ENEE739B Fall 2005
Part 2 Secure Media Communications

2.1 Basic Cryptography Concepts

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Part of the slides are used or revised from material courtesy of Prof. Y. Sun of Univ. Rhode Island.

Outline: Basic Security/Crypto Concepts

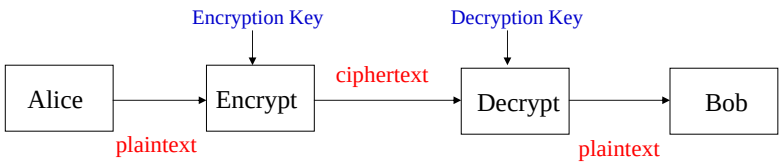
- Typical scenarios and attacks on secure communications
- Kerckhoff principle
- Major security aspects
- Symmetric vs. Asymmetric encryption

Crypto Terminologies

- **Cryptography**: the art of secret writing
  - The art of mangling information into apparent unintelligibility in a manner that allows a secret method of unmangling.
- Three related terminologies
  - ***Cryptology*****:** The study of communication over non-secure channels, and related problems
  - ***Cryptography*****:** The process of designing systems that achieve secure communications.
  - ***Cryptanalysis*****:** Breaking such systems. (The techniques used to recover the secret information hidden in cryptographic systems)

They are often used interchangeably.

Basic Secure Communication Scenario

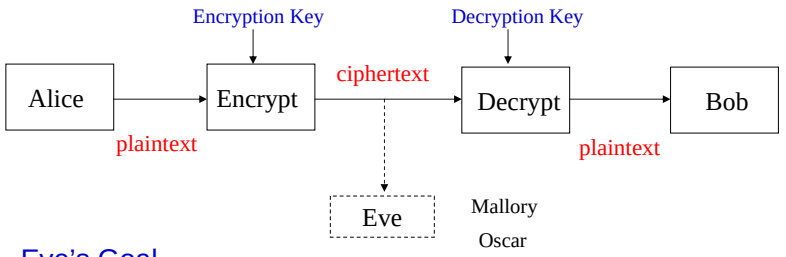


- Plaintext: the message in its original form
- Ciphertext: the mangled information

- Encryption: the process of produce ciphertext from plaintext
- Decryption: the process reversing the encryption

Encryption and Decryption involve some Algorithm and secret values (keys)

Adversaries



Eve's Goal

1. Read the message
2. Figure out the key Alice is using and read all the messages encrypted with that key

Passive observer "Olive"

3. Modify the content of the message in such a way that Bob will think Alice sent the altered message.
4. Impersonate Alice and communicate with Bob who thinks he is communicating with Alice.

Active adversary "Mallory"

Attack Methods

- **Ciphertext only**
  - Eve has only a copy of ciphertext
- **Known Plaintext**
  - Eve has ciphertext and the corresponding plaintext, and tries the deduce the key.
- **Chosen Plaintext ***
  - Eve has ciphertext corresponding to some plaintext selected by her, believing it useful to deduce the key.
- **Chosen Ciphertext ***
  - Eve has a copy plaintext corresponding to a copy of ciphertext selected by her, believing it is useful to deduce the key.

* Possible when Eve gains temporary access to encrypter / decrypter

Kerckhoff's Principle

- Relying on secrecy of the crypto algorithm?
  - Hard to quantify the security strength
    - *some thinking process of people may be alike*
    - *may have to abandon the entire system when compromised*

security by obscurity

=> Should always assume an adversary knows the crypto algorithm used when assessing a crytosystem's strength

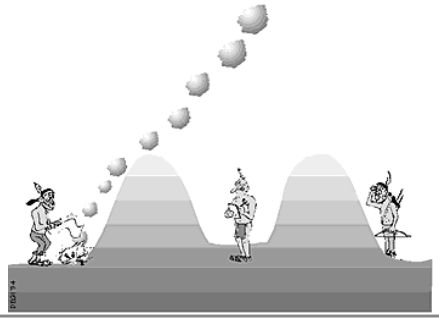
- The security of a crypo system should be based on
  - the quality/strength of the algorithm but not its obscurity
  - secrecy of the key over a sufficiently large key space (or key length)

Major Cryptographic Objectives

- Confidentiality
  - Hide the contents of a message from unauthorized observer
  - Main tools: encryption / decryption
- Data integrity
  - Ensuring the message sent has not been altered
  - Main tools: hash functions to detect tampering
- Authentication: entity identification & data-origin authentication
  - Correctly verify a user's identity: through password protocol
  - Verify the origin of a message (creator, creation time, etc)
- Non-repudiation
  - A sender cannot deny a transmitted message or transaction

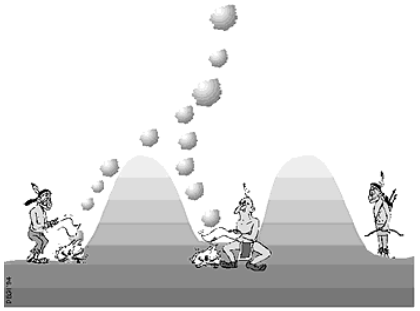
Data Confidentiality

- Eve should not be able to read Alice's' message to Bob.
- The oldest and best known aspect of data security.
  - The main tools are encryption / decryption



Data Integrity

- Bob wants be sure that Alice's message has not been altered.
  - Transmission errors may occur
  - An adversary might intercept the transmission and alter it.

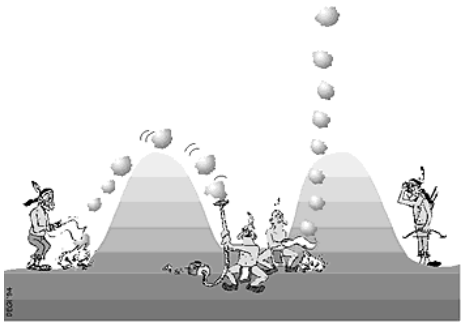


User Authentication

- Password protocol
  - When you log on to a computer, the computer need to identify your identity.
- Verify communication partner
  - Verify that we are communicating with the right person.

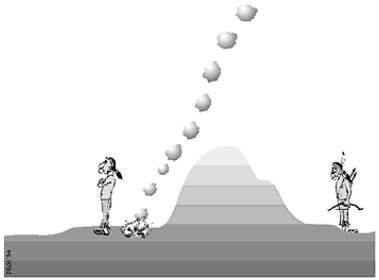
Data Origin Authentication

- Authenticate the information about the origin of the data, such as the creator and time of creation.
  - Bob wants to make sure that the message is really from Alice, and the message was not a replay of previous messages from Alice.



Non-repudiation

- Alice cannot claim that she did not send the message.
  - Suppose Bob takes orders from his customer through e-mails. Alice made a order through email and later denied this purchase. Bob needs to show that Alice did send the email.
- Data-origin authentication vs. non-repudiation
  - In a paper and pencil world, non-repudiation is provided by a manual signature
  - Hard to show non-repudiation in symmetric-key crypto
  - Public-key crypto can do both



Symmetric Key Cryptography

- Alice and Bob know both the encryption key and the decryption key.
  - Encryption key and decryption keys are the same;
  - The encryption key is shared and the decryption key is easy to be calculated from the encryption key.
- Symmetric cryptosystems:
  - All of the classical (pre-1970) systems
  - DES and AES
- Challenge: Alice and Bob need to agree upon a key.

Public Key Cryptography

What if Alice and Bob cannot hold a common key ?

- A nonmathematical way
  - Bob: send Alice a box and an unlocked padlock
  - Alice: put her message in the box, lock it using Bob's lock, and send the box back to Bob.
  - Bob can open the box and read the message
  - Potential attacks: man-in-the-middle
- Public key cryptography (asymmetric cryptography)
  - The encryption key is made public.
  - The decryption key is only known by Bob.
  - It is computationally infeasible to find the decryption key without information known only to Bob.

Public Key Cryptography

- Each user has a public key and a secret key.
- When Alice encrypts her message with Bob's public key
  - Since Bob is the only one who has access to the secret key, Bob is the only one who can decrypt the message and read the contents.

Symmetric versus Asymmetric Encryption

- Pubic key cryptography is several orders of magnitude more expensive than symmetric one
  - On a Pentium PC, *DES: 15 Mbit/s encryption rate*
    AES: 6 Kbits/s encryption rate
  - DES is typically 1000 times faster than the RSA-scheme
- Public-key systems provide significant benefits in terms of key management:
  - Assume *n* users want to securely communicate to each other.
    Symmetric: n(n-1)/2 keys; *Asymmetric: 2n keys*
- Hybrid system
  - Using a public-key system for distributing secret "session key"
  - A symmetric cipher for the bulk encryption of the data

Key Length

- Brute force attack: try every possible key and see which one yields meaning decryption.
  - DES: $2^{56} \approx 7.2 \times 10^{16}$ possibilities
- Longer keys are advantageous, but not guaranteed to make an adversary's task difficult.
  - Not all 128-bit algorithms are equally secure
  - Guessing the keys is often only one of many ways to break/attack the system.
  - Public-key crypto usually requires longer keys
    - *owing to the cipher structure that allows for asymmetry*

Key Length (cont'd)

- Key sizes for symmetric ciphers
  - 40 bits ($2^{40} \approx 10^{12}$) were used in the 1980s and 1990s in Internet applications
  - 56 bits ($2^{56} \approx 10^{17}$) are used by DES, good in the 1980s; not strong enough today.
  - 64 bits ($2^{64} \approx 10^{20}$) are used by some ciphers today.
  - 128 bits ($2^{128} \approx 10^{40}$) are considered the smallest number of bits to be used by modern algorithms today.
- An algorithm secure today does not mean an algorithm secure in the future

Summary

- Typical scenarios and attacks on secure communications
  - Understand attacker's goals and strategies
- Kerckhoff principle:
  - Should assume algorithm is known but key unknown
  - Rely on algorithm's strength and key space
- Major security aspects: C.I.A.N.
  - Confidentiality, Integrity, Authentication, Non-repudiation
- Symmetric vs. Asymmetric encryption
- Next time:
  - Encryption basics

Preview of Next Sections: Basic Crypto Tools

- Symmetric Encryption ^
  - Substitution cipher
  - Block cipher: DES, AES
  - Stream cipher: one-time pad
- Random number generators
- Asymmetric Tools
  - Based on discrete math / algebra
  - Encryption: RSA ^
  - Key establishment: Diffie-Hellman
- One-way functions
  - Hash / Message Digest

^ to be covered in Section 2.2

Reading Assignment

- HAC (Handbook on Applied Crypto) Chapt. 1 Overview

  http://www.cacr.math.uwaterloo.ca/hac/

  Students new to crypto background may find the online survey on crypto concepts "Cryptography A-Z" a helpful start

  http://www.ssh.fi/support/cryptography/

  and/or Trappe-Washington's Crypto textbook Chapt. 1

- Bruce Schneier, "Why Cryptography Is Harder Than It Looks."

  http://www.schneier.com/essay-whycrypto.html