CSE 433S HW 1 - Comm with Stream Cipher

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Contents

1 Implementation

I find I make a mistake in the previous homework. I should use stream cipher to encrypt the message. But I use AES block cipher to encrypt the message. This is wrong. I will hand in stream cipher in my next homework.

I have desgined a Diffie-Hellman function to exchange AES key and IV to make sure our key is secure.

However, some unrecognized problem happened, and after 4 hours of debugging, I still cannot find the problem. So I failed to implement the Diffie-Hellman function.

I don't know why there is a block error in AES decryption. I don't want to waste too much time on this problem since I have already spent 4 hours on it and I have other homework to do.

I think this problem will happended only when my AES is too long and more than my buffer but this is impossible.

```
Msg from client: p
20E084347EEF0000:error:1C80006B:Provider routines:
    ossl_cipher_generic_block_final:wrong final block
    length:../providers/implementations/ciphers/
    ciphercommon.c:429:
Aborted
```

1.1 OTP

I have desgined a OTP encryption function to encrypt the message. I use rand() function to generate the OTP key. And the OTP has the same length with the message. And OTP has the same encryption and decryption function as follows.

```
    // Init OTP as length of the client_message
    char otp_key[strlen(client_message)];
    for (int i = 0; i < strlen(client_message); i++) {
        otp_key[i] = rand() % 256;
    }

void otp_encrypt(char *plaintext, char *key, char *
    ciphertext) {
    for (int i = 0; i < strlen(plaintext); i++) {
        ciphertext[i] = plaintext[i] ^ key[i];
    }
}
```

1.2 AES

I have designed a AES stream cipher encryption and decryption function as follows.

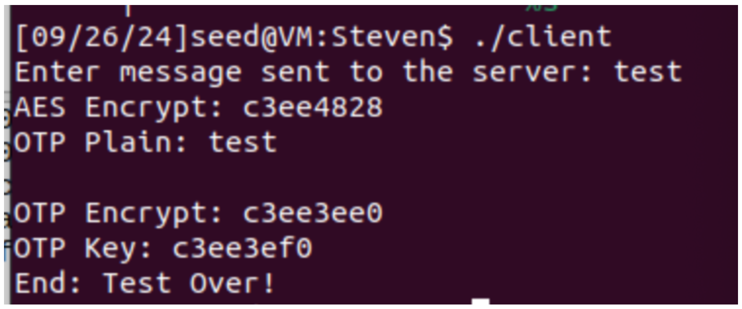
I choose AES-256-CBC as my encryption method. This is because AES-256 is a secure encryption method and CBC is the most secure mode of operation in my understanding. I use openssl library rand() function to generate the key and iv.

```
// Declare key and iv
unsigned char key[AES_KEY_LENGTH];
unsigned char iv[AES_BLOCK_SIZE];

// Initialize key and iv
if(RAND_bytes(key, AES_KEY_LENGTH) != 1) {
    printf("Error in generating key\n");
    return;
}

if(RAND_bytes(iv, AES_BLOCK_SIZE) != 1) {
    printf("Error in generating iv\n");
    return;
}
```

2 Result

The server and client are able to communicate with each other.

The client send a message within two types of encryption, AES and OTP.



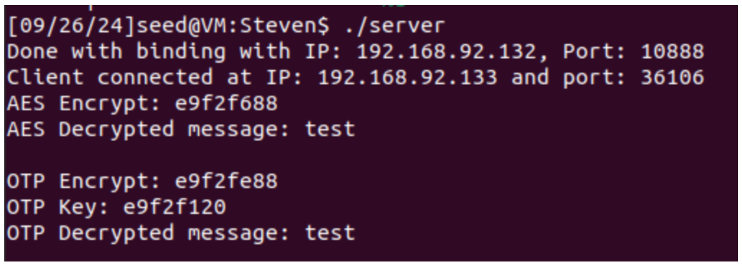
```
[09/26/24]seed@VM:Steven$ ./client
Enter message sent to the server: test
AES Encrypt: c3ee4828
OTP Plain: test

OTP Encrypt: c3ee3ee0
OTP Key: c3ee3ef0
End: Test Over!
```

Figure 1: Client

The server will decrypt AES message and OTP message, and send a "Test Over" message to the client.

Here it is very interesting that the AES encrypted message is not the same in the client and server. Why this happended? It is very strange. I think this may related to the padding of the message.

Also, the OTP encrypted message is not the same in the client and server. Interesting.



```
[09/26/24]seed@VM:Steven$ ./server
Done with binding with IP: 192.168.92.132, Port: 10888
Client connected at IP: 192.168.92.133 and port: 36106
AES Encrypt: e9f2f688
AES Decrypted message: test

OTP Encrypt: e9f2fe88
OTP Key: e9f2f120
OTP Decrypted message: test
```

Figure 2: Server

3 appendix

3.1 Client.c

```
#include <stdio.h>
#include <string.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <errno.h>
#include <unistd.h>

#include <openssl/conf.h>
#include <openssl/evp.h>
#include <openssl/err.h>
#include <openssl/dh.h>
#include <openssl/rand.h>

#define AES_KEY_LENGTH 32
#define AES_BLOCK_SIZE 16

void handleErrors(void)
{
    ERR_print_errors_fp(stderr);
    abort();
}

int stream_decrypt(unsigned char *ciphertext, int
    ciphertext_len, unsigned char *key, unsigned char
    *iv, unsigned char *plaintext)
{
   /* Declare cipher context */
   EVP_CIPHER_CTX *ctx;

   int len, plaintext_len;
```

```
    /* Create and initialize the context */
    ctx = EVP_CIPHER_CTX_new();
    if(!ctx) {
          handleErrors();
     }

    /* Initialize the decryption operation. */
    if(EVP_DecryptInit_ex(ctx, EVP_aes_256_cbc(), NULL
        , key, iv) != 1) {
          handleErrors();
    }

    /* Provide the message to be decrypted, and obtain
          the plaintext output. EVP_DecryptUpdate can be
          called multiple times if necessary. */
    if(EVP_DecryptUpdate(ctx, plaintext, &
        plaintext_len, ciphertext, ciphertext_len) !=
        1) {
          handleErrors();
    }


    /* Finalize the decryption. Further plaintext
        bytes may be written at this stage. */
    if(EVP_DecryptFinal_ex(ctx, plaintext +
        plaintext_len, &len) != 1) {
          handleErrors();
    }
     plaintext_len += len;

    /* Clean up */
    EVP_CIPHER_CTX_free(ctx);

    return plaintext_len;
}

int stream_encrypt(unsigned char *plaintext, int
    plaintext_len, unsigned char *key, unsigned char *
    iv, unsigned char *ciphertext)
{
  /* Declare cipher context */
   EVP_CIPHER_CTX *ctx;

    int len, ciphertext_len = 0;
    /* Create and initialize the context */
    ctx = EVP_CIPHER_CTX_new();
     if(!ctx) {
         handleErrors();
     }

    /* Initialize the encryption operation. */
    if(EVP_EncryptInit_ex(ctx, EVP_aes_256_cbc(), NULL
        , key, iv) != 1) {
         handleErrors();
      }


    /* Provide the message to be encrypted, and obtain
         the encrypted output. EVP_EncryptUpdate can be
         called multiple times if necessary */
     if(EVP_EncryptUpdate(ctx, ciphertext, &
        ciphertext_len, plaintext, plaintext_len) !=
        1) {
         handleErrors();
      }


    /* Finalize the encryption. Further ciphertext
        bytes may be written at this stage. */
    if(EVP_EncryptFinal_ex(ctx, ciphertext+
        ciphertext_len, &len) != 1) {
         handleErrors();
      }
    ciphertext_len += len;

    /* Clean up */
    EVP_CIPHER_CTX_free(ctx);


    return ciphertext_len;
}

// Generate Diffie-Hellman keys and get AES key and
    IV
void generateDHKeys(DH **dh, BIGNUM **pub_key, BIGNUM
     **priv_key) {
     *dh = DH_new();
     if (*dh == NULL) handleErrors();

     if (1 != DH_generate_parameters_ex(*dh, 2048,
            DH_GENERATOR_2, NULL))
            handleErrors();

        if (1 != DH_generate_key(*dh)) handleErrors();

        DH_get0_key(*dh, (const BIGNUM **)pub_key, (const
            BIGNUM **)priv_key);
}

void computeSharedSecret(DH *dh, BIGNUM *peer_pub_key
    , unsigned char *shared_secret, int *
    shared_secret_len) {
        *shared_secret_len = DH_compute_key(shared_secret
            , peer_pub_key, dh);
        if (*shared_secret_len == -1) handleErrors();
}

// One Time Pad encryption
void otp_encrypt(char *plaintext, char *key, char *
    ciphertext) {
        for (int i = 0; i < strlen(plaintext); i++) {
            ciphertext[i] = plaintext[i] ^ key[i];
        }
}

int main() {
        // Declare Variables
        struct sockaddr_in server_addr;

        char server_ip[16] = "192.168.92.132";
        int server_port = 10888;
        char server_message[1024];
        char client_message[1024];

        ssize_t varread;
        unsigned char ciphertext[1024];
        unsigned char aes_key[AES_KEY_LENGTH];
        unsigned char aes_iv[AES_BLOCK_SIZE];

        // Create socket:
        int sock = socket(AF_INET, SOCK_STREAM, 0);

        server_addr.sin_family = AF_INET;
        server_addr.sin_port = htons(server_port);
        server_addr.sin_addr.s_addr = inet_addr(server_ip
            );
```

```
// Send connection request to server, be sure to
    set port and IP the same as server-side
if(connect(sock, (struct sockaddr*) &server_addr,
     sizeof(server_addr)) < 0) {
    perror("Connection failed with error!");
    return 1;
}

// Perform Diffie-Hellman key exchange and
    decrypt AES key and IV

// recv key and iv
varread = recv(sock, aes_key, AES_KEY_LENGTH, 0);
varread = recv(sock, aes_iv, AES_BLOCK_SIZE, 0);

// Get input from the user:
printf("Enter message sent to the server: ");
fgets(client_message, sizeof(client_message),
    stdin);

// Encrypt the message
int ciphertext_len = stream_encrypt(
    client_message, strlen(client_message),
    aes_key, aes_iv, ciphertext);

// print the encrypted message
printf("AES Encrypt: %x\n",ciphertext);

// Send the message to server:
send(sock, ciphertext, ciphertext_len, 0);

// Init OTP as length of the client_message
char otp_key[strlen(client_message)];
for (int i = 0; i < strlen(client_message); i++)
    {
    otp_key[i] = rand() % 256;
}

// print
printf("OTP Plain: %s\n", client_message);

// Encrypt the message with OTP
char otp_ciphertext[strlen(client_message)];
otp_encrypt(client_message, otp_key,
    otp_ciphertext);
```

```
        // print the OTP encrypted message
        printf("OTP Encrypt: %x\n",otp_ciphertext);
        printf("OTP Key: %x\n",otp_key);

        // send the OTP ciphertext to server
        send(sock, otp_ciphertext, strlen(otp_ciphertext)
            , 0);

        // wait
        sleep(1);

        // send the OTP key to server
        send(sock, otp_key, strlen(otp_key), 0);



        // Receive the server's response:
        varread = read(sock, server_message, 1024);
        printf("End: %s\n", server_message);

        // Close the socket:
        close(sock);

        return 0;

    }
```

3.2 Server.c

```
#include <stdio.h>
#include <string.h>
#include <sys/socket.h>
#include <arpa/inet.h>
#include <errno.h>
#include <netinet/in.h>
#include <unistd.h>

#include <openssl/conf.h>
#include <openssl/evp.h>
#include <openssl/err.h>
#include <openssl/rand.h>
#include <openssl/aes.h>
#include <openssl/dh.h>
#include <openssl/bio.h>
```

```
#include <openssl/engine.h>

#define AES_KEY_LENGTH 32
#define AES_BLOCK_SIZE 16


// Handle errors
void handleErrors(void)
{
     ERR_print_errors_fp(stderr);
     abort();
}

// Define the decryption function
int stream_decrypt(unsigned char *ciphertext, int
    ciphertext_len, unsigned char *key, unsigned char *iv,
     unsigned char *plaintext)
{
   /* Declare cipher context */
   EVP_CIPHER_CTX *ctx;

   int len, plaintext_len;

   /* Create and initialize the context */
   ctx = EVP_CIPHER_CTX_new();
   if(!ctx) {
        handleErrors();
    }

   /* Initialize the decryption operation. */
   if(EVP_DecryptInit_ex(ctx, EVP_aes_256_cbc(), NULL,
       key, iv) != 1) {
        handleErrors();
   }

   /* Provide the message to be decrypted, and obtain the
        plaintext output. EVP_DecryptUpdate can be called
       multiple times if necessary. */
   if(EVP_DecryptUpdate(ctx, plaintext, &plaintext_len,
       ciphertext, ciphertext_len) != 1) {
        handleErrors();
   }


   /* Finalize the decryption. Further plaintext bytes
       may be written at this stage. */
   if(EVP_DecryptFinal_ex(ctx, plaintext + plaintext_len,
       &len) != 1) {
        handleErrors();
   }
    plaintext_len += len;

   /* Clean up */
   EVP_CIPHER_CTX_free(ctx);

   return plaintext_len;
}

int stream_encrypt(unsigned char *plaintext, int
    plaintext_len, unsigned char *key, unsigned char *iv,
    unsigned char *ciphertext)
{
  /* Declare cipher context */
   EVP_CIPHER_CTX *ctx;

   int len, ciphertext_len = 0;

   /* Create and initialize the context */
   ctx = EVP_CIPHER_CTX_new();
    if(!ctx) {
        handleErrors();
    }

   /* Initialize the encryption operation. */
   if(EVP_EncryptInit_ex(ctx, EVP_aes_256_cbc(), NULL,
       key, iv) != 1) {
        handleErrors();
    }


   /* Provide the message to be encrypted, and obtain the
        encrypted output. EVP_EncryptUpdate can be called
       multiple times if necessary */
    if(EVP_EncryptUpdate(ctx, ciphertext, &ciphertext_len
        , plaintext, plaintext_len) != 1) {
        handleErrors();
    }


   /* Finalize the encryption. Further ciphertext bytes
       may be written at this stage. */
   if(EVP_EncryptFinal_ex(ctx, ciphertext+ciphertext_len,
        &len) != 1) {
        handleErrors();
     }
    ciphertext_len += len;

    /* Clean up */
    EVP_CIPHER_CTX_free(ctx);


    return ciphertext_len;
}

int main() {
    // Declare variables
        ssize_t varread;
    char server_message[1024];
    char client_message[1024];

    struct sockaddr_in server_addr;
    char server_ip[16]= "192.168.92.132";
    int server_port = 10888;

    struct sockaddr_in client_addr;
    socklen_t client_addr_len = sizeof(client_addr);

    // Create socket
    int client_sock;
        int sever_sock = socket(AF_INET, SOCK_STREAM, 0);
    if (sever_sock < 0) {
        perror("Socket creation failed with error!");
        return 1;
    }
    if(setsockopt(sever_sock, SOL_SOCKET, SO_REUSEADDR,
        &(int){1}, sizeof(int)) < 0) {
        perror("Socket option failed with error!");
        return 1;
    }
    server_addr.sin_family = AF_INET;
    server_addr.sin_port = htons(server_port);
    server_addr.sin_addr.s_addr = inet_addr(server_ip);


    // Bind to the set port and IP
    if(bind(sever_sock, (struct sockaddr*)&server_addr,
        sizeof(server_addr)) < 0) {
        perror("Binding failed with error!");
        return 1;
    }
    printf("Done with binding with IP: %s, Port: %d\n",
        server_ip, server_port);

    // Listen for clients:
    if(listen(sever_sock, 3) < 0) {
        perror("Listening failed with error!");
        return 1;
    }

    // Accept an incoming connection
    if((client_sock = accept(sever_sock, (struct sockaddr
        *)&client_addr, &client_addr_len)) < 0) {
        perror("Accepting failed with error!");
        return 1;
    }
    char * client_ip = inet_ntoa(client_addr.sin_addr);
    int client_port = ntohs(client_addr.sin_port);
    printf("Client connected at IP: %s and port: %i\n",
        client_ip, client_port);

    // Declare key and iv
    unsigned char key[AES_KEY_LENGTH];
    unsigned char iv[AES_BLOCK_SIZE];

    // Initialize key and iv
    if(RAND_bytes(key, AES_KEY_LENGTH) != 1) {
        printf("Error in generating key\n");
        return;
    }

    if(RAND_bytes(iv, AES_BLOCK_SIZE) != 1) {
        printf("Error in generating iv\n");
        return;
    }

    // Send AES key and IV to client
    send(client_sock, key, AES_KEY_LENGTH, 0);
    send(client_sock, iv, AES_BLOCK_SIZE, 0);

    // Receive client's message
    varread = recv(client_sock, client_message, 1024, 0);
    printf("AES Encrypt: %x\n", client_message);

    // Decrypt the message
    unsigned char decrypted_message[1024];
    int decrypted_message_len = stream_decrypt(
        client_message, varread, key, iv,
        decrypted_message);

    // Print the decrypted message
    printf("AES Decrypted message: %s\n",
        decrypted_message);


    // Receive OTP encrypted message
    char otp_encrypted_message[1024];
    char otp_key[varread];
    varread = recv(client_sock, otp_encrypted_message,
        1024, 0);
    varread = recv(client_sock, otp_key, 1024, 0);
    printf("OTP Encrypt: %x\n", otp_encrypted_message);
    printf("OTP Key: %x\n", otp_key);

    // Decrypt the OTP message
    char otp_decrypted_message[varread];
    for (int i = 0; i < varread; i++) {
         otp_decrypted_message[i] = otp_encrypted_message[
             i] ^ otp_key[i];
    }

    // Print the OTP decrypted message
    printf("OTP Decrypted message: %s\n",
        otp_decrypted_message);

    // Respond to client
    strcpy(server_message, "Test Over!");

    // Send the message to the client
    send(client_sock, server_message, strlen(
        server_message), 0);

    // Close the socket
    close(client_sock);
    close(sever_sock);


    return 0;
}
```