CSC 4103 - Operating Systems
Fall 2009

Lecture - XXIII

Protection and Security

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The Security Problem

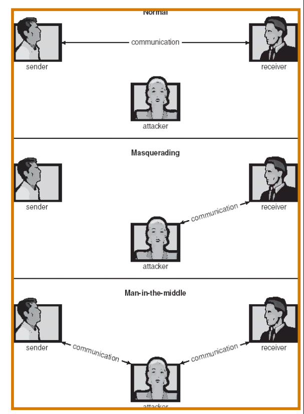
- Protecting your system resources, your files, identity, confidentiality, or privacy
- **Intruders** (crackers) attempt to breach security
- **Threat** is potential security violation
- **Attack** is attempt to breach security
- Attack can be accidental or malicious
- Easier to protect against accidental than malicious misuse

Security Violations

- Categories
  - Breach of **confidentiality**
    - information theft, identity theft
  - Breach of **integrity**
    - unauthorized modification of data
  - Breach of **availability**
    - unauthorized destruction of data
  - **Theft of service**
    - unauthorized use of resources
  - **Denial of service**
    - crashing web servers

Security Violation Methods

- Masquerading (breach authentication)
  - Pretending to be somebody else
- Replay attack (message modification)
  - Repeating a valid data transmission (eg. Money transfer)
  - May include message modification
- Session hijacking
  - The act of intercepting an active communication session
- Man-in-the-middle attack
  - Masquerading both sender and receiver by intercepting messages



Program Threats

- Trojan Horse
  - Code segment that misuses its environment
  - Exploits mechanisms for allowing programs written by users to be executed by other users
  - Spyware, pop-up browser windows, covert channels
- Trap Door
  - A hole in the security of a system deliberately left in place by designers or maintainers
  - Specific user identifier or password that circumvents normal security procedures
- Logic Bomb
  - Program that initiates a security incident under certain circumstances
- Stack and Buffer Overflow
  - Exploits a bug in a program (overflow either the stack or memory buffers)

Program Threats (Cont.)

- Viruses
  - Code fragment embedded in legitimate program
  - Very specific to CPU architecture, operating system, applications
  - Usually borne via email or as a macro
    - Visual Basic Macro to reformat hard drive

```
Sub AutoOpen()
Dim oFS
  Set oFS =
  CreateObject(''Scripting.FileSystemObject'')
  vs = Shell(''c:command.com /k format   c:'',vbHide)
End Sub
```

Program Threats (Cont.)

- **Virus dropper** inserts virus onto the system
- Many categories of viruses, literally many thousands of viruses:
  - File (appends itself to a file, changes start pointer, returns to original code)
  - Boot (writes to the boot sector, gets exec before OS)
  - Macro (runs as soon as document containing macro is opened)
  - Source code (modifies existing source codes to spread)
  - Polymorphic (changes each time to prevent detection)
  - Encrypted (first decrypts, then executes)
  - Stealth (modify parts of the system to prevent detection, eg read system call)
  - Tunneling (installs itself as interrupt handler or device driver)
  - Multipartite (can infect multiple pars of the system, eg. Memory, bootsector, files)
  - Armored (hidden and compressed virus files)

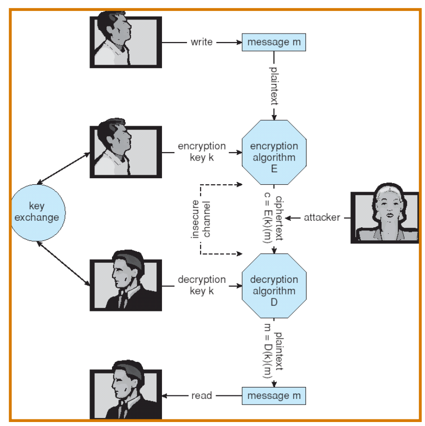
System and Network Threats

- Worms – use **spawn** mechanism; standalone program
- Internet worm *(Robert Morris, 1998, Cornell)*
  - Exploited UNIX networking features (remote access) and bugs in *finger* and *sendmail* programs
  - **Grappling hook** program uploaded main worm program
- Port scanning
  - Automated attempt to connect to a range of ports on one or a range of IP addresses
- Denial of Service
  - Overload the targeted computer preventing it from doing any useful work
  - Distributed denial-of-service (**DDOS**) come from multiple sites at once

Cryptography as a Security Tool

- Broadest security tool available
  - Source and destination of messages cannot be trusted without cryptography
  - Means to constrain potential senders (*sources*) and / or receivers (*destinations*) of *messages*
- Based on secrets (**keys**)

Secure Communication over Insecure Medium



Encryption

- Encryption algorithm consists of
  - Set of K keys
  - Set of M Messages
  - Set of C ciphertexts (encrypted messages)
  - A function $E : K \rightarrow (M \rightarrow C)$. That is, for each $k \in K$, $E(k)$ is a function for generating ciphertexts from messages.
  - A function $D : K \rightarrow (C \rightarrow M)$. That is, for each $k \in K$, $D(k)$ is a function for generating messages from ciphertexts.
  -

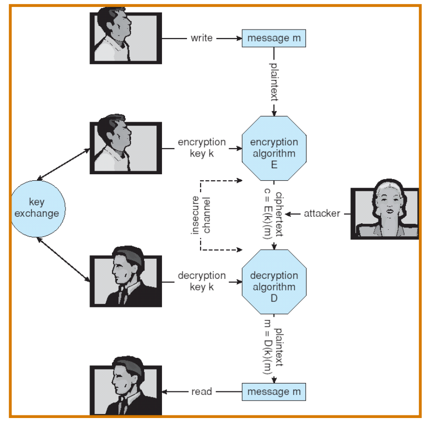
Encryption

- An encryption algorithm must provide this essential property: Given a ciphertext $c \in C$, a computer can compute m such that $E(k)(m) = c$ only if it possesses $D(k)$.
  - Thus, a computer holding $D(k)$ can decrypt ciphertexts to the plaintexts used to produce them, but a computer not holding $D(k)$ cannot decrypt ciphertexts.
  - Since ciphertexts are generally exposed (for example, sent on the network), it is important that it be infeasible to derive $D(k)$ from the ciphertexts

Symmetric Encryption

- Same key used to encrypt and decrypt
  - $E(k)$ can be derived from $D(k)$, and vice versa
- **DES** is most commonly used symmetric block-encryption algorithm (created by US Govt)
  - Encrypts a block of data at a time (64 bit messages, with 56 bit key)
- **Triple-DES** considered more secure (repeat DES three times with three different keys)
- Advanced Encryption Standard (**AES**) replaces DES
  - Key length upto 256 bits, working on 128 bit blocks
- **RC4** is most common symmetric stream cipher (works on bits, not blocks), but known to have vulnerabilities
  - Encrypts/decrypts a stream of bytes (i.e wireless transmission, web browsers)
  - Key is a input to psuedo-random-bit generator
    - Generates an infinite **keystream**

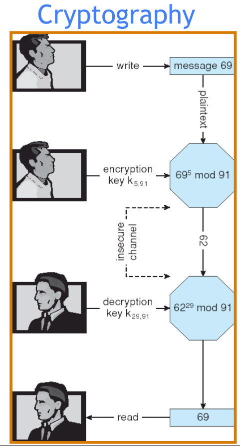
Secure Communication over Insecure Medium



Asymmetric Encryption

- Encryption and decryption keys are different
- Public-key encryption based on each user having two keys:
  - public key - published key used to encrypt data
  - private key - key known only to individual user used to decrypt data
- Must be an encryption scheme that can be made public without making it easy to figure out the decryption scheme
  - Most common is RSA *(Rivest, Shamir, Adleman)* block cipher

Encryption and Decryption using RSA Asymmetric Cryptography



Asymmetric Encryption (Cont.)

- Formally, it is computationally infeasible to derive $D(k_d , N)$ from $E(k_e , N)$, and so $E(k_e , N)$ need not be kept secret and can be widely disseminated
  - $E(k_e , N)$ (or just k_e) is the **public key**
  - $D(k_d , N)$ (or just k_d) is the **private key**
  - N is the product of two large, randomly chosen prime numbers p and q (for example, p and q are 512 bits each)
  - Select k_e and k_d, where k_e satisfies $k_e k_d \bmod (p-1)(q-1) = 1$
  - Encryption algorithm is $E(k_e , N)(m) = m^{k_e} \bmod N$,
  - Decryption algorithm is then $D(k_d , N)(c) = c^{k_d} \bmod N$

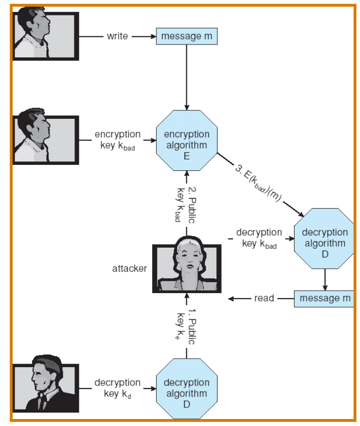
Asymmetric Encryption Example

- For example. choose $p = 7$ and $q = 13$
- We then calculate $N = 7*13 = 91$ and $(p-1)(q-1) = 72$
- We next select k_e relatively prime to 72 and< 72, yielding 5
- Finally,we calculate k_d such that $k_e k_d \bmod 72 = 1$, yielding 29
- We how have our keys
  - Public key, k_e, N = 5, 91
  - Private key, k_d , N = 29, 91
- Encrypting the message 69 with the public key results in the cyphertext 62 ($E=69^5 \bmod 91$)
- Cyphertext can be decoded with the private key
  - Public key can be distributed in cleartext to anyone who wants to communicate with holder of public key

Cryptography (Cont.)

- Note symmetric cryptography based on transformations, asymmetric based on mathematical functions
  - Asymmetric much more compute intensive
  - Typically not used for bulk data encryption
  - Used for authentication, confidentiality, key distribution

Man-in-the-middle Attack on Asymmetric Cryptography



Key Distribution

- Delivery of symmetric key is huge challenge
  - Sometimes done **out-of-band,** via paper documents or conversation
- Asymmetric keys can proliferate – stored on **key ring**
  - Even asymmetric key distribution needs care – man-in-the-middle attack

Digital Certificates

- Proof of who or what owns a public key
- Public key digitally signed a trusted party
- Trusted party receives proof of identification from entity and certifies that public key belongs to entity
- Certificate authority are trusted party – their public keys included with web browser distributions
  - They vouch for other authorities via digitally signing their keys, and so on
  - i.e. VeriSign, Comodo etc.