │ │ │ │ │ ├── SimplePing
    │ │ │ │ │ │ ├── SimplePing.m
    │ │ │ │ │ │ └── SimplePing.m
    │ │ ├── baseinfo_plugin
    │ │ ├── plugin_utils
    │ │ ├── BasePlugin.mm
    │ │ └── BasePlugin.mm
    │ ├── irc_framework
    │ │ ├── KeyChain
    │ │ ├── KeyChain
    │ │ ├── KeyChain.m
    │ │ └── KeyChain.m
    │ │ ├── light
    │ │ ├── FileManage
    │ │ ├── FileManage
    │ │ ├── FileManage.m
    │ │ └── FileManage.m
    │ ├── light
    │ │ ├── light
    │ │ ├── fmdb
    │ │ ├── FMDatabase.m
    │ │ └── FMDatabase.m
    │ │ ├── FMDatabaseQueue.m
    │ │ └── FMDatabaseQueue.m
```

## Stage 1: Dropper

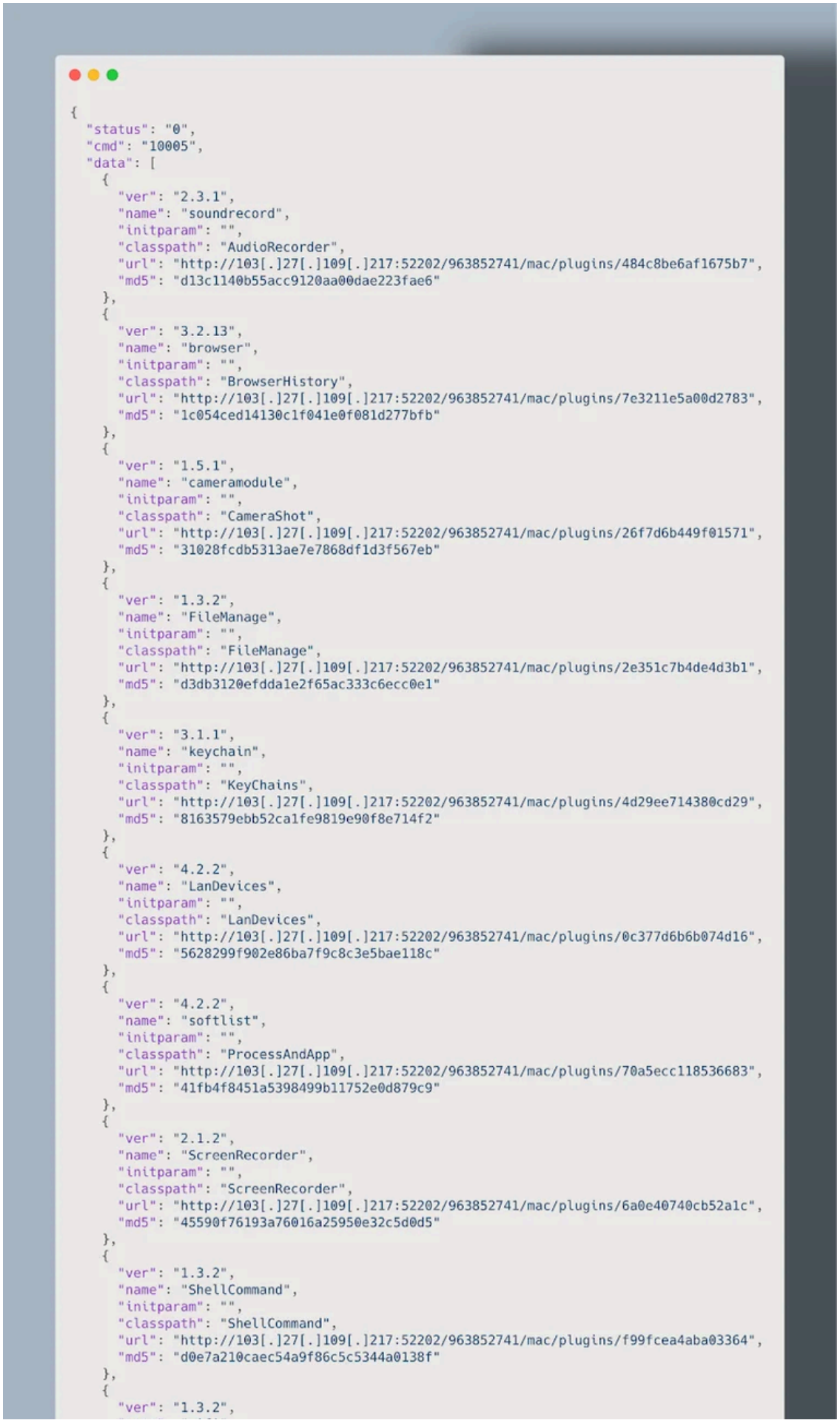
The first stage of this malware is a dropper (SHA256: **afd03337d1500d6af9bc447bd900df26786ea4a4**) which downloads and runs the core implant dylib.

**Checking PID File:**
The macOS version of this malware makes use of a process identification number (PID) file located at **/Users/Shared/irc.pid** to verify that the implant isn't already running. A PID file is just a file containing the PID of a running process—it's used to verify a specific running process in order to reference it at a later time.

**Configuration Extraction:**
The configuration for this malware is appended to the end of the binary (in this case the last **0x1d0** bytes) and is encrypted with AES with a static key of **3e2717e8b3873b29**.

```
{
"cc_ip" = "103[.]27[.]109[.]217",
"framework_param" = "s10|12|27",
"install_path" = "/Users/Shared/update.app/Contents",
"manifest_url" = "http[:]//103[.]27[.]109[.]217:52202/963852741/mac/macmanifest.json",
"irc_url" = "http[:]//103[.]27[.]109[.]217:52202/963852741/mac/",
"cc_port":"51200",
}
```

**Download Stage 2 and Plugins:**
Before downloading the plugins from the C2 server, the dropper requests **macmanifest.json** which contains lots of information about the plugins. The MD5s correspond to the encrypted versions.




```
{
  "status": "0",
  "cmd": "10005",
  "data": [
    {
      "ver": "2.3.1",
      "name": "soundrecord",
      "initparam": "",
      "classpath": "AudioRecorder",
      "url": "http://103[.]27[.]109[.]217:52202/963852741/mac/plugins/484c8be6af1675b7",
      "md5": "d13c1140b55acc9120aa00dae223fae6"
    },
    {
      "ver": "3.2.13",
      "name": "browser",
      "initparam": "",
      "classpath": "BrowserHistory",
      "url": "http://103[.]27[.]109[.]217:52202/963852741/mac/plugins/7e3211e5a00d2783",
      "md5": "1c054ced14130c1f041e0f081d277bfb"
    },
    {
      "ver": "1.5.1",
      "name": "cameramodule",
      "initparam": "",
      "classpath": "CameraShot",
      "url": "http://103[.]27[.]109[.]217:52202/963852741/mac/plugins/26f7d6b449f01571",
      "md5": "31028fcdb5313ae7e7868df1d3f567eb"
    },
    {
      "ver": "1.3.2",
      "name": "FileManage",
      "initparam": "",
      "classpath": "FileManage",
      "url": "http://103[.]27[.]109[.]217:52202/963852741/mac/plugins/2e351c7b4de4d3b1",
      "md5": "d3db3120efdda1e2f65ac333c6ecc0e1"
    },
    {
      "ver": "3.1.1",
      "name": "keychain",
      "initparam": "",
      "classpath": "KeyChains",
      "url": "http://103[.]27[.]109[.]217:52202/963852741/mac/plugins/4d29ee714380cd29",
      "md5": "8163579ebb52ca1fe9819e90f8e714f2"
    },
    {
      "ver": "4.2.2",
      "name": "LanDevices",
      "initparam": "",
      "classpath": "LanDevices",
      "url": "http://103[.]27[.]109[.]217:52202/963852741/mac/plugins/0c377d6b6b074d16",
      "md5": "5628299f902e86ba7f9c8c3e5bae118c"
    },
    {
      "ver": "4.2.2",
      "name": "softlist",
      "initparam": "",
      "classpath": "ProcessAndApp",
      "url": "http://103[.]27[.]109[.]217:52202/963852741/mac/plugins/70a5ecc118536683",
      "md5": "41fb4f8451a5398499b11752e0d879c9"
    },
    {
      "ver": "2.1.2",
      "name": "ScreenRecorder",
      "initparam": "",
      "classpath": "ScreenRecorder",
      "url": "http://103[.]27[.]109[.]217:52202/963852741/mac/plugins/6a0e40740cb52a1c",
      "md5": "45590f76193a76016a25950e32c5d0d5"
    },
    {
      "ver": "1.3.2",
      "name": "ShellCommand",
      "initparam": "",
      "classpath": "ShellCommand",
      "url": "http://103[.]27[.]109[.]217:52202/963852741/mac/plugins/f99fcea4aba03364",
      "md5": "d0e7a210caec54a9f86c5c5344a0138f"
    },
    {
      "ver": "1.3.2",
```


*Figure 3: manifest.json file*

**Payload Verification:**

After downloading the core **dylib** responsible, another call is made to the following address:

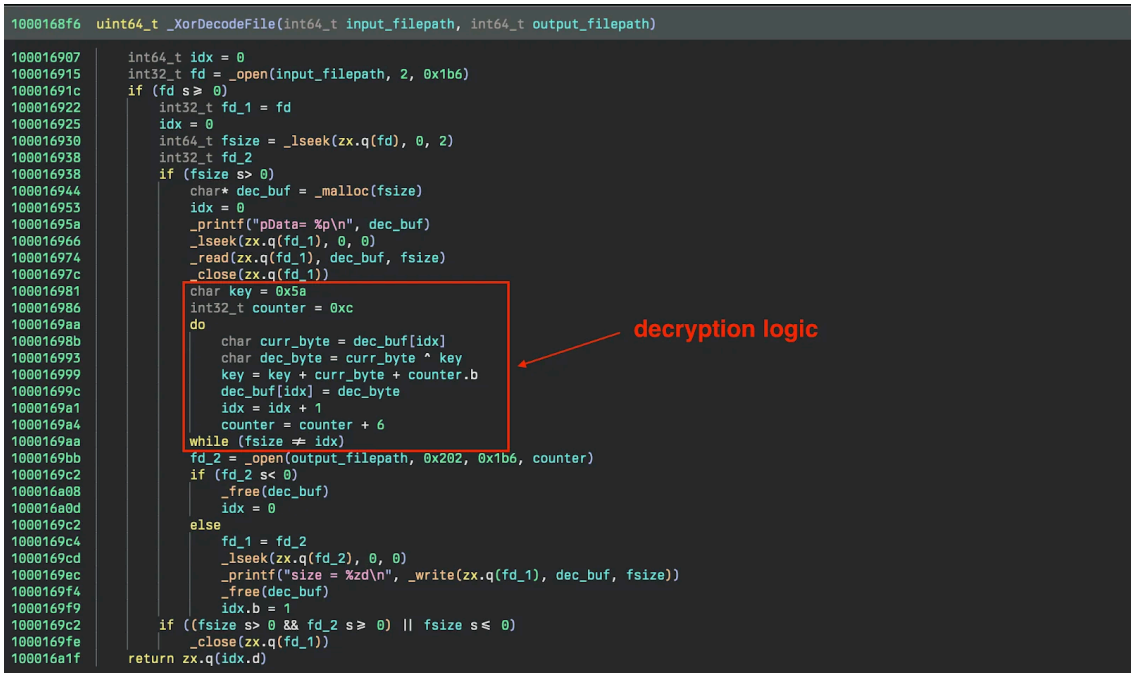
| | |
|---|---|
| | http[:]//103[.]27[.]109[.]217:52202/963852741/mac/macversion.json |

Which returns a JSON blob used to verify the integrity of the second stage. The other interesting aspect to note is the date, which shows this being at least three years old. This timeframe lines up with the original discovery of the LightSpy malware in 2020.

| | |
|---|---|
| | { |
| | "date":"2021-06-30", |
| | "filename":"C40F0D27", |
| | "md5":"a381ea6193f3efd3b587c4a8e67706bf" |
| | } |

**Payload Decryption:**

The plugins and core dylib are encrypted with a rolling-type XOR located in the **_XorDecodeFile** function.




```
1000168f6  uint64_t _XorDecodeFile(int64_t input_filepath, int64_t output_filepath)

100016907      int64_t idx = 0
100016915      int32_t fd = _open(input_filepath, 2, 0x1b6)
10001691c      if (fd s≥ 0)
100016922          int32_t fd_1 = fd
100016925          idx = 0
100016930          int64_t fsize = _lseek(zx.q(fd), 0, 2)
100016938          int32_t fd_2
100016938          if (fsize s> 0)
100016944              char* dec_buf = _malloc(fsize)
100016953              idx = 0
10001695a              _printf("pData= %p\n", dec_buf)
100016966              _lseek(zx.q(fd_1), 0, 0)
100016974              _read(zx.q(fd_1), dec_buf, fsize)
10001697c              _close(zx.q(fd_1))
100016981              char key = 0x5a
100016986              int32_t counter = 0xc
1000169aa              do
10001698b                  char curr_byte = dec_buf[idx]
100016993                  char dec_byte = curr_byte ^ key
100016999                  key = key + curr_byte + counter.b
10001699c                  dec_buf[idx] = dec_byte
1000169a1                  idx = idx + 1
1000169a4                  counter = counter + 6
1000169aa              while (fsize ≠ idx)
1000169bb              fd_2 = _open(output_filepath, 0x202, 0x1b6, counter)
1000169c2              if (fd_2 s< 0)
100016a08                  _free(dec_buf)
100016a0d                  idx = 0
1000169c2              else
1000169c4                  fd_1 = fd_2
1000169cd                  _lseek(zx.q(fd_2), 0, 0)
1000169ec                  _printf("size = %zd\n", _write(zx.q(fd_1), dec_buf, fsize))
1000169f4                  _free(dec_buf)
1000169f9                  idx.b = 1
1000169c2          if ((fsize s> 0 && fd_2 s≥ 0) || fsize s≤ 0)
1000169fe              _close(zx.q(fd_1))
100016a1f      return zx.q(idx.d)
```

*Figure 4: Screenshot of decryption function decompilation*

Luckily, reimplementing the routine is quite simple and allows for easy analysis of the downloaded plugins.

| | |
|---|---|
| | xor_key = 0x5A |
| | xor_increment = 0xC |
| | decoded_data = bytearray() |
| | for byte in data: |
| | decoded_byte = byte ^ xor_key |
| | xor_key = (xor_key + byte + xor_increment) & 0xFF |
| | xor_increment = (xor_increment + 6) & 0xFF |
| | decoded_data.append(decoded_byte) |

## Stage 2: Implant

The second stage (SHA256: **0f66a4daba647486d2c9d838592cba298df2dbf38f2008b6571af8a562bc306c**) is responsible for loading, maintaining, and using the plugins. During this stage, the implant queries the device for system information using the `DeviceInformation` class. It collects a standard set of device information:

```
➜  diff diff -y ios.txt macos.txt | colordiff
_+[DeviceInformation deviceNetType]                              _+[DeviceInformation deviceNetType]
_+[DeviceInformation getAPPVerion]                               _+[DeviceInformation getAPPVerion]
_+[DeviceInformation getAvailableMemorySize]                     _+[DeviceInformation getAvailableMemorySize]
_+[DeviceInformation getAvailableRomSize]                        _+[DeviceInformation getAvailableRomSize]
_+[DeviceInformation getBatteryLevel]                    <
_+[DeviceInformation getBatteryState]                    <
_+[DeviceInformation getCpuCores]                                _+[DeviceInformation getCpuCores]
_+[DeviceInformation getCpuFreq]                                 _+[DeviceInformation getCpuFreq]
_+[DeviceInformation getCpuType]                                 _+[DeviceInformation getCpuType]
_+[DeviceInformation getCpuUsage]                                _+[DeviceInformation getCpuUsage]
_+[DeviceInformation getCurrentBatteryLevel]             <
_+[DeviceInformation getDeviceIPAdress]                          _+[DeviceInformation getDeviceIPAdress]
_+[DeviceInformation getDeviceInfoWithJson]                      _+[DeviceInformation getDeviceInfoWithJson]
_+[DeviceInformation getDeviceName]                              _+[DeviceInformation getDeviceName]
_+[DeviceInformation getDeviceNetworkName]                       _+[DeviceInformation getDeviceNetworkName]
_+[DeviceInformation getIMEI]                            <
_+[DeviceInformation getIMSI]                            <
_+[DeviceInformation getNetworkType]                     <
_+[DeviceInformation getPhoneNumber]                     <
_+[DeviceInformation getRunningProcesses]                        _+[DeviceInformation getRunningProcesses]
_+[DeviceInformation getScreenSizeInches]                        _+[DeviceInformation getScreenSizeInches]
_+[DeviceInformation getSysctlIntValue:]                         _+[DeviceInformation getSysctlIntValue:]
_+[DeviceInformation getSystlStringValue:]                       _+[DeviceInformation getSystlStringValue:]
_+[DeviceInformation getTotalMemorySize]                         _+[DeviceInformation getTotalMemorySize]
_+[DeviceInformation getTotalRomSize]                            _+[DeviceInformation getTotalRomSize]
_+[DeviceInformation getUUID]                            <
_+[DeviceInformation getWifiInfo]                                _+[DeviceInformation getWifiInfo]
_+[DeviceInformation getiPhoneName]                              _+[DeviceInformation getiPhoneName]
_+[DeviceInformation networktype]                                _+[DeviceInformation networktype]
_+[DeviceInformation platform]                                   _+[DeviceInformation platform]
                                                         >       _+[DeviceInformation screenResolutio]
```

*Figure 5: Diff of DeviceInformation function, iOS on left and macOS on right*

When you diff the methods within that class, the macOS version doesn't collect information that would be found on a phone such as the International Mobile Subscriber Identity (IMSI) or International Mobile Equipment Identity (IMEI) numbers. Additionally, when analyzing functions like **getScreenSizeInches**, the iOS version will return dimensions of iOS devices, whereas the macOS version only returns a single string, **13.3 inches**.

```
00026244  int64_t _+[DeviceInformation getScreenSizeInches]() __pure
00026250  |    return &cf_133Inches  // {"13.3 inches"}
```

*Figure 6: macOS version of getScreenSizeInches*

```
0000b53c  int64_t _+[DeviceInformation getScreenSizeInches]()

0000b558      int64_t x8 = *___stack_chk_guard
0000b568      void var_538
0000b568      _uname(&var_538)
0000b584      void var_138
0000b584      _objc_msgSend(_OBJC_CLASS_$_NSString, "stringWithCString:encoding:", &var_138, 4)
0000b58c      int64_t x0_2 = _objc_retainAutoreleasedReturnValue()
0000b5ac      struct CFString* x20
0000b5ac      if (_objc_msgSend() != 0)
0000b5fc          label_b5fc:
0000b5fc          x20 = &cf_35Inches
0000b5ac      else
0000b5c4          if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone32) != 0)
0000b5c4              goto label_b5fc
0000b5dc          if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone33) != 0)
0000b5dc              goto label_b5fc
0000b5f4          if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone41) != 0)
0000b5f4              goto label_b5fc
0000b654          if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone51) != 0)
0000b6d4              label_b6d4:
0000b6d4              x20 = &cf_40Inches
0000b654          else
0000b66c              if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone52) != 0)
0000b66c                  goto label_b6d4
0000b684              if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone53) != 0)
0000b684                  goto label_b6d4
0000b69c              if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone54) != 0)
0000b69c                  goto label_b6d4
0000b6b4              if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone61) != 0)
0000b6b4                  goto label_b6d4
0000b6cc              if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone62) != 0)
0000b6cc                  goto label_b6d4
0000b6f0              if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone71) != 0)
0000b728                  label_b728:
0000b728                  x20 = &cf_55Inches
0000b6f0              else if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone72) != 0)
0000b7dc                  label_b7dc:
0000b7dc                  x20 = &cf_47Inches
0000b708              else
0000b720                  if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone81) != 0)
0000b720                      goto label_b728
0000b744                  if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone82) != 0)
0000b744                      goto label_b7dc
0000b75c                  if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone84) != 0)
0000b75c                      goto label_b6d4
0000b774                  if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone91) != 0)
0000b774                      goto label_b7dc
0000b78c                  if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone92) != 0)
0000b78c                      goto label_b728
0000b7a4                  if (_objc_msgSend(x0_2, "isEqualToString:", &cf_IPhone93) != 0)
```

*Figure 7: iOS version of getScreenSizeInches*

Communication with the C2 is still performed over WebSockets using the open source library SocketRocket with all the standard functionality you'd expect: sending heartbeats, receiving commands, updating command status, etc.

### Stage 3: Plugins

This particular implant downloads 10 additional payloads, each to accomplish a particular task. Since they've been covered pretty extensively, we noted below, in the IOCs, the different plugins (dylibs) that are associated with the macOS variant.

| **iOS Implant[2]** | **macOS Implant** |
|---|---|
| | AudioRecorder (Plugin ID: 18000) |
| Browser (Plugin ID: 14000) | BrowserHistory (Plugin ID: 14000) |
| | CameraShot (Plugin ID: 19000) |
| FileManage (Plugin ID: 15000) | FileManage (Plugin ID: 15000) |
| KeyChain (Plugin ID: 31000) | KeyChains (Plugin ID: 31000) |
| | LanDevices (Plugin ID: 33000) |
| | ProcessAndApp (Plugin ID: 16000) |
| | ScreenRecorder (Plugin ID: 34000) |
| ShellCommandaaa (Plugin ID: 20000) | ShellCommand (Plugin ID: 20000) |
| WifiList (Plugin ID: 17000) | WifiList (Plugin ID: 17000) |
| BasicInfo (Plugin ID: 11000) | |
| SoftInfoaaa (Plugin ID: 16000) | |
| Screenaaa (Plugin ID: 33000) | |
| Locationaaa  (Plugin ID: 13000) | |
| iOS WeChat (Plugin ID: 12000) | |
| iOS QQ (Plugin ID: 25000) | |
| iOS Telegram (Plugin ID: 26000) | |

## Conclusion

Even though we've historically seen LightSpy target iOS, this variant very clearly is targeting macOS. As the macOS landscape constantly evolves, and attacks that specifically target the Apple ecosystem become more prevalent, we wanted to include some detection opportunities here as well.

It's also worth noting that while this sample was uploaded to VirusTotal recently from India, this isn't a particularly strong indicator of an active campaign, nor targeting within the region. It's a contributing factor, but without more concrete evidence or visibility into delivery mechanisms, it should be taken with a heavy grain of salt.

While we haven't made any attribution claims in this post, most prior research has associated this malware to APT 41. We're confident that this sample is indeed part of the LightSpy framework, and have no reason to disagree with that attribution.

Apple, in an attempt to thwart threat actors, has introduced new features to their *OS such as Lockdown Mode, additional TCC restrictions, and constantly evolving XProtect/XProtectRemediator modules designed to protect the end user. It's also a great opportunity to remember to keep devices updated, regardless of platform.

## Appendix A

We created YARA rules that will detect the implant, loader, and the dylibs. We included a private rule that will assist in paring down detections to only Macho binaries. It's important to note that without that private rule, the rules will not run, as they all check for a Macho in their condition. The rules are available below and on GitHub.

### YARA Rules

```
private rule Macho {
meta:
description = "private rule to match Mach-O binaries"
condition:
uint32(0) == 0xfeedface or uint32(0) == 0xcefaedfe or uint32(0) == 0xfeedfacf or uint32(0) == 0xcffaedfe or uint32(0) == 0xcafebabe or uint32(0) == 0xbebafeca

}

rule MACOS_LIGHTSPY_LOADER_20240422 {
meta:
description = "Detects on the LightSpy loader"
author = "Stuart Ashenbrenner, Alden Schmidt"
date = "2024-04-22"
modified = "2024-04-22"

reference = "https://huntress.com/blog/lightspy-malware-variant-targeting-macos"
hash1 = "4b973335755bd8d48f34081b6d1bea9ed18ac1f68879d4b0a9211bbab8fa5ff4"
hash2 = "77e983dcde7752278c0fbfc29d92b237c3961de7517d7bcf0877ce83e9b58278"

strings:
$a0 = "FrameworkLoader"
```

```
$a1 = "PLATFORM_MACOS"
$a2 = { 44 6f 77 6e 6c 6f 61 64 65 72 }

condition:
Macho and all of them
}

rule MACOS_LIGHTSPY_IMPLANT_20240422 {
meta:
description = "Detects on the LightSpy implant"
author = "Stuart Ashenbrenner, Alden Schmidt"
date = "2024-04-22"
modified = "2024-04-22"

reference = "https://huntress.com/blog/lightspy-malware-variant-targeting-macos"
hash1 = "0f66a4daba647486d2c9d838592cba298df2dbf38f2008b6571af8a562bc306c"

strings:
$a0 = { 52 65 61 6c 54 69 6d 65 43 6d 64 }
$a1 = { 73 65 6c 65 63 74 20 2a 20 66 72 6f 6d 20 74 5f 63 6f 6e 66 69 67 }
$a2 = { 2f 76 61 72 2f 63 6f 6e 74 61 69 6e 65 72 73 2f 42 75 6e 64 6c 65 2f 69 72 63 62 69 6e 2e 70 6c 69 73 74 }
$a3 = { 74 5f 63 6f 6d 6d 61 6e 64 5f 70 6c 61 6e }
$a4 = { 63 6f 6d 2e 61 6c 61 6d 6f 66 69 72 65 2e }

condition:
Macho and all of them
}

rule MACOS_LIGHTSPY_AUDIODYLIB_20240422 {
```

```
    meta:
    description = "Detects on the LightSpy libAudioRecorder dylib"
    author = "Stuart Ashenbrenner, Alden Schmidt"
    date = "2024-04-22"
    modified = "2024-04-22"

    reference = "https://huntress.com/blog/lightspy-malware-variant-targeting-macos"
    hash1 = "0f662991dbd0568fc073b592f46e60b081eedf0c18313f2c3789e8e3f7cb8144"

    strings:
    $path = "/usr/local/lib/libAudioRecorder.dylib"

    $a0 = { 61 72 63 6c 69 74 65 }
    $a1 = { 41 75 64 69 6f 52 65 63 6f 72 64 65 72 }

    condition:
    Macho and all of them
    }

    rule MACOS_LIGHTSPY_BROWSERHISTORYDYLIB_20240422 {
    meta:
    description = "Detects on the LightSpy libBrowserHistory dylib"
    author = "Stuart Ashenbrenner, Alden Schmidt"
    date = "2024-04-22"
    modified = "2024-04-22"

    reference = "https://huntress.com/blog/lightspy-malware-variant-targeting-macos"
    hash1 = "3d6ef4d88d3d132b1e479cf211c9f8422997bfcaa72e55e9cc5d985fd2939e6d"

    strings:
    $path = "/usr/local/lib/libBrowserHistory.dylib"
```

```
$a0 = "/Library/Application Support/Google/Chrome/Default/History"
$a1 = "/Library/Safari/History.db"
$a2 = { 42 72 6f 77 73 65 72 48 69 73 74 6f 72 79 }
$a3 = { 61 72 63 6c 69 74 65 }

condition:
Macho and all of them
}

rule MACOS_LIGHTSPY_CAMERADYLIB_20240422 {
meta:
description = "Detects on the LightSpy libCameraShot dylib"
author = "Stuart Ashenbrenner, Alden Schmidt"
date = "2024-04-22"
modified = "2024-04-22"

reference = "https://huntress.com/blog/lightspy-malware-variant-targeting-macos"
hash1 = "18bad57109ac9be968280ea27ae3112858e8bc18c3aec02565f4c199a7295f3a"

strings:
$path = "/usr/local/lib/libCameraShot.dylib"

$a0 = { 61 72 63 6c 69 74 65 }
$a1 = { 43 61 6d 65 72 61 53 68 6f 74 }
$a2 = { 54 61 6b 65 50 69 63 74 75 72 65 2e (6d | 68) }

condition:
Macho and all of them
}

rule MACOS_LIGHTSPY_FILEMANAGEDYLIB_20240422 {
```

```
    meta:
    description = "Detects on the LightSpy libFileManage dylib"
    author = "Stuart Ashenbrenner, Alden Schmidt"
    date = "2024-04-22"
    modified = "2024-04-22"

    reference = "https://huntress.com/blog/lightspy-malware-variant-targeting-macos"
    hash1 = "5fb67d42575151dd2a04d7dda7bd9331651c270d0f4426acd422b26a711156b5"

    strings:
    $path = "/usr/local/lib/libFileManage.dylib"

    $a0 = "GetTelegramFileDir"
    $a1 = { 46 69 6c 65 4d 61 6e 61 67 65 20 44 6f 77 6e 4c 6f 61 64 46 69 6c 65 }

    condition:
    Macho and all of them
    }

    rule MACOS_LIGHTSPY_KEYCHAINDYLIB_20240422 {
    meta:
    description = "Detects on the LightSpy libKeyChains dylib"
    author = "Stuart Ashenbrenner, Alden Schmidt"
    date = "2024-04-22"
    modified = "2024-04-22"

    reference = "https://huntress.com/blog/lightspy-malware-variant-targeting-macos"
    hash1 = "65aa91d8ae68e64607652cad89dab3273cf5cd3551c2c1fda2a7b90aed2b3883"

    strings:
    $path = "/usr/local/lib/libKeyChains.dylib"
```

```
$a0 = { 6d 61 63 20 4b 65 79 20 43 68 61 69 6e 73 }
$a1 = { 2f 61 70 69 2f 6b 65 79 63 68 61 69 6e }
$a2 = { 6b 53 65 63 41 74 74 72 49 73 73 75 65 72 }
$a3 = "PLATFORM_MACOS"

condition:
Macho and all of them
}

rule MACOS_LIGHTSPY_LANDYLIB_20240422 {
meta:
description = "Detects on the LightSpy libLanDevices dylib"
author = "Stuart Ashenbrenner, Alden Schmidt"
date = "2024-04-22"
modified = "2024-04-22"

reference = "https://huntress.com/blog/lightspy-malware-variant-targeting-macos"
hash1 = "4511567b33915a4c8972ef16e5d7de89de5c6dffe18231528a1d93bfc9acc59f"

strings:
$path = "/usr/local/lib/libLanDevices.dylib"

$a0 = "CoreWLAN.framework"
$a1 = { 2f 61 70 69 2f 6c 61 6e 5f 64 65 76 69 63 65 73 }
$a2 = { 4d 61 63 46 69 6e 64 65 72 }

condition:
Macho and all of them
}

rule MACOS_LIGHTSPY_PROCESSANDAPPDYLIB_20240422 {
```

```
    meta:
    description = "Detects on the LightSpy libProcessAndApp dylib"
    author = "Stuart Ashenbrenner, Alden Schmidt"
    date = "2024-04-22"
    modified = "2024-04-22"

    reference = "https://huntress.com/blog/lightspy-malware-variant-targeting-macos"
    hash1 = "d2ccbf41552299b24f186f905c846fb20b9f76ed94773677703f75189b838f63"

    strings:
    $path = "/usr/local/lib/libProcessAndApp.dylib"

    $a0 = { 50 72 6f 67 72 65 73 73 4c 6f 67 2e 6d }
    $a1 = { 2f 61 70 69 2f (61 70 70 2f | 70 72 6f 63 65 73 73 2f) }
    condition:
    Macho and all of them
    }

    rule MACOS_LIGHTSPY_SCREENRECORDERDYLIB_20240422 {
    meta:
    description = "Detects on the LightSpy libScreenRecorder dylib"
    author = "Stuart Ashenbrenner, Alden Schmidt"
    date = "2024-04-22"
    modified = "2024-04-22"

    reference = "https://huntress.com/blog/lightspy-malware-variant-targeting-macos"
    hash1 = "7ed786a259982cce0fad8a704547c72690970145b9587d84ee6205b7c578b663"

    strings:
    $path = "/usr/local/lib/libScreenRecorder.dylib"
```

```
$a0 = { 2f 78 38 36 5f 36 34 2f 53 63 72 65 65 6e 52 65 63 6f 72 64 65 72 2e 6f }
$a1 = { 00 72 65 63 6f 72 64 20 73 63 72 65 65 6e }

condition:
Macho and all of them
}

rule MACOS_LIGHTSPY_SHELLDYLIB_20240422 {
meta:
description = "Detects on the LightSpy libShellCommand dylib"
author = "Stuart Ashenbrenner, Alden Schmidt"
date = "2024-04-22"
modified = "2024-04-22"

reference = "https://huntress.com/blog/lightspy-malware-variant-targeting-macos"
hash1 = "ac6d34f09fcac49c203e860da00bbbe97290d5466295ab0650265be242d692a6"

strings:
$path = "/usr/local/lib/libShellCommand.dylib"

$a0 = { 2f 61 70 69 2f 73 68 65 6c 6c 2f 72 65 73 75 6c 74 }
$a1 = "XXXExeCommand"
$a2 = "GetDeviceID"

condition:
Macho and all of them
}

rule MACOS_LIGHTSPY_WIFIDYLIB_20240422 {
meta:
description = "Detects on the LightSpy libWifiList dylib"
```

```
    author = "Stuart Ashenbrenner, Alden Schmidt"
    date = "2024-04-22"
    modified = "2024-04-22"

    reference = "https://huntress.com/blog/lightspy-malware-variant-targeting-macos"
    hash1 = "fc7e77a56772d5ff644da143718ee7dbaf7a1da37cceb446580cd5efb96a9835"

    strings:
    $path = "/usr/local/lib/libWifiList.dylib"

    $a0 = { 2f 61 70 69 2f 77 69 66 69 5f (63 6f 6e 6e 65 63 74 69 6f 6e 2f | 6e 65 61 72 62 79 2f) }
    $a1 = { 57 50 41 [1] 2d 50 53 4b }

    condition:
    Macho and all of them
}
```

## Sigma Rule

```
title: LightSpy MacOS Malware
id: 75d6d6fc-026f-11ef-aa62-f23ada0a3aed
status: test
description: Detects the creation of malicious files in the Shared directory.
author: Stuart Ashenbrenner
references:
- https://huntress.com/blog/lightspy-malware-variant-targeting-macos
date: 2024/04/24
logsource:
category: process_creation
product: macos
```

| | |
|---|---|
| | detection: |
| | selection0: |
| | CommandLine\|contains: '/Users/Shared/update.app' |
| | condition: selection0 |
| | falsepositives: |
| | - None observed |
| | level: high |
| | tags: |
| | - attack.exfiltration |
| | - attack.t1041 |

# Appendix B

## IOCs

| Filename | SHA1 | Description |
|---|---|---|
| loader | afd03337d1500d6af9bc447bd900df26786ea4a4 | |
| C40F0D27 | fd49866245721acc6e7431ec61b066696b72a1e1 | core implant |
| soundrecord | 0563225dcc2767357748d9f1f6ac2db9825d3cf9 | Plugin ID: 18000 |
| browser | 476c726b58409a8e3e6cf8fb6bb7d46596917e24 | Plugin ID: 14000 |
| cameramodule | 33c39728a0393d4271f27cc1d85cf3c1610be333 | Plugin ID: 19000 |
| FileManage | 9a00f6ca0d9140316f9ae03f79c7511cec32849f | Plugin ID: 15000 |
| keychain | 8f390335b571297a9eb605576745876666ee7f6a | Plugin ID: 31000 |
| LanDevices | 7aceb8db03b8b8c7899982b5befcaf455a86fe0b | Plugin ID: 33000 |
| softlist | c65817a55b003462d48189875f18fa8bdb57b402 | Plugin ID: 16000 |
| ScreenRecorder | e9ba5d2dd449678628834cf5a11cffe042a4f6d6 | Plugin ID: 34000 |
| ShellCommand | 30e33f1188ca4cffc997260c9929738594e7488c | Plugin ID: 20000 |
| wifi | 8e7e8d896ed61bea7a49271e2e6ffc982942e5c7 | Plugin ID: 17000 |

## Infrastructure

| IP | Description |
| --- | --- |
| 103[.]27[.]109[.]217 | Primary C2 |

## References

[1] https://blogs.blackberry.com/en/2024/04/lightspy-returns-renewed-espionage-campaign-targets-southern-asia-possibly-india

[2] https://documents.trendmicro.com/assets/Tech-Brief-Operation-Poisoned-News-Hong-Kong-Users-Targeted-with-Mobile-Malware-via-Local-News-Links.pdf

[3] https://www.threatfabric.com/blogs/lightspy-mapt-mobile-payment-system-attack

[4] https://securelist.com/ios-exploit-chain-deploys-lightspy-malware/96407/

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