Security Essentials for Systems Programmers

CS 3214

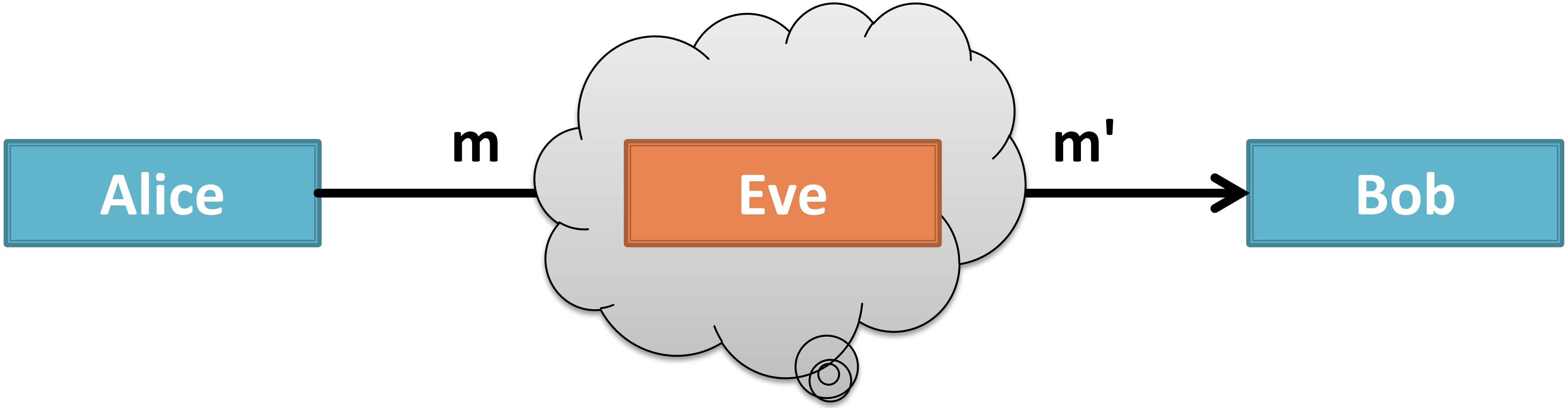
Security properties you should learn

- Confidentiality
- Integrity
- Availability
- Authenticity

Known as **CIA**

Confidentiality is preventing others from reading your data

- **Goal:** Communicate across an untrusted medium, but only Alice and Bob know what is being communicated



- **Adversary:** Eve is an eavesdropper who can read every message sent between Alice and Bob

Confidentiality is preventing others from reading your data

- **Goal:** Communicate across an untrusted medium, but only Alice and Bob know what is being communicated

Alice

Encryption provides confidentiality

Bob

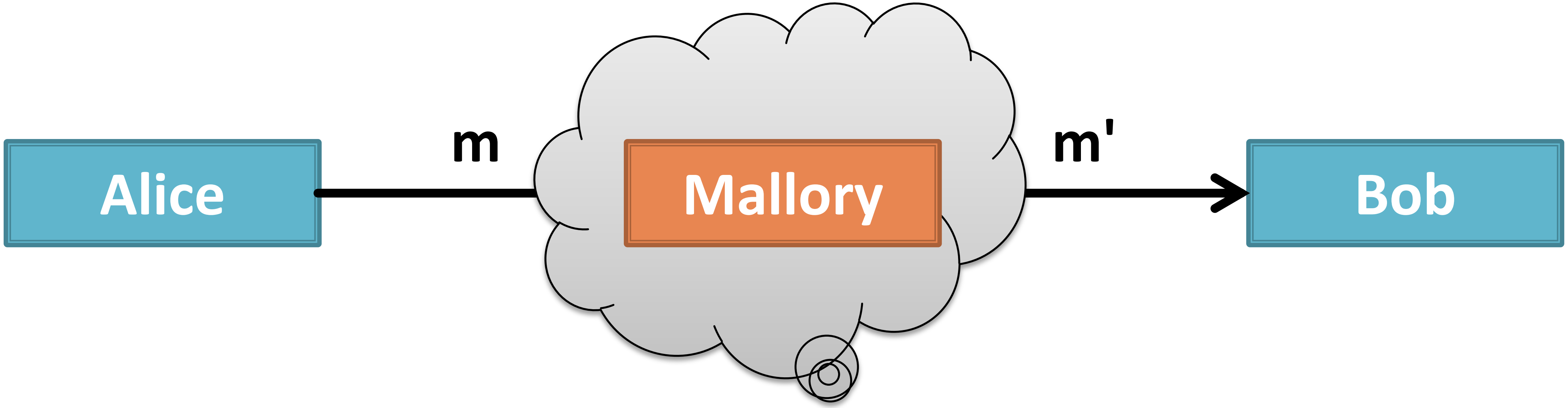
- **Adversary:** Eve is an eavesdropper who can read every message sent between Alice and Bob

Confidentiality Use Cases

- Internet communication
  - Web pages
  - Email
  - Audio and video
  - Conference calls
- File storage
  - On a managed system
  - On a system you may lose control of
    - Theft and hacking
- General communication
  - Phone
  - WiFi
  - Bluetooth
- Extortion (see ransomware)

Integrity is preventing others from modifying your data (with you being aware of it)

- **Goal:** Communicate across an untrusted medium, but every message received must be exactly what was sent



- **Adversary:** Mallory is an malicious entity who can modify, reorder, and replay every message sent between Alice and Bob

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- **Goal:** Communicate across an untrusted medium, but every message received must be exactly what was sent

Alice

Hashing provides integrity

Bob

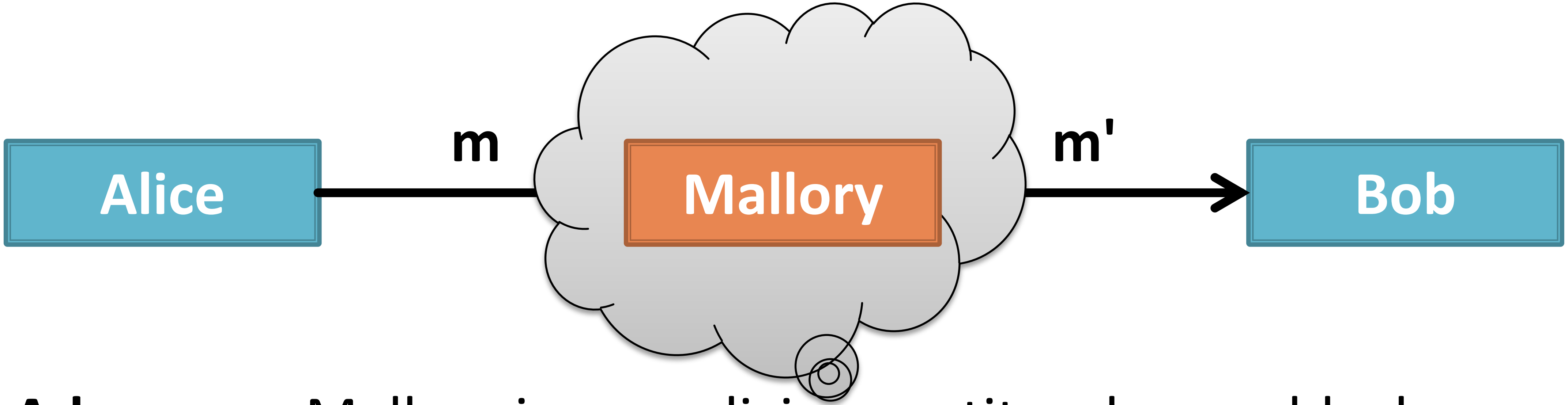
- **Adversary:** Mallory is an malicious entity who can modify, reorder, and replay every message sent between Alice and Bob

(cryptographic) Integrity use cases

- Web pages
- Email
- Password storage and comparison
- Secure system memory
- Software downloads
- Bitcoin et al.
  - Block chain
- SSH
- Malware checking

Availability is making sure your data/service is accessible

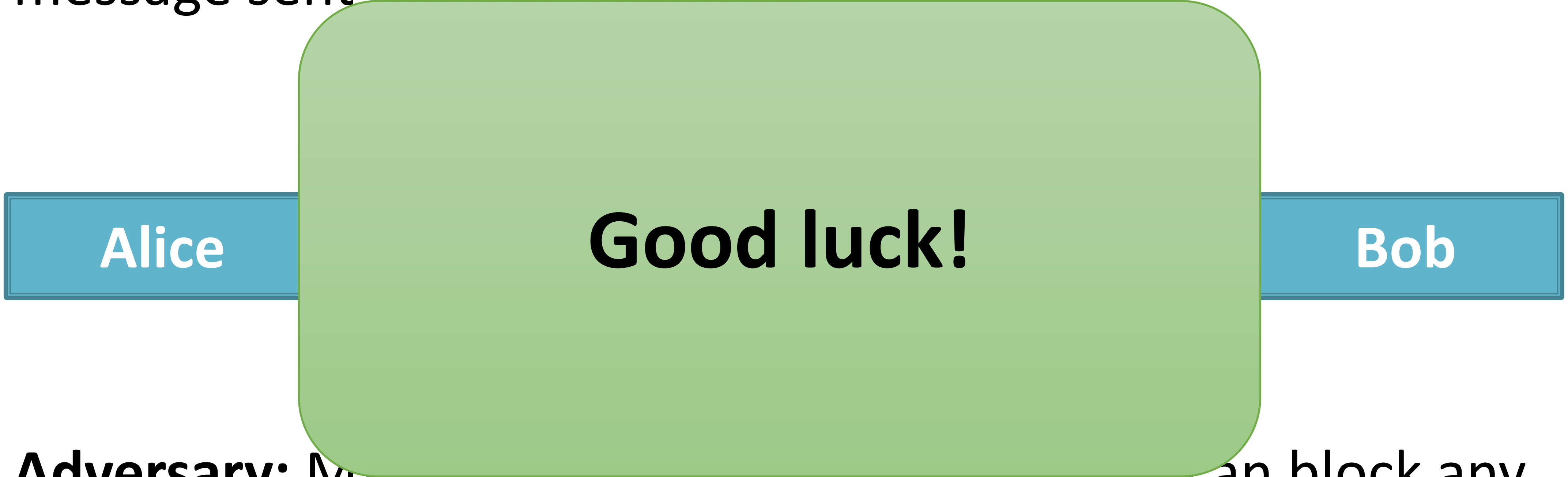
- **Goal:** Communicate across an untrusted medium, but every message sent must be received



- **Adversary:** Mallory is an malicious entity who can block any message sent between Alice and Bob or flood them with messages

Availability is making sure your data/service is accessible

- **Goal:** Communicate across an <u>untrusted</u> medium, but every message sent must be received



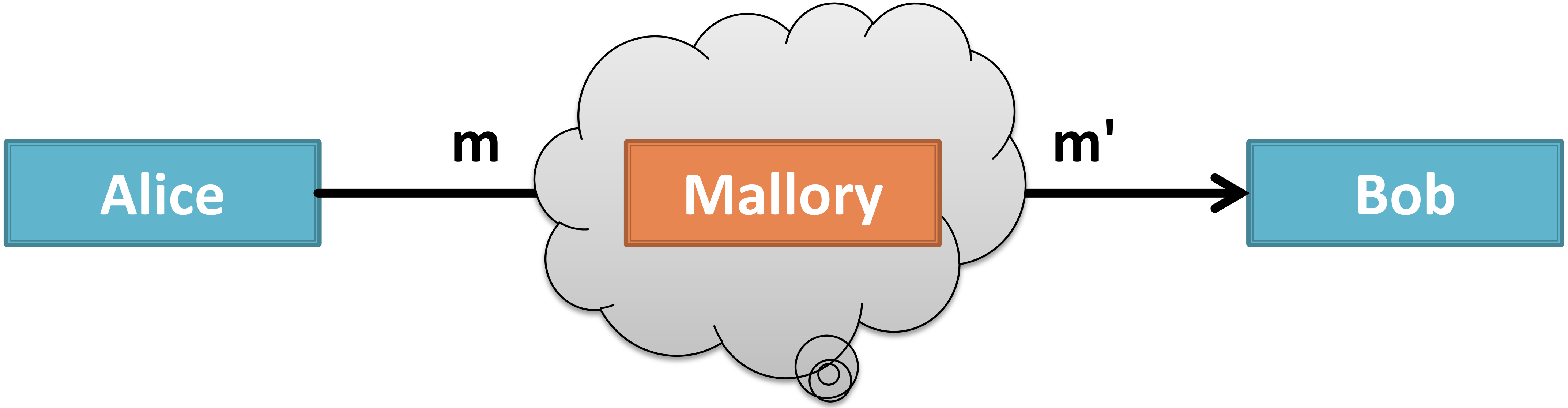
- **Adversary:** Mallory is an malicious entity who can block any message sent between Alice and Bob or flood them with messages

Availability use case

- If you cannot access it, it doesn’t exist

Authenticity is ensuring the other party is who you think they are

- **Goal:** Communicate across an <u>untrusted</u> medium, but Bob must be able to prove the message came from Alice



- **Adversary:** Mallory is an malicious entity who pretends to be Alice

Authenticity is ensuring the other party is who you think they are

- **Goal:** Communicate across an <u>untrusted</u> medium, but Bob must be able to prove the message came from Alice

Shared keys, public keys, passwords/tokens/fingerprints provide authenticity

- **Adversary:** Mallory is an malicious entity who pretends to be Alice

Authentication use case

- Access control
  - Physical access
    - Buildings, cars, parking, airplanes…
  - System access
    - Your computer, rlogin…
  - Service access
    - Hokiespa, library, Zoom…
  - Data access
- Bitcoin
  - Money
- Communication channel access
  - Public Key Certificates

Security Easy Buttons (card subject to change)

- Confidentiality – AES (gov. uses 192-bit+)
- Integrity – SHA256
  - Never md5 or SHA1
- Availability – duplication and distribution, client filtering, push work/state on to client
- Authentication
  - Host
    - Salted hash (SHA256) password comparison
  - Network
    - Shared keys + SHA256
    - Public keys: ECDSA (P-256) + SHA256

How do you implement these in your own programs?

Don’t roll your own!

Choose a **trusted+open source** crypto library

- What most people use: Openssl
  - C/C++ library
  - Command line tool
  - Python: pyopenssl
  - Lack of diversity in crypto. Implementations is problematic: see HeartBleed
- Another option: Crypto++
  - C/C++ library
  - Python: pycryptopp wrapper
- Note: SSL is the predecessor to the modern day TLS

Prerequisites

- What I tested this on
  - Ubuntu 20.04
  - Openssl 1.1.1f
  - Intel x86_64
- Required packages
  - sudo apt install clang libssl-dev
- How I compile
  - clang -Wall -O3 -o example.bin example.c -lssl –lcrypto
- Assumes plaintext.txt in the same directory

Using Openssl for AES Encryption

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

static const unsigned char key[] =  "thiskeyisverybad12345678"; // 192 bits
static const unsigned char iv[] =   "publicButUnique";          // 128 bits (aka block size)
```

```c
long int getFileSize(FILE *fp) {
    struct stat fInfo;
    fstat(fileno(fp), &fInfo);
    off_t size = fInfo.st_size;
    return (long int)size;
}

int main(int argc, char *argv[])
{
    FILE *fIN, *fOUT;


    // Encrypt
    fIN = fopen("plaintext.txt", "rb");
    fOUT = fopen("ciphertext.txt", "wb");
    encrypt(fIN, fOUT);
    fclose(fIN);
    fclose(fOUT);


    // Decrypt
    fIN = fopen("ciphertext.txt", "rb");
    fOUT = fopen("plaintext2.txt", "wb");
    decrypt(fIN, fOUT);
    fclose(fIN);
    fclose(fOUT);
}
```

```c
void encrypt(FILE *ifp, FILE *ofp)
{
    long int fsize = getFileSize(ifp);

    int outLen1 = 0; int outLen2 = 0;
    unsigned char *indata = malloc(fsize);
    unsigned char *outdata = malloc(fsize + AES_BLOCK_SIZE); // May need an extra block's worth of bytes

    // Read entire file as bytes
    fread(indata, sizeof(char), fsize, ifp);

    // Setup
    EVP_CIPHER_CTX *ctx = EVP_CIPHER_CTX_new();
    EVP_CIPHER_CTX_init(ctx);

    // Encrypt plaintext
    EVP_EncryptInit(ctx, EVP_aes_192_cbc(), key, iv);
    EVP_EncryptUpdate(ctx, outdata, &outLen1, indata, fsize);
    EVP_EncryptFinal(ctx, outdata + outLen1, &outLen2); // Handle padding

    // Write ciphertext to file as bytes
    fwrite(outdata, sizeof(char), outLen1 + outLen2, ofp);

    // Cleanup
    EVP_CIPHER_CTX_free(ctx);
}
```

```c
void decrypt(FILE *ifp, FILE *ofp)
{
    int fsize = getFileSize(ifp);

    int outLen1 = 0; int outLen2 = 0;
    unsigned char *indata = malloc(fsize);
    unsigned char *outdata = malloc(fsize); // Ciphertext always larger than plaintext due to padding

    //Read entire ciphertext as bytes
    fread(indata, sizeof(char), fsize, ifp);

    // Setup
    EVP_CIPHER_CTX *ctx = EVP_CIPHER_CTX_new();
    EVP_CIPHER_CTX_init(ctx);

    // Decrypt ciphertext
    EVP_DecryptInit(ctx, EVP_aes_192_cbc(), key, iv);
    EVP_DecryptUpdate(ctx, outdata, &outLen1, indata, fsize);
    EVP_DecryptFinal(ctx, outdata + outLen1, &outLen2); // Last block will always have padding

    // Write plaintext to file as bytes
    fwrite(outdata, sizeof(char), outLen1 + outLen2, ofp);

    // Cleanup
    EVP_CIPHER_CTX_free(ctx);
}
```

Using Openssl for SHA Hashing

```
#include <string.h>
#include <stdio.h>
#include <stdlib.h>
#include <openssl/evp.h>
#include <openssl/sha.h>
#include <openssl/hmac.h>
#include <sys/types.h>
#include <sys/stat.h>
#include <unistd.h>


static const unsigned char key[] =  "thiskeyisverybad12345678"; // 192 bits


long int getFileSize(FILE *fp) {
    struct stat fInfo;
    fstat(fileno(fp), &fInfo);
    off_t size = fInfo.st_size;
    return (long int)size;
}
```

```c
int main(int argc, char *argv[])
{
    FILE *fIN;

    // Get a hash digest of the file
    fIN = fopen("plaintext.txt", "rb");
    unsigned char digest[SHA256_DIGEST_LENGTH + 1];
    digest[32] = '\0';

    // Hash
    hash(fIN, digest);
    printf("%s\n", digest);

    fseek(fIN, 0L, SEEK_SET);

    // HMAC ~ keyed hash
    hmac(fIN, digest);
    printf("%s\n", digest);

    fclose(fIN);
}
```

```
void hash(FILE *fp, unsigned char *digest) {
    long int fsize = getFileSize(fp);

    unsigned char *indata = malloc(fsize);
    fread(indata, sizeof(char), fsize, fp);

    unsigned int outlen = 0;
    // CTK creation, Init, Update, and Final all in one
    EVP_Digest(indata, fsize, digest, &outlen, EVP_sha256(), NULL);
}
```

```c
void hmac(FILE *fp, unsigned char *digest) {
    long int fsize = getFileSize(fp);

    unsigned char *indata = malloc(fsize);
    fread(indata, sizeof(char), fsize, fp);

    unsigned int outlen = 0;
    // CTK creation, Init, Update, and Final all in one
    HMAC(EVP_sha256(), key, sizeof(key) - 1, indata, fsize, digest, &outlen);
}
```

Using Openssl for Symmetric Key Generation

```
…
#include <openssl/rand.h>
…

#define KEY_BITS 192
static unsigned char key[KEY_BITS/8];

int main(int argc, char *argv[])
{
    …
    // Get random key
    RAND_bytes(key, sizeof(key));
    …
}
```

CS 4264

Principles of Computer Security

Lots more details

Lots more topics

…and public key fun