Payload Encryption - AES Encryption

Advanced Encryption Standard

This module discusses a more secure encryption algorithm, Advanced Encryption Standard (AES). It is a symmetric-key algorithm, meaning the same key is used for both encryption and decryption. There are several types of AES encryption such as AES128, AES192, and AES256 that vary by the key size. For example, AES128 uses a 128-bit key whereas AES256 uses a 256-bit key.

Additionally, AES can use different block cipher modes of operation such as CBC and GCM. Depending on the AES mode, the AES algorithm will require an additional component along with the encryption key called an Initialization Vector or IV. Providing an IV provides an additional layer of security to the encryption process.

Regardless of the chosen AES type, AES always requires a 128-bit input and produces a 128-bit output blocks. The important thing to keep in mind is that the input data should be multiples of 16 bytes (128 bits). If the payload being encrypted is not a multiple of 16 bytes then padding is required to increase the size of the payload and make it a multiple of 16 bytes.

The module provides 2 code samples that use AES256-CBC. The first sample is achieved through the bCrypt library which utilizes WinAPIs and the second sample uses Tiny Aes Project. Note that since the AES256-CBC is being used, the code uses a 32-byte key and a 16-byte IV. Again, this would vary if the code used a different AES type or mode.

AES Using WinAPIs (bCrypt Library)

There are several ways to implement the AES encryption algorithm. This section utilizes the bCrypt library (bcrypt.h) to perform AES encryption. This section will explain the code which is available for download as usual at the top right of the module box.

AES Structure

To start, an `AES` structure is created which contains the required data to perform encryption and decryption.

```
typedef struct _AES {

        PBYTE   pPlainText;         // base address of the plain text data
        DWORD   dwPlainSize;        // size of the plain text data

        PBYTE   pCipherText;        // base address of the encrypted data
        DWORD   dwCipherSize;       // size of it (this can change from
dwPlainSize in case there was padding)

        PBYTE   pKey;               // the 32 byte key
```

```
        PBYTE   pIv;                 // the 16 byte iv

} AES, *PAES;
```

SimpleEncryption Wrapper

The `SimpleEncryption` function has six parameters that are used to initialize the `AES` structure. Once the structure is initialized, the function will call `InstallAesEncryption` to perform the AES encryption process. Note that two of its parameters are `OUT` parameters, therefore the function returns the following:

- `pCipherTextData` - A pointer to the newly allocated heap buffer which contains the ciphertext data.
- `sCipherTextSize` - The size of the ciphertext buffer.

The function returns `TRUE` if the `InstallAesEncryption` succeeds, otherwise `FALSE`.

```
// Wrapper function for InstallAesEncryption that makes things easier
BOOL SimpleEncryption(IN PVOID pPlainTextData, IN DWORD sPlainTextSize, IN
PBYTE pKey, IN PBYTE pIv, OUT PVOID* pCipherTextData, OUT DWORD*
sCipherTextSize) {

        if (pPlainTextData == NULL || sPlainTextSize == NULL || pKey == NULL
|| pIv == NULL)
                return FALSE;

        // Intializing the struct
        AES Aes = {
                .pKey        = pKey,
                .pIv         = pIv,
                .pPlainText  = pPlainTextData,
                .dwPlainSize = sPlainTextSize
        };

        if (!InstallAesEncryption(&Aes)) {
                return FALSE;
        }

        // Saving output
        *pCipherTextData = Aes.pCipherText;
        *sCipherTextSize = Aes.dwCipherSize;

        return TRUE;
}
```

SimpleDecryption Wrapper

The `SimpleDecryption` function also has six parameters and behaves similarly to `SimpleEncryption` with the difference being that it calls the `InstallAesDecryption` function and it returns two different values.

- `pPlainTextData` - A pointer to the newly allocated heap buffer which contains the plaintext data.
- `sPlainTextSize` - The size of the plaintext buffer.

The function returns `TRUE` if the `InstallAesDecryption` succeeds, otherwise `FALSE`.

```
// Wrapper function for InstallAesDecryption that make things easier
BOOL SimpleDecryption(IN PVOID pCipherTextData, IN DWORD sCipherTextSize, IN PBYTE pKey, IN PBYTE pIv, OUT PVOID* pPlainTextData, OUT DWORD* sPlainTextSize) {

        if (pCipherTextData == NULL || sCipherTextSize == NULL || pKey == NULL || pIv == NULL)
                return FALSE;

        // Intializing the struct
        AES Aes = {
                .pKey           = pKey,
                .pIv            = pIv,
                .pCipherText    = pCipherTextData,
                .dwCipherSize   = sCipherTextSize
        };

        if (!InstallAesDecryption(&Aes)) {
                return FALSE;
        }

        // Saving output
        *pPlainTextData = Aes.pPlainText;
        *sPlainTextSize = Aes.dwPlainSize;

        return TRUE;
}
```

Cryptographic Next Generation

Cryptographic Next Generation (CNG) provides a set of cryptographic functions that can be used by applications of the OS. CNG provides a standardized interface for cryptographic operations, making it easier for developers to implement security features in their applications. Both `InstallAesEncryption` and `InstallAesDecryption` functions make use of CNG.

More information about CNG is available here.

InstallAesEncryption Function

The `InstallAesEncryption` is the function that performs AES encryption. The function has one parameter, `PAES`, which is a pointer to a populated `AES` structure. The bCrypt library functions used in the function are shown below.

- BCryptOpenAlgorithmProvider - Used to load the BCRYPT_AES_ALGORITHM Cryptographic Next Generation (CNG) provider to enable the use of cryptographic functions.
- BCryptGetProperty - This function is called twice, the first time to retrieve the value of BCRYPT_OBJECT_LENGTH and the second time to fetch the value of BCRYPT_BLOCK_LENGTH property identifiers.
- BCryptSetProperty - Used to initialize the `BCRYPT_OBJECT_LENGTH` property identifier.
- BCryptGenerateSymmetricKey - Used to create a key object from the input AES key specified.
- BCryptEncrypt - Used to encrypt a specified block of data. This function is called twice, the first time retrieves the size of the encrypted data to allocate a heap buffer of that size. The second call encrypts the data and stores the ciphertext in the allocated heap.
- BCryptDestroyKey - Used to clean up by destroying the key object created using `BCryptGenerateSymmetricKey`.
- BCryptCloseAlgorithmProvider - Used to clean up by closing the object handle of the algorithm provider created earlier using `BCryptOpenAlgorithmProvider`.

The function returns `TRUE` if it successfully encrypts the payload, otherwise `FALSE`.

```
// The encryption implementation
BOOL InstallAesEncryption(PAES pAes) {

  BOOL                  bSTATE          = TRUE;
  BCRYPT_ALG_HANDLE     hAlgorithm      = NULL;
  BCRYPT_KEY_HANDLE     hKeyHandle      = NULL;

  ULONG                 cbResult        = NULL;
  DWORD                 dwBlockSize     = NULL;

  DWORD                 cbKeyObject     = NULL;
  PBYTE                 pbKeyObject     = NULL;

  PBYTE                 pbCipherText    = NULL;
  DWORD                 cbCipherText    = NULL;
  NTSTATUS           STATUS          = NULL;

  // Intializing "hAlgorithm" as AES algorithm Handle
  STATUS = BCryptOpenAlgorithmProvider(&hAlgorithm, BCRYPT_AES_ALGORITHM,
```

```
NULL, 0);
  if (!NT_SUCCESS(STATUS)) {
        printf("[!] BCryptOpenAlgorithmProvider Failed With Error: 0x%0.8X
\n", STATUS);
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Getting the size of the key object variable pbKeyObject. This is used by
the BCryptGenerateSymmetricKey function later
  STATUS = BCryptGetProperty(hAlgorithm, BCRYPT_OBJECT_LENGTH,
(PBYTE)&cbKeyObject, sizeof(DWORD), &cbResult, 0);
  if (!NT_SUCCESS(STATUS)) {
        printf("[!] BCryptGetProperty[1] Failed With Error: 0x%0.8X \n",
STATUS);
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Getting the size of the block used in the encryption. Since this is AES
it must be 16 bytes.
  STATUS = BCryptGetProperty(hAlgorithm, BCRYPT_BLOCK_LENGTH,
(PBYTE)&dwBlockSize, sizeof(DWORD), &cbResult, 0);
  if (!NT_SUCCESS(STATUS)) {
        printf("[!] BCryptGetProperty[2] Failed With Error: 0x%0.8X \n",
STATUS);
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Checking if block size is 16 bytes
  if (dwBlockSize != 16) {
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Allocating memory for the key object
  pbKeyObject = (PBYTE)HeapAlloc(GetProcessHeap(), 0, cbKeyObject);
  if (pbKeyObject == NULL) {
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Setting Block Cipher Mode to CBC. This uses a 32 byte key and a 16 byte
IV.
  STATUS = BCryptSetProperty(hAlgorithm, BCRYPT_CHAINING_MODE,
(PBYTE)BCRYPT_CHAIN_MODE_CBC, sizeof(BCRYPT_CHAIN_MODE_CBC), 0);
  if (!NT_SUCCESS(STATUS)) {
        printf("[!] BCryptSetProperty Failed With Error: 0x%0.8X \n",
STATUS);
        bSTATE = FALSE; goto _EndOfFunc;
```

```
  }

  // Generating the key object from the AES key "pAes->pKey". The output will
be saved in pbKeyObject and will be of size cbKeyObject
  STATUS = BCryptGenerateSymmetricKey(hAlgorithm, &hKeyHandle, pbKeyObject,
cbKeyObject, (PBYTE)pAes->pKey, KEYSIZE, 0);
  if (!NT_SUCCESS(STATUS)) {
        printf("[!] BCryptGenerateSymmetricKey Failed With Error: 0x%0.8X
\n", STATUS);
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Running BCryptEncrypt first time with NULL output parameters to retrieve
the size of the output buffer which is saved in cbCipherText
  STATUS = BCryptEncrypt(hKeyHandle, (PUCHAR)pAes->pPlainText, (ULONG)pAes-
>dwPlainSize, NULL, pAes->pIv, IVSIZE, NULL, 0, &cbCipherText,
BCRYPT_BLOCK_PADDING);
  if (!NT_SUCCESS(STATUS)) {
        printf("[!] BCryptEncrypt[1] Failed With Error: 0x%0.8X \n", STATUS);
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Allocating enough memory for the output buffer, cbCipherText
  pbCipherText = (PBYTE)HeapAlloc(GetProcessHeap(), 0, cbCipherText);
  if (pbCipherText == NULL) {
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Running BCryptEncrypt again with pbCipherText as the output buffer
  STATUS = BCryptEncrypt(hKeyHandle, (PUCHAR)pAes->pPlainText, (ULONG)pAes-
>dwPlainSize, NULL, pAes->pIv, IVSIZE, pbCipherText, cbCipherText, &cbResult,
BCRYPT_BLOCK_PADDING);
  if (!NT_SUCCESS(STATUS)) {
        printf("[!] BCryptEncrypt[2] Failed With Error: 0x%0.8X \n", STATUS);
        bSTATE = FALSE; goto _EndOfFunc;
  }


  // Clean up
_EndOfFunc:
  if (hKeyHandle)
        BCryptDestroyKey(hKeyHandle);
  if (hAlgorithm)
        BCryptCloseAlgorithmProvider(hAlgorithm, 0);
  if (pbKeyObject)
        HeapFree(GetProcessHeap(), 0, pbKeyObject);
```

```
  if (pbCipherText != NULL && bSTATE) {
        // If everything worked, save pbCipherText and cbCipherText
        pAes->pCipherText       = pbCipherText;
        pAes->dwCipherSize      = cbCipherText;
  }
  return bSTATE;
}
```

InstallAesDecryption Function

The `InstallAesDecryption` is the function that performs AES decryption. The function has one parameter, `PAES`, which is a pointer to a populated `AES` structure. The bCrypt library functions used in the function are the same as in the `InstallAesEncryption` function above, with the only difference being that `BCryptDecrypt` is used instead of `BCryptEncrypt`.

- BCryptDecrypt - Used to decrypt a specified block of data. This function is called twice, the first time retrieves the size of the decrypted data to allocate a heap buffer of that size. The second call decrypts the data and stores the plaintext data in the allocated heap.

The function returns `TRUE` if it successfully decrypts the payload, otherwise `FALSE`.

```
// The decryption implementation
BOOL InstallAesDecryption(PAES pAes) {

  BOOL                  bSTATE          = TRUE;
  BCRYPT_ALG_HANDLE     hAlgorithm      = NULL;
  BCRYPT_KEY_HANDLE     hKeyHandle      = NULL;

  ULONG                 cbResult        = NULL;
  DWORD                 dwBlockSize     = NULL;

  DWORD                 cbKeyObject     = NULL;
  PBYTE                 pbKeyObject     = NULL;

  PBYTE                 pbPlainText     = NULL;
  DWORD                 cbPlainText     = NULL;
  NTSTATUS              STATUS          = NULL;

  // Intializing "hAlgorithm" as AES algorithm Handle
  STATUS = BCryptOpenAlgorithmProvider(&hAlgorithm, BCRYPT_AES_ALGORITHM,
NULL, 0);
  if (!NT_SUCCESS(STATUS)) {
        printf("[!] BCryptOpenAlgorithmProvider Failed With Error: 0x%0.8X
\n", STATUS);
        bSTATE = FALSE; goto _EndOfFunc;
  }
```

```
  // Getting the size of the key object variable pbKeyObject. This is used by
the BCryptGenerateSymmetricKey function later
  STATUS = BCryptGetProperty(hAlgorithm, BCRYPT_OBJECT_LENGTH,
(PBYTE)&cbKeyObject, sizeof(DWORD), &cbResult, 0);
  if (!NT_SUCCESS(STATUS)) {
        printf("[!] BCryptGetProperty[1] Failed With Error: 0x%0.8X \n",
STATUS);
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Getting the size of the block used in the encryption. Since this is AES
it should be 16 bytes.
  STATUS = BCryptGetProperty(hAlgorithm, BCRYPT_BLOCK_LENGTH,
(PBYTE)&dwBlockSize, sizeof(DWORD), &cbResult, 0);
  if (!NT_SUCCESS(STATUS)) {
        printf("[!] BCryptGetProperty[2] Failed With Error: 0x%0.8X \n",
STATUS);
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Checking if block size is 16 bytes
  if (dwBlockSize != 16) {
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Allocating memory for the key object
  pbKeyObject = (PBYTE)HeapAlloc(GetProcessHeap(), 0, cbKeyObject);
  if (pbKeyObject == NULL) {
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Setting Block Cipher Mode to CBC. This uses a 32 byte key and a 16 byte
IV.
  STATUS = BCryptSetProperty(hAlgorithm, BCRYPT_CHAINING_MODE,
(PBYTE)BCRYPT_CHAIN_MODE_CBC, sizeof(BCRYPT_CHAIN_MODE_CBC), 0);
  if (!NT_SUCCESS(STATUS)) {
        printf("[!] BCryptSetProperty Failed With Error: 0x%0.8X \n",
STATUS);
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Generating the key object from the AES key "pAes->pKey". The output will
be saved in pbKeyObject of size cbKeyObject
  STATUS = BCryptGenerateSymmetricKey(hAlgorithm, &hKeyHandle, pbKeyObject,
cbKeyObject, (PBYTE)pAes->pKey, KEYSIZE, 0);
```

```
  if (!NT_SUCCESS(STATUS)) {
        printf("[!] BCryptGenerateSymmetricKey Failed With Error: 0x%0.8X
\n", STATUS);
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Running BCryptDecrypt first time with NULL output parameters to retrieve
the size of the output buffer which is saved in cbPlainText
  STATUS = BCryptDecrypt(hKeyHandle, (PUCHAR)pAes->pCipherText, (ULONG)pAes-
>dwCipherSize, NULL, pAes->pIv, IVSIZE, NULL, 0, &cbPlainText,
BCRYPT_BLOCK_PADDING);
  if (!NT_SUCCESS(STATUS)) {
        printf("[!] BCryptDecrypt[1] Failed With Error: 0x%0.8X \n", STATUS);
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Allocating enough memory for the output buffer, cbPlainText
  pbPlainText = (PBYTE)HeapAlloc(GetProcessHeap(), 0, cbPlainText);
  if (pbPlainText == NULL) {
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Running BCryptDecrypt again with pbPlainText as the output buffer
  STATUS = BCryptDecrypt(hKeyHandle, (PUCHAR)pAes->pCipherText, (ULONG)pAes-
>dwCipherSize, NULL, pAes->pIv, IVSIZE, pbPlainText, cbPlainText, &cbResult,
BCRYPT_BLOCK_PADDING);
  if (!NT_SUCCESS(STATUS)) {
        printf("[!] BCryptDecrypt[2] Failed With Error: 0x%0.8X \n", STATUS);
        bSTATE = FALSE; goto _EndOfFunc;
  }

  // Clean up
_EndOfFunc:
  if (hKeyHandle)
        BCryptDestroyKey(hKeyHandle);
  if (hAlgorithm)
        BCryptCloseAlgorithmProvider(hAlgorithm, 0);
  if (pbKeyObject)
        HeapFree(GetProcessHeap(), 0, pbKeyObject);
  if (pbPlainText != NULL && bSTATE) {
        // if everything went well, we save pbPlainText and cbPlainText
        pAes->pPlainText   = pbPlainText;
        pAes->dwPlainSize  = cbPlainText;
  }
  return bSTATE;
```

```
}
```

Additional Helper Functions

The code also includes two small helper functions as well, `PrintHexData` and `GenerateRandomBytes`.

The first function, `PrintHexData`, prints an input buffer as a char array in C syntax to the console.

```
// Print the input buffer as a hex char array
VOID PrintHexData(LPCSTR Name, PBYTE Data, SIZE_T Size) {

  printf("unsigned char %s[] = {", Name);

  for (int i = 0; i < Size; i++) {
        if (i % 16 == 0)
            printf("\n\t");

      if (i < Size - 1) {
          printf("0x%0.2X, ", Data[i]);
      } else {
          printf("0x%0.2X ", Data[i]);
      }

  printf("};\n\n\n");

}
```

The other function, `GenerateRandomBytes`, fills up an input buffer with random bytes which in this case is used to generate a random key and IV.

```
// Generate random bytes of size sSize
VOID GenerateRandomBytes(PBYTE pByte, SIZE_T sSize) {

  for (int i = 0; i < sSize; i++) {
        pByte[i] = (BYTE)rand() % 0xFF;
  }

}
```

Padding

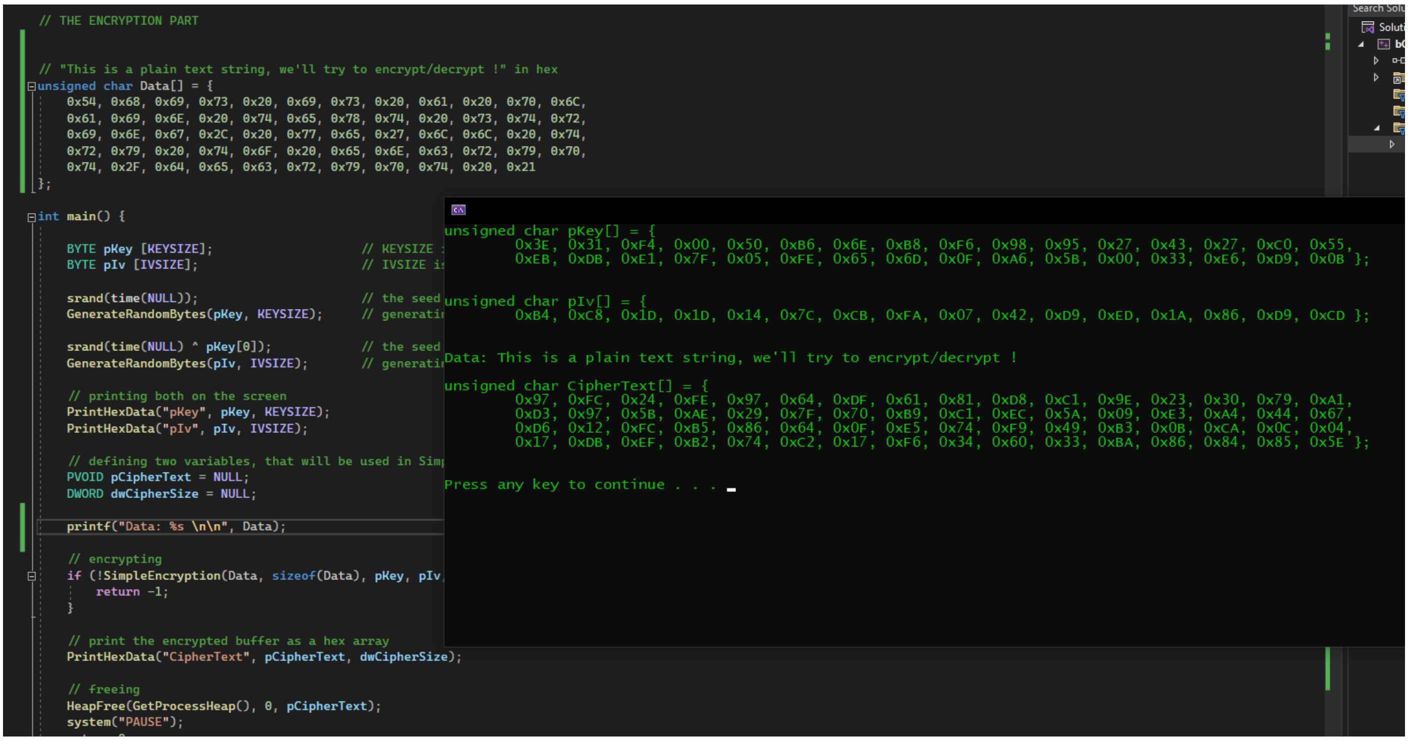
Both `InstallAesEncryption` and `InstallAesDecryption` functions use the `BCRYPT_BLOCK_PADDING` flag with the `BCryptEncrypt` and `BCryptDecrypt` bcrypt functions respectively, which will automatically pad the input buffer, if required, to be a multiple of 16 bytes, solving the AES padding issue.

Main Function - Encryption

The main function below is used to perform the encryption routine on an array of plaintext data.

```
// The plaintext, in hex format, that will be encrypted
// this is the following string in hex "This is a plain text string, we'll
try to encrypt/decrypt !"
unsigned char Data[] = {
        0x54, 0x68, 0x69, 0x73, 0x20, 0x69, 0x73, 0x20, 0x61, 0x20, 0x70,
0x6C,
        0x61, 0x69, 0x6E, 0x20, 0x74, 0x65, 0x78, 0x74, 0x20, 0x73, 0x74,
0x72,
        0x69, 0x6E, 0x67, 0x2C, 0x20, 0x77, 0x65, 0x27, 0x6C, 0x6C, 0x20,
0x74,
        0x72, 0x79, 0x20, 0x74, 0x6F, 0x20, 0x65, 0x6E, 0x63, 0x72, 0x79,
0x70,
        0x74, 0x2F, 0x64, 0x65, 0x63, 0x72, 0x79, 0x70, 0x74, 0x20, 0x21
};

int main() {

        BYTE pKey [KEYSIZE];                    // KEYSIZE is 32 bytes
        BYTE pIv [IVSIZE];                      // IVSIZE is 16 bytes

        srand(time(NULL));                      // The seed to generate the
key. This is used to further randomize the key.
        GenerateRandomBytes(pKey, KEYSIZE);     // Generating a key with the
helper function

        srand(time(NULL) ^ pKey[0]);            // The seed to generate the
IV. Use the first byte of the key to add more randomness.
        GenerateRandomBytes(pIv, IVSIZE);       // Generating the IV with the
helper function

        // Printing both key and IV onto the console
        PrintHexData("pKey", pKey, KEYSIZE);
        PrintHexData("pIv", pIv, IVSIZE);

        // Defining two variables the output buffer and its respective size
which will be used in SimpleEncryption
        PVOID pCipherText = NULL;
        DWORD dwCipherSize = NULL;

        // Encrypting
        if (!SimpleEncryption(Data, sizeof(Data), pKey, pIv, &pCipherText,
&dwCipherSize)) {
```

```
                return -1;
        }

        // Print the encrypted buffer as a hex array
        PrintHexData("CipherText", pCipherText, dwCipherSize);

        // Clean up
        HeapFree(GetProcessHeap(), 0, pCipherText);
        system("PAUSE");
        return 0;
}
```

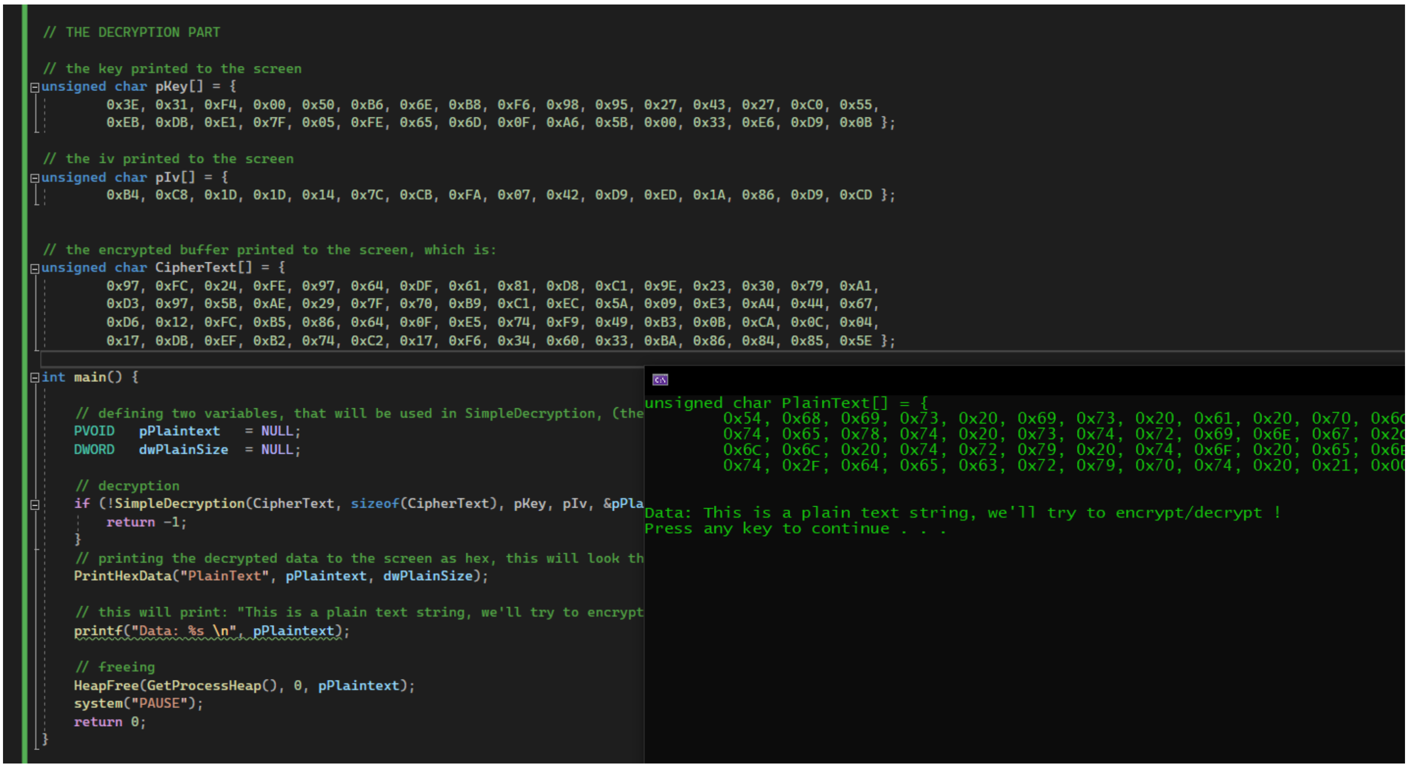


Main Function - Decryption

The main function below is used to perform the decryption routine. The decryption routine requires the decryption key, IV and ciphertext.

```
// the key printed to the screen
unsigned char pKey[] = {
                0x3E, 0x31, 0xF4, 0x00, 0x50, 0xB6, 0x6E, 0xB8, 0xF6, 0x98,
0x95, 0x27, 0x43, 0x27, 0xC0, 0x55,
                0xEB, 0xDB, 0xE1, 0x7F, 0x05, 0xFE, 0x65, 0x6D, 0x0F, 0xA6,
0x5B, 0x00, 0x33, 0xE6, 0xD9, 0x0B };

// the iv printed to the screen
unsigned char pIv[] = {
                0xB4, 0xC8, 0x1D, 0x1D, 0x14, 0x7C, 0xCB, 0xFA, 0x07, 0x42,
0xD9, 0xED, 0x1A, 0x86, 0xD9, 0xCD };
```

```c
// the encrypted buffer printed to the screen, which is:
unsigned char CipherText[] = {
                0x97, 0xFC, 0x24, 0xFE, 0x97, 0x64, 0xDF, 0x61, 0x81, 0xD8,
0xC1, 0x9E, 0x23, 0x30, 0x79, 0xA1,
                0xD3, 0x97, 0x5B, 0xAE, 0x29, 0x7F, 0x70, 0xB9, 0xC1, 0xEC,
0x5A, 0x09, 0xE3, 0xA4, 0x44, 0x67,
                0xD6, 0x12, 0xFC, 0xB5, 0x86, 0x64, 0x0F, 0xE5, 0x74, 0xF9,
0x49, 0xB3, 0x0B, 0xCA, 0x0C, 0x04,
                0x17, 0xDB, 0xEF, 0xB2, 0x74, 0xC2, 0x17, 0xF6, 0x34, 0x60,
0x33, 0xBA, 0x86, 0x84, 0x85, 0x5E };

int main() {

        // Defining two variables the output buffer and its respective size
which will be used in SimpleDecryption
        PVOID   pPlaintext  = NULL;
        DWORD   dwPlainSize = NULL;

        // Decrypting
        if (!SimpleDecryption(CipherText, sizeof(CipherText), pKey, pIv,
&pPlaintext, &dwPlainSize)) {
                return -1;
        }

        // Printing the decrypted data to the screen in hex format
        PrintHexData("PlainText", pPlaintext, dwPlainSize);

        // this will print: "This is a plain text string, we'll try to
encrypt/decrypt !"
        printf("Data: %s \n", pPlaintext);

        // Clean up
        HeapFree(GetProcessHeap(), 0, pPlaintext);
        system("PAUSE");
        return 0;
}
```



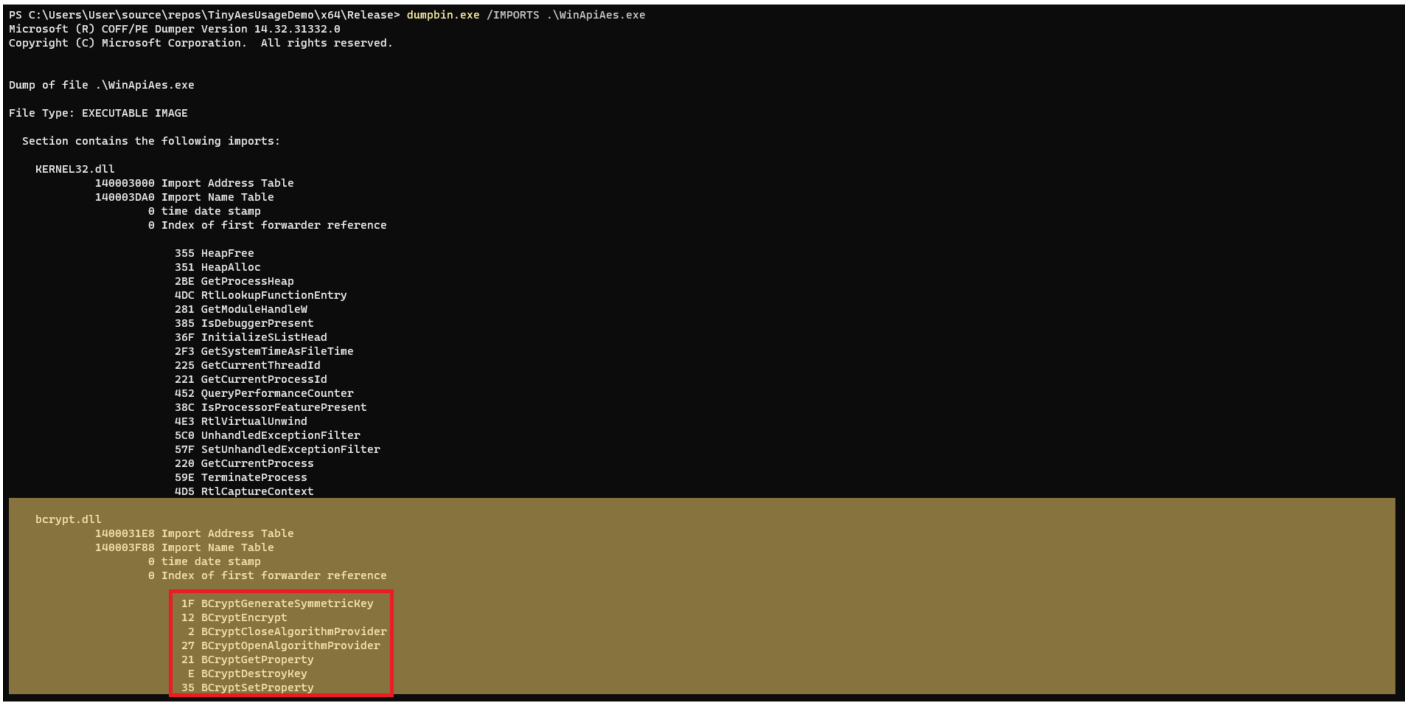
```c
// THE DECRYPTION PART

// the key printed to the screen
unsigned char pKey[] = {
        0x3E, 0x31, 0xF4, 0x00, 0x50, 0xB6, 0x6E, 0xB8, 0xF6, 0x98, 0x95, 0x27, 0x43, 0x27, 0xC0, 0x55,
        0xEB, 0xDB, 0xE1, 0x7F, 0x05, 0xFE, 0x65, 0x6D, 0x0F, 0xA6, 0x5B, 0x00, 0x33, 0xE6, 0xD9, 0x0B };

// the iv printed to the screen
unsigned char pIv[] = {
        0xB4, 0xC8, 0x1D, 0x1D, 0x14, 0x7C, 0xCB, 0xFA, 0x07, 0x42, 0xD9, 0xED, 0x1A, 0x86, 0xD9, 0xCD };


// the encrypted buffer printed to the screen, which is:
unsigned char CipherText[] = {
        0x97, 0xFC, 0x24, 0xFE, 0x97, 0x64, 0xDF, 0x61, 0x81, 0xD8, 0xC1, 0x9E, 0x23, 0x30, 0x79, 0xA1,
        0xD3, 0x97, 0x5B, 0xAE, 0x29, 0x7F, 0x70, 0xB9, 0xC1, 0xEC, 0x5A, 0x09, 0xE3, 0xA4, 0x44, 0x67,
        0xD6, 0x12, 0xFC, 0xB5, 0x86, 0x64, 0x0F, 0xE5, 0x74, 0xF9, 0x49, 0xB3, 0x0B, 0xCA, 0x0C, 0x04,
        0x17, 0xDB, 0xEF, 0xB2, 0x74, 0xC2, 0x17, 0xF6, 0x34, 0x60, 0x33, 0xBA, 0x86, 0x84, 0x85, 0x5E };

int main() {

    // defining two variables, that will be used in SimpleDecryption, (the
    PVOID   pPlaintext   = NULL;
    DWORD   dwPlainSize  = NULL;

    // decryption
    if (!SimpleDecryption(CipherText, sizeof(CipherText), pKey, pIv, &pPla
        return -1;
    }
    // printing the decrypted data to the screen as hex, this will look th
    PrintHexData("PlainText", pPlaintext, dwPlainSize);

    // this will print: "This is a plain text string, we'll try to encrypt
    printf("Data: %s \n", pPlaintext);

    // freeing
    HeapFree(GetProcessHeap(), 0, pPlaintext);
    system("PAUSE");
    return 0;
}
```

```
unsigned char PlainText[] = {
        0x54, 0x68, 0x69, 0x73, 0x20, 0x69, 0x73, 0x20, 0x61, 0x20, 0x70, 0x6C
        0x74, 0x65, 0x78, 0x74, 0x20, 0x73, 0x74, 0x72, 0x69, 0x6E, 0x67, 0x2C
        0x6C, 0x6C, 0x20, 0x74, 0x72, 0x79, 0x20, 0x74, 0x6F, 0x20, 0x65, 0x6E
        0x74, 0x2F, 0x64, 0x65, 0x63, 0x72, 0x79, 0x70, 0x74, 0x20, 0x21, 0x00

Data: This is a plain text string, we'll try to encrypt/decrypt !
Press any key to continue . . .
```

bCrypt Library Drawbacks

One of the primary drawbacks of using the method outlined above to implement AES encryption is that the usage of the cryptographic WinAPIs results in them being visible in the binary's Import Address Table (IAT). Security solutions can detect the use of cryptographic functions by scanning the IAT, which can potentially indicate malicious behavior or raise suspicion. Hiding WinAPIs in the IAT is possible and will be discussed in a future module.

The image below shows the IAT of the binary using Windows APIs for AES encryption. The usage of the `bcrypt.dll` library and the cryptographic functions is clearly visible.



```
PS C:\Users\User\source\repos\TinyAesUsageDemo\x64\Release> dumpbin.exe /IMPORTS .\WinApiAes.exe
Microsoft (R) COFF/PE Dumper Version 14.32.31332.0
Copyright (C) Microsoft Corporation.  All rights reserved.


Dump of file .\WinApiAes.exe

File Type: EXECUTABLE IMAGE

  Section contains the following imports:

    KERNEL32.dll
             140003000 Import Address Table
             140003DA0 Import Name Table
                     0 time date stamp
                     0 Index of first forwarder reference

                       355 HeapFree
                       351 HeapAlloc
                       2BE GetProcessHeap
                       4DC RtlLookupFunctionEntry
                       281 GetModuleHandleW
                       385 IsDebuggerPresent
                       36F InitializeSListHead
                       2F3 GetSystemTimeAsFileTime
                       225 GetCurrentThreadId
                       221 GetCurrentProcessId
                       452 QueryPerformanceCounter
                       38C IsProcessorFeaturePresent
                       4E3 RtlVirtualUnwind
                       5C0 UnhandledExceptionFilter
                       57F SetUnhandledExceptionFilter
                       220 GetCurrentProcess
                       59E TerminateProcess
                       4D5 RtlCaptureContext

    bcrypt.dll
             1400031E8 Import Address Table
             140003F88 Import Name Table
                     0 time date stamp
                     0 Index of first forwarder reference

                        1F BCryptGenerateSymmetricKey
                        12 BCryptEncrypt
                         2 BCryptCloseAlgorithmProvider
                        27 BCryptOpenAlgorithmProvider
                        21 BCryptGetProperty
                         E BCryptDestroyKey
                        35 BCryptSetProperty
```

AES Using Tiny-AES Library

This section makes use of the tiny-AES-c third-party encryption library that performs AES encryption without the use of WinAPIs. Tiny-AES-C is a small portable library that can perform AES128/192/256 in C.

Setting Up Tiny-AES

To begin using Tiny-AES there are two requirements:

1. Include `aes.hpp` (C++) or include `aes.h` (C) in the project.

2. Add the `aes.c` file to the project.

Setting The AES256 Flag

By default, the library applies the AES128 algorithm for encryption and decryption. However, one can set the library to use AES256 or AES192 algorithms by enabling one of the AESXXX flags located in the `aes.h` file and commenting the other flags accordingly. For example, enabling the `AES256` flag will force the library to use the AES256 algorithm, which is the algorithm used in this module. Therefore, the flags in `aes.h` should look like the following:

```
//#define AES128 1
//#define AES192 1
#define AES256 1
```

Tiny-AES Library Drawbacks

Before diving into the code it's important to be aware of the drawbacks of the tiny-AES library.

1. The library does not support padding. All buffers must be multiples of 16 bytes.

2. The arrays used in the library can be signatured by security solutions to detect the usage of Tiny-AES. These arrays are used to apply the AES algorithm and therefore are a requirement to have in the code. With that being said, there are ways to modify their signature in order to avoid security solutions detecting the usage of Tiny-AES. One possible solution is to XOR these arrays, for example, to decrypt them at runtime right before calling the initialization function, `AES_init_ctx_iv`.

Custom Padding Function

The lack of padding support can be solved by creating a custom padding function as shown in the code snippet below.

```
BOOL PaddBuffer(IN PBYTE InputBuffer, IN SIZE_T InputBufferSize, OUT PBYTE*
OutputPaddedBuffer, OUT SIZE_T* OutputPaddedSize) {

        PBYTE    PaddedBuffer         = NULL;
        SIZE_T   PaddedSize           = NULL;

```

```
        // calculate the nearest number that is multiple of 16 and saving it
to PaddedSize
        PaddedSize = InputBufferSize + 16 - (InputBufferSize % 16);
        // allocating buffer of size "PaddedSize"
        PaddedBuffer = (PBYTE)HeapAlloc(GetProcessHeap(), 0, PaddedSize);
        if (!PaddedBuffer){
                return FALSE;
        }
        // cleaning the allocated buffer
        ZeroMemory(PaddedBuffer, PaddedSize);
        // copying old buffer to new padded buffer
        memcpy(PaddedBuffer, InputBuffer, InputBufferSize);
        //saving results :
        *OutputPaddedBuffer = PaddedBuffer;
        *OutputPaddedSize   = PaddedSize;

        return TRUE;
}
```

Tiny-AES Encryption

Similar to how the bCrypt library's encryption and decryption process was explained earlier in the module, the snippets below explain Tiny-AES's encryption and decryption process.

```
#include <Windows.h>
#include <stdio.h>
#include "aes.h"

// "this is plaintext string, we'll try to encrypt... lets hope everything
goes well :)" in hex
// since the upper string is 82 byte in size, and 82 is not mulitple of 16,
we cant encrypt this directly using tiny-aes
unsigned char Data[] = {
        0x74, 0x68, 0x69, 0x73, 0x20, 0x69, 0x73, 0x20, 0x70, 0x6C, 0x61,
0x6E,
        0x65, 0x20, 0x74, 0x65, 0x78, 0x74, 0x20, 0x73, 0x74, 0x69, 0x6E,
0x67,
        0x2C, 0x20, 0x77, 0x65, 0x27, 0x6C, 0x6C, 0x20, 0x74, 0x72, 0x79,
0x20,
        0x74, 0x6F, 0x20, 0x65, 0x6E, 0x63, 0x72, 0x79, 0x70, 0x74, 0x2E,
0x2E,
        0x2E, 0x20, 0x6C, 0x65, 0x74, 0x73, 0x20, 0x68, 0x6F, 0x70, 0x65,
0x20,
        0x65, 0x76, 0x65, 0x72, 0x79, 0x74, 0x68, 0x69, 0x67, 0x6E, 0x20,
0x67,
        0x6F, 0x20, 0x77, 0x65, 0x6C, 0x6C, 0x20, 0x3A, 0x29, 0x00
```

```
};



int main() {
	// struct needed for Tiny-AES library
	struct AES_ctx ctx;


	BYTE pKey[KEYSIZE];                               // KEYSIZE is 32
bytes
	BYTE pIv[IVSIZE];                                 // IVSIZE is 16 bytes


	srand(time(NULL));                                // the seed to
generate the key
	GenerateRandomBytes(pKey, KEYSIZE);               // generating the key
bytes

	srand(time(NULL) ^ pKey[0]);                      // The seed to
generate the IV. Use the first byte of the key to add more randomness.
	GenerateRandomBytes(pIv, IVSIZE);                 // Generating the IV

	// Prints both key and IV to the console
	PrintHexData("pKey", pKey, KEYSIZE);
	PrintHexData("pIv", pIv, IVSIZE);

	// Initializing the Tiny-AES Library
	AES_init_ctx_iv(&ctx, pKey, pIv);



	// Initializing variables that will hold the new buffer base address
in the case where padding is required and its size
	PBYTE	PaddedBuffer		= NULL;
	SIZE_T	PAddedSize		= NULL;

	// Padding the buffer, if required
	if (sizeof(Data) % 16 != 0){
		PaddBuffer(Data, sizeof(Data), &PaddedBuffer, &PAddedSize);
		// Encrypting the padded buffer instead
		AES_CBC_encrypt_buffer(&ctx, PaddedBuffer, PAddedSize);
		// Printing the encrypted buffer to the console
		PrintHexData("CipherText", PaddedBuffer, PAddedSize);
	}
	// No padding is required, encrypt 'Data' directly
	else {
```

```
                AES_CBC_encrypt_buffer(&ctx, Data, sizeof(Data));
                // Printing the encrypted buffer to the console
                PrintHexData("CipherText", Data, sizeof(Data));
        }
        // Freeing PaddedBuffer, if necessary
        if (PaddedBuffer != NULL){
                HeapFree(GetProcessHeap(), 0, PaddedBuffer);
        }
        system("PAUSE");
        return 0;
}
```

Tiny-AES Decryption

```
#include <Windows.h>
#include <stdio.h>
#include "aes.h"

// Key
unsigned char pKey[] = {
                0x00, 0xB8, 0x80, 0x7E, 0xF0, 0x09, 0x65, 0x8B, 0xD6, 0x6E,
0x2D, 0x8B, 0x0C, 0x6A, 0xA2, 0x34,
                0x42, 0x7A, 0x9D, 0x06, 0xC5, 0x48, 0x6E, 0x22, 0x01, 0x21,
0x7D, 0x5F, 0x44, 0xA9, 0x32, 0x9B };

// IV
unsigned char pIv[] = {
                0x00, 0xB8, 0x80, 0x7E, 0xF0, 0x09, 0x65, 0x8B, 0xD6, 0x6E,
0x2D, 0x8B, 0x0C, 0x6A, 0xA2, 0x34 };

// Encrypted data, multiples of 16 bytes
unsigned char CipherText[] = {
                0xB9, 0x49, 0x12, 0x36, 0xFC, 0xAD, 0x15, 0xDA, 0x27, 0xA2,
0x02, 0xD4, 0x77, 0x8B, 0xBB, 0x4E,
                0xDA, 0xE5, 0x60, 0x71, 0x2F, 0xF4, 0x69, 0x2D, 0x9C, 0x12,
0x8D, 0xD0, 0xA3, 0x0E, 0xB7, 0x26,
                0x21, 0xE4, 0xA4, 0xAD, 0xB3, 0x05, 0xD9, 0x13, 0x8D, 0x2B,
0x0E, 0x0C, 0x21, 0x85, 0xD1, 0xC4,
                0xC1, 0x5A, 0x5F, 0x64, 0xDA, 0x1B, 0xB4, 0x7A, 0x7E, 0x6B,
0xE6, 0x80, 0x17, 0x28, 0x43, 0x4E,
                0xA6, 0x0A, 0x40, 0xB8, 0xBB, 0x1E, 0x27, 0x6A, 0x29, 0xE4,
0x5A, 0xA5, 0x4A, 0x4C, 0xB0, 0xA3,
                0x7D, 0x7A, 0x4E, 0x6D, 0x48, 0x86, 0xEB, 0xB2, 0xFD, 0x1B,
0x21, 0x89, 0xB0, 0x83, 0x14, 0xFE };
```

```c
int main() {

        // Struct needed for Tiny-AES library
        struct AES_ctx ctx;
        // Initializing the Tiny-AES Library
        AES_init_ctx_iv(&ctx, pKey, pIv);

        // Decrypting
        AES_CBC_decrypt_buffer(&ctx, CipherText, sizeof(CipherText));

        // Print the decrypted buffer to the console
        PrintHexData("PlainText", CipherText, sizeof(CipherText));

        // Print the string
        printf("Data: %s \n", CipherText);

        // exit
        system("PAUSE");
        return 0;
}
```

Tiny-AES IAT

The image below shows a binary's IAT which uses Tiny-AES to perform encryption instead of WinAPIs. No cryptographic functions are visible in the IAT of the binary.

```
PS C:\Users\User\source\repos\TinyAesUsageDemo\x64\Release> dumpbin.exe /IMPORTS .\TinyAesUsageDemo.exe
Microsoft (R) COFF/PE Dumper Version 14.32.31332.0
Copyright (C) Microsoft Corporation.  All rights reserved.


Dump of file .\TinyAesUsageDemo.exe

File Type: EXECUTABLE IMAGE

  Section contains the following imports:

    KERNEL32.dll
             140003000 Import Address Table
             140003C70 Import Name Table
                     0 time date stamp
                     0 Index of first forwarder reference

                         4DC RtlLookupFunctionEntry
                         4E3 RtlVirtualUnwind
                         5C0 UnhandledExceptionFilter
                         57F SetUnhandledExceptionFilter
                         220 GetCurrentProcess
                         59E TerminateProcess
                         281 GetModuleHandleW
                         385 IsDebuggerPresent
                         36F InitializeSListHead
                         2F3 GetSystemTimeAsFileTime
                         225 GetCurrentThreadId
                         221 GetCurrentProcessId
                         452 QueryPerformanceCounter
                         38C IsProcessorFeaturePresent
                         4D5 RtlCaptureContext

    VCRUNTIME140.dll
             140003080 Import Address Table
             140003CF0 Import Name Table
                     0 time date stamp
                     0 Index of first forwarder reference

                           8 __C_specific_handler
                          1B __current_exception
                          1C __current_exception_context
                          3E memset
                          3C memcpy

    api-ms-win-crt-stdio-l1-1-0.dll
             140003180 Import Address Table
```

Conclusion

This module explained the basics of AES and provided two working AES implementations. One should also have an idea of how security solutions will detect the usage of encryption libraries.