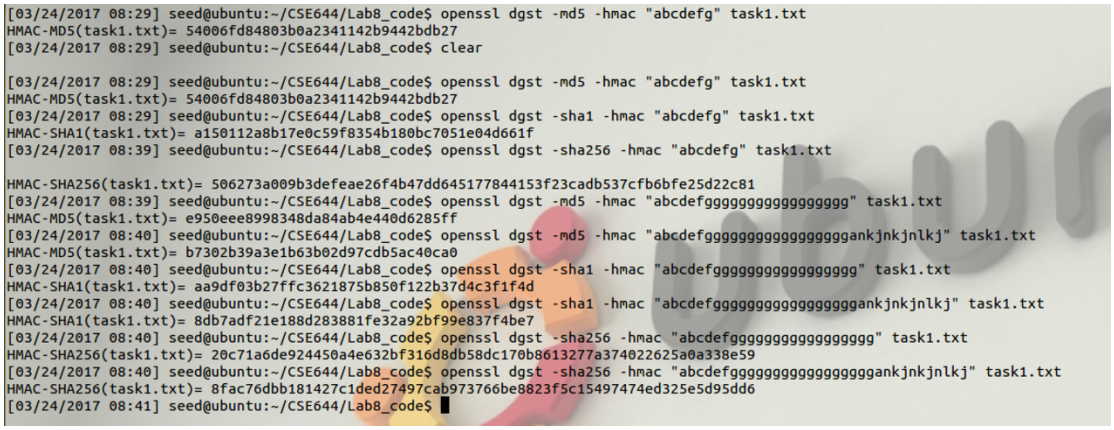
Lab 8 Crypto Lab II – One-way Hash Function and MAC

Task 1, Generating Message Digest and MAC

Observation: The three algorithms I used are MD5, SHA1 and SHA256. As we can see in this pic, the length of the generated text is different. MD5 is 16 bytes, SHA1 is 20 bytes and SHA256 is 32 bytes. The same plain text will generate the same hash value no matter how many times you try.

Task 2, Keyed Hash and HMAC

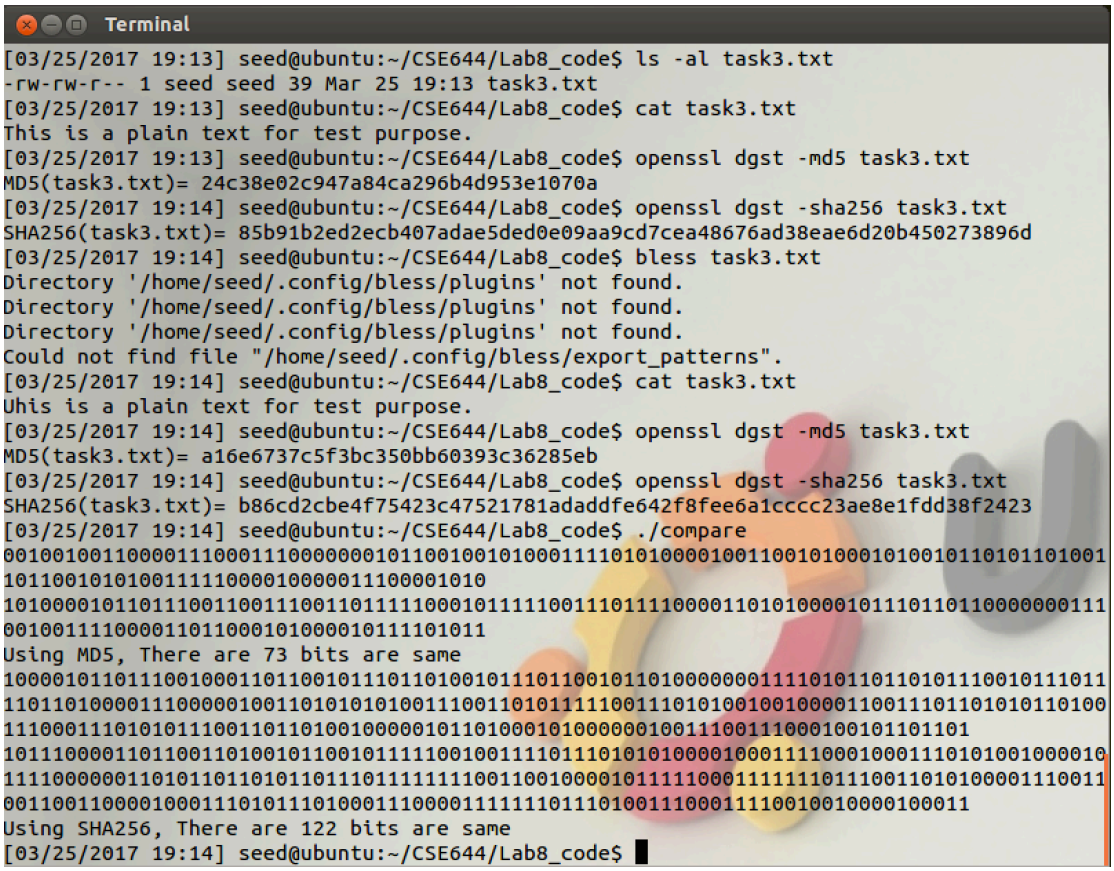


Observation: If the hash algorithm is fixes, then no matter how long the HMAC key is, the length of hash value is fixed. However, if the HMAC key is different, the generated text is different, even though the plain text is the same.

- **Do we have to use a key with a fixed size in HMAC? WHY?**

  It is unnecessary to use a key with a fixed size. Because if the HMAC key is longer than the block length of a specific hash algorithm, the extra part will be cut; if the HMAC key is shorter than the block size, zero will be padded.

Task 3, The Randomness of One-Way Hash

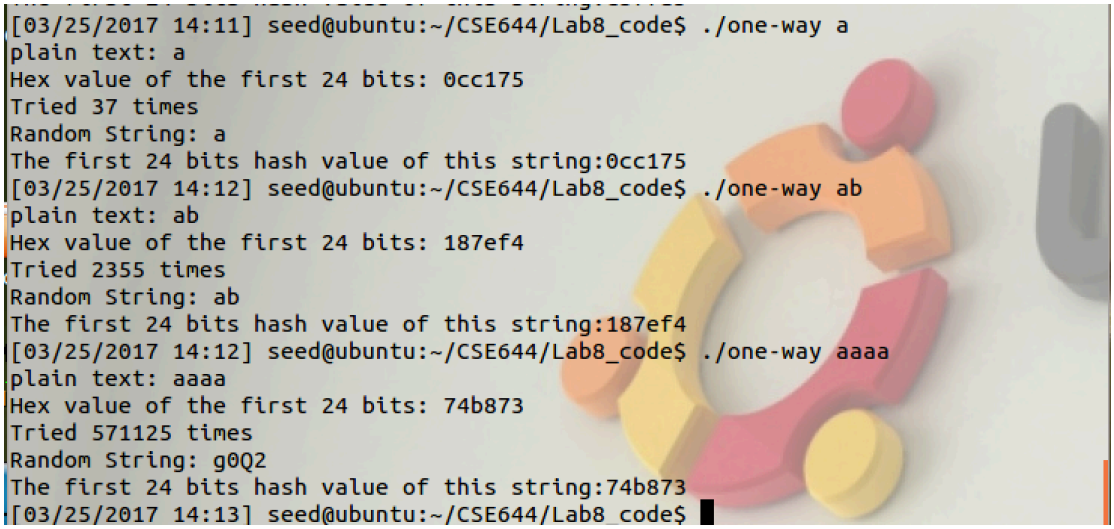


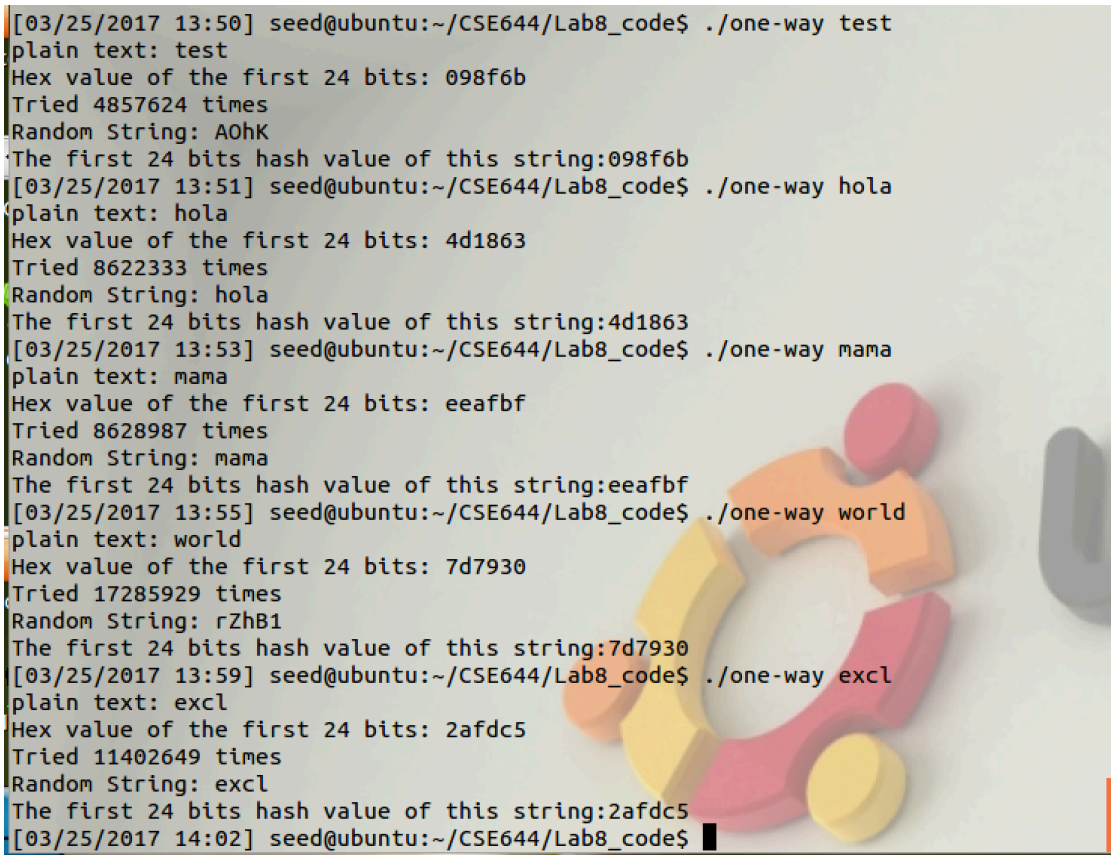
Observation: I used “bless” to flip the fourth bit of the plain text, as we can see, the hash value of the revised text is not quite similar, for both MD5 algorithm and SHA256 algorithm. It seems like generally half of the digits is same if one bit is flipped.

Task 4, One-Way Property versus Collision-Free Property

• break one-way property

Design: 1, supplying a plain text and generating its hash value; 2, randomly generating a string, comparing the fist 24 bits of its hash value with the plain text’s; 3, if found matches, report the string.

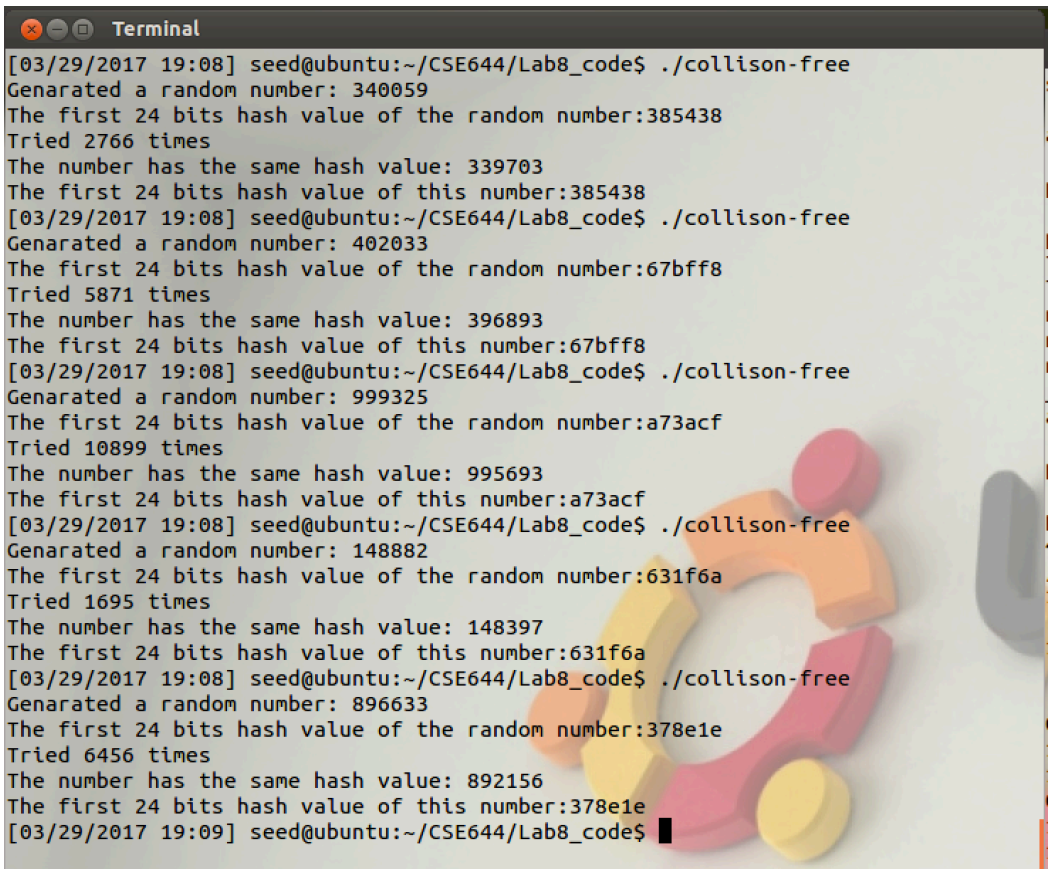




Observation: As we can see in the screenshot above, I have tried 8 times. By using my method of brute-force, the simpler the plaintext, the less the trial times. For the string with four characters, the average running times are around 8,000,000. For these 8 experiments, the average trials are more than 4,000,000.

• **break collision-free property**

Design: The basic idea to break collision-free property is: starting from a random number and then increasing this random number by 1 for several times until finding two numbers in this range—from start number to current number—that the first 24 bits have the same hash value.



Observation: Using this method to break collision free property, the average trials I observed through the above experiment is around 5000 times. Comparing with the one-way property broken experiment, the trying times is much smaller.

• Based on your observation, which property is easier to break using the brute-force methods?

Collision-free property is easier to break based on my observation.

• Can you explain the difference in your observation mathematically?

For a hash function with a n-bit output, it will cost roughly 2^n to break one-way property, and $2^{n/2}$ to break collision-free property.

Appendix:

Compare.c

```
#include <stdio.h>
#include <string.h>

// convert hex to bit
void HexToBit(char* cvrt, char* hexStr)
{
    for(int i=0; i<strlen(hexStr);i++)
    {
        switch(hexStr[i])
```

```
{
    case '0':
        strcat(cvrt, "0000");
        break;
    case '1':
        strcat(cvrt, "0001");
        break;
    case '2':
        strcat(cvrt, "0010");
        break;
    case '3':
        strcat(cvrt, "0011");
        break;
    case '4':
        strcat(cvrt, "0100");
        break;
    case '5':
        strcat(cvrt, "0101");
        break;
    case '6':
        strcat(cvrt, "0110");
        break;
    case '7':
        strcat(cvrt, "0111");
        break;
    case '8':
        strcat(cvrt, "1000");
        break;
    case '9':
        strcat(cvrt, "1001");
        break;
    case 'a':
        strcat(cvrt, "1010");
        break;
    case 'b':
        strcat(cvrt, "1011");
        break;
    case 'c':
        strcat(cvrt, "1100");
        break;
    case 'd':
        strcat(cvrt, "1101");
        break;
    case 'e':
```

```
                strcat(cvrt, "1110");
                break;
            case 'f':
                strcat(cvrt, "1111");
                break;
            default:
                break;
        }
    }
}

// do comparasion
int compareMD5(char* Binary1, char* Binary2)
{
    int cnt=0;
    for(int i=0;i <128; i++)
    {
        if(Binary1[i]==Binary2[i])
            cnt++;
    }
    return cnt;
}

int compareSHA256(char* Binary1, char* Binary2)
{
    int cnt=0;
    for(int i=0;i <256; i++)
    {
        if(Binary1[i]==Binary2[i])
            cnt++;
    }
    return cnt;
}
int main()
{
    char* txt1="24c38e02c947a84ca296b4d953e1070a";
    char* txt2="a16e6737c5f3bc350bb60393c36285eb";
    char cvrt1[1024]={};char cvrt2[1024]={};
    HexToBit(cvrt1,txt1); HexToBit(cvrt2,txt2);
    printf("%s\n%s\n", cvrt1, cvrt2);
    int cnt=compareMD5(cvrt1,cvrt2);
    printf("Using MD5, There are %d bits are same\n", cnt);
    ////////////////////////////
    char* sha1="85b91b2ed2ecb407adae5ded0e09aa9cd7cea48676ad38eae6d20b450273896d";
```

```
    char* sha2="b86cd2cbe4f75423c47521781adaddfe642f8fee6a1cccc23ae8e1fdd38f2423";
    char cvrt3[1024]={};char cvrt4[1024]={};
    HexToBit(cvrt3,sha1); HexToBit(cvrt4,sha2);
    printf("%s\n%s\n", cvrt3, cvrt4);
    cnt=compareSHA256(cvrt3,cvrt4);
    printf("Using SHA256, There are %d bits are same\n", cnt);
    return 0;
}
```

One-way.c

```
#include <stdio.h>
#include <openssl/evp.h>
#include <string.h>
void GetHashValue(char* plain, unsigned char* hashValue)
{
    EVP_MD_CTX* mdctx;
    const EVP_MD* md;
    unsigned char md_value[EVP_MAX_MD_SIZE];
    int md_len, i;
    OpenSSL_add_all_digests();

    md=EVP_get_digestbyname("md5");

    // allocate, initialize and return a digest context
    mdctx=EVP_MD_CTX_create();
    // set up digest context ctx to use a digest type
    EVP_DigestInit_ex(mdctx,md,NULL);
    // hashes cnt bytes of data at plain into the digest context ctx
    EVP_DigestUpdate(mdctx, plain, strlen(plain));
    // retrieves the digest value from ctx and places it in md
    EVP_DigestFinal_ex(mdctx, hashValue, &md_len);
    // cleans up digest context ctx and frees up the space allocated to it
    EVP_MD_CTX_destroy(mdctx);
    EVP_cleanup();
}

int main(int argc, char* argv[])
{
    char* plain=argv[1];
    unsigned char hashValue[EVP_MAX_MD_SIZE];
    unsigned                                                                    char
dict[]="0123456789ABCDEFGHIJKLMNOPQRSTUVWXYZabcdefghijklmnopqrstuvwxyz";
    char str[1000];
    GetHashValue(plain, hashValue);
    printf("plain text: %s\n", plain);
```

```
    // print the first 24 bits of the hash value
    printf("Hex value of the first 24 bits: ");
    for(int i=0;i<3;i++) printf("%02x", hashValue[i]);
    printf("\n");
    // generate random strings for hash

    int cnt=0, j=0,k=0;
    while(1)
    {
        unsigned char temp[EVP_MAX_MD_SIZE];
        j=cnt; k=0;
        while(j>=1)
        {
            str[k]=dict[j%(strlen(dict)-1)];
            k+=1;
            j=j/strlen(dict);
        }
        GetHashValue(str,temp);
        if(strncmp(temp, hashValue, 3)==0)
        {
            printf("Tried %d times\n", cnt+1);
            printf("Random String: %s\n", str);
            printf("The first 24 bits hash value of this string:");
            for(int i=0;i<3;i++)printf("%02x",temp[i]);
          //for(int i=0;i<3;i++)printf("%02x",hashValue[i]);
            printf("\n");
            break;
        }
        cnt++;
    }
    return 0;
}
```

Collision-free.c

```
#include <sys/types.h>
#include <stdio.h>
#include <stdlib.h>
#include <openssl/evp.h>
#include <string.h>

void HashValue(char* plain, unsigned char* hashValue)
{
    EVP_MD_CTX* mdctx;
    const EVP_MD* md;
```

```
    int md_len, i;
    OpenSSL_add_all_digests();

    md=EVP_get_digestbyname("md5");

    // allocate, initialize and return a digest context
    mdctx=EVP_MD_CTX_create();
    // set up digest context ctx to use a digest type
    EVP_DigestInit_ex(mdctx,md,NULL);
    // hashes cnt bytes of data at plain into the digest context ctx
    EVP_DigestUpdate(mdctx, plain, strlen(plain));
    // retrieves the digest value from ctx and places it in md
    EVP_DigestFinal_ex(mdctx, hashValue, &md_len);
    // cleans up digest context ctx and frees up the space allocated to it
    EVP_MD_CTX_destroy(mdctx);
    EVP_cleanup();
}

int main(int argc, const char* argv)
{
    unsigned char hashValue[EVP_MAX_MD_SIZE];
    srand((unsigned)time(NULL));
    int random=rand()%1000000+1;
    int begin=random;
    unsigned char* hash=(unsigned char*)(malloc(sizeof(unsigned char)*10000000));
    // convert to string to get hash value
    char* plain=malloc(16);
    snprintf(plain, 16, "%d", random);
    // get hash value
    HashValue(plain, hashValue);

    memcpy(hash, hashValue,3);

    // generate random strings for hash
    int cnt=1, j=3,k=0;
    while(1)
    {
        random+=1;
        snprintf(plain, 16, "%d", random);
        // get hash value
        HashValue(plain, hashValue);

        for(int i=0;i<j;i=i+3)
        {
```

```
            if(memcmp(hash+i, hashValue, 3)==0)
            {
                printf("Genarated a random number: %d\n", random);
                // print the first 24 bits
                printf("The first 24 bits hash value of the random number:");
                for(int p=0;p<3;p++)printf("%02x",(hash+i)[p]);
                printf("\n");
                //printf("H1: %s, H2: %s\n", hash+i, hashValue);
                printf("Tried %d times\n", cnt);
                printf("The number has the same hash value: %d\n", begin+i/3);
                printf("The first 24 bits hash value of this number:");
                for(int z=0;z<3;z++)printf("%02x",hashValue[z]);
                printf("\n");
                return 0;
            }
        }
        memcpy(hash+j, hashValue, 3);
        j+=3;
        cnt++;
    }
}
```