Operating Systems CS3500

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Security

Outline :

- The Security Problem
- *Program Threats*
- *System and Network Threats*
- *Cryptography as a Security Tool*
- *User Authentication*
- Implementing Security Defenses
- Firewalling to Protect Systems and Networks
- Computer-Security Classifications
- An Example: Windows 10

The Security Problem

- System secure if resources used and accessed as intended under all circumstances
    - Unachievable
- 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 Violation Categories

- **Breach of confidentiality**
  - Unauthorized reading of data
- **Breach of integrity**
  - Unauthorized modification of data
- **Breach of availability**
  - Unauthorized destruction of data
- **Theft of service**
  - Unauthorized use of resources
- **Denial of service (DOS)**
  - Prevention of legitimate use

Security Violation Methods

- Masquerading (breach authentication)
  - Pretending to be an authorized user to escalate privileges
- Replay attack
  - As is or with message modification
- Man-in-the-middle attack
  - Intruder sits in data flow, masquerading as sender to receiver and vice versa
- Session hijacking
  - Intercept an already-established session to bypass authentication
- Privilege escalation
  - Common attack type with access beyond what a user or resource is supposed to have

Security Measure Levels

- Impossible to have absolute security, but make cost to perpetrator sufficiently high to deter most intruders

- Security must occur at four levels to be effective:
  - **Physical**
    - Data centers, servers, connected terminals
  - **Application**
    - Benign or malicious apps can ca~~~~ problems
  - **Operating System**
    - Protection mechanisms, debugg~~~~
  - **Network**
    - Intercepted communications, interruption, DOS

forms of social engineering attacks.

Phishing.
Baiting.
Pretexting.
Scareware.
Business Email Compromise (BEC

- Security is as weak as the weakest link in the chain

- Humans a risk too via phishing and

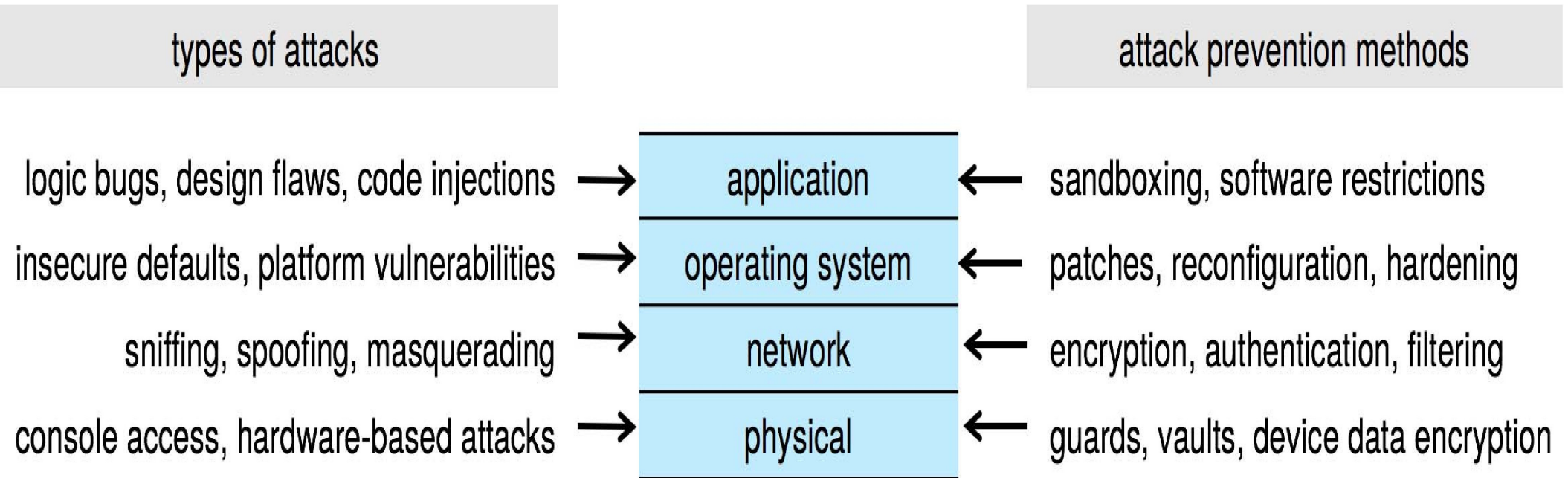 social-engineering attacks

- But can too much security be a problem?

Program Threats

- Many variations, many names

- 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 *(A covert channel is any communication channel that can be exploited by a process to transfer information in a manner that violates the systems security policy. In short, covert channels transfer information using non-standard methods against the system design)*
  - Up to 80% of spam delivered by spyware-infected systems

- Trap Door
  - Specific user identifier or password that circumvents normal security procedures
  - Could be included in a compiler
  - How to detect them?

Four-layered Model of Security

types of attacks		attack prevention methods

logic bugs, design flaws, code injections → **application** ← sandboxing, software restrictions

insecure defaults, platform vulnerabilities → **operating system** ← patches, reconfiguration, hardening

sniffing, spoofing, masquerading → **network** ← encryption, authentication, filtering

console access, hardware-based attacks → **physical** ← guards, vaults, device data encryption

Sandboxing is a cybersecurity practice where you run code, observe and analyze the code in a safe, isolated environment on a network that mimics end-user operating environments.

Sandboxing is designed to prevent threats from getting on the network and is frequently used to inspect untested or untrusted code.

Attack surface is the set of points in an OS, at which an attacker can try to break into the system.

Program Threats (Cont.)

- Malware - Software designed to exploit, disable, or damage computer
- Trojan Horse – Program that acts in a clandestine manner
  - Spyware – Program frequently installed with legitimate software to display adds, capture user data
  - Ransomware – locks up data via encryption, demanding payment to unlock it
- Others include trap doors, logic bombs *(A logic bomb is a piece of code intentionally inserted into a software system that will set off a malicious function when specified conditions are met.)*

- All try to violate the

  Principle of

  Least Privilege

THE PRINCIPLE OF LEAST PRIVILEGE

"The principle of least privilege. Every program and every privileged user of the system should operate using the least amount of privilege necessary to complete the job. The purpose of this principle is to reduce the number of potential interactions among privileged programs to the minimum necessary to operate correctly, so that one may develop confidence that unintentional, unwanted, or improper uses of privilege do not occur."—Jerome H. Saltzer, describing a design principle of the Multics operating system in 1974: https://pdfs.semanticscholar.org/1c8d/06510ad449ad24fbdd164f8008cc730cab47.pdf.

- Goal frequently is to leave behind Remote Access Tool (RAT) for repeated access

A remote administration tool (RAT) is a software program that gives you the ability to control another device remotely. You then have access to the device's system as if you had physical access to the device itself.

A remote access Trojan (RAT) is a malware program that opens a backdoor, enabling administrative control over the victim's computer. RATs are typically downloaded together with a seemingly legitimate program, like a game, or are sent to the target as an email attachment.

Remote access trojans (RATs) are malware designed to allow an attacker to remotely control an infected computer. Once the RAT is running on a compromised system, the attacker can send commands to it and receive data back in response.

—intrusion detection systems are your best bet for preventing a Remote Access Trojan from slipping past your security setup. Examples:

- SolarWinds Security Event Manager ,
  - *Snort*
  - *OSSEC*
  - *Zeek*
  - *Suricata*
- TeamViewer
- VNC Connect
- Dameware

C Program with Buffer-overflow Condition

```c
#include <stdio.h>
#define BUFFER SIZE 256
int main(int argc, char *argv[])
{
 char buffer[BUFFER SIZE];
 if (argc < 2)
    return -1;
 else {
    strcpy(buffer, argv[1]);
    return 0;
 }
}
```
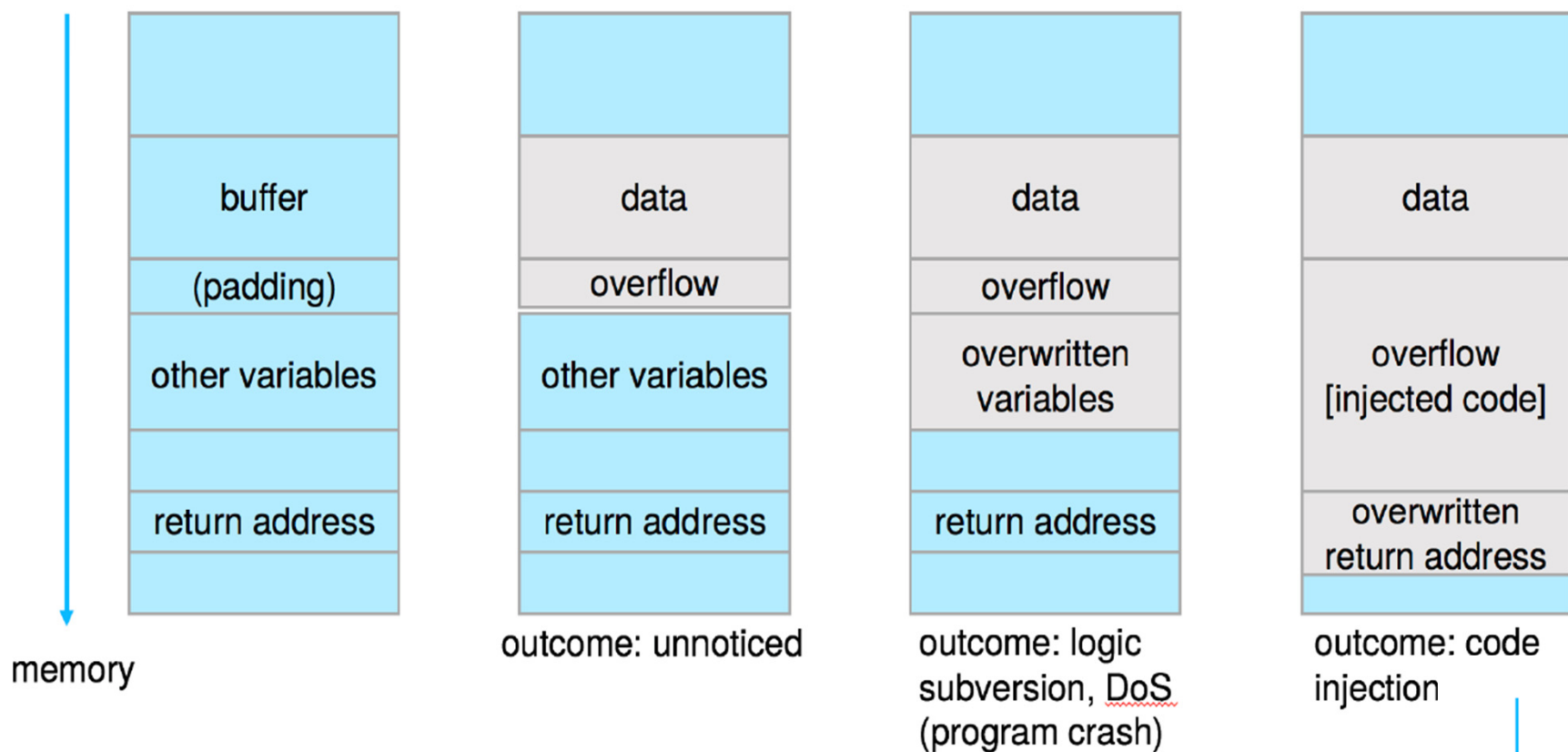
- Code review can help – programmers review each other's code, looking for logic flows, programming flaws

Code Injection

- Code-injection attack occurs when system code is not malicious but has bugs allowing executable code to be added or modified

  - Results from poor or insecure programming paradigms, commonly in low level languages like C or C++ which allow for direct memory access through pointers

  - Goal is a buffer overflow in which code is placed in a buffer and execution caused by the attack

 - Can be run by *script kiddies* – use tools written but exploit identifiers

- Outcomes from code injection include:

buffer
(padding)
other variables
return address

memory

data
overflow
other variables
return address

outcome: unnoticed

data
overflow
overwritten variables
return address

outcome: logic subversion, DoS (program crash)

data
overflow [injected code]
overwritten return address

outcome: code injection

- Frequently use trampoline to code execution to exploit buffer overflow:

Trampolines (sometimes referred to as indirect jump vectors) are memory locations holding addresses pointing to interrupt service routines, I/O routines, etc. Execution jumps into the trampoline and then immediately jumps out, or bounces, hence the term trampoline.

dummy opcodes
shellcode
address of shellcode

memory
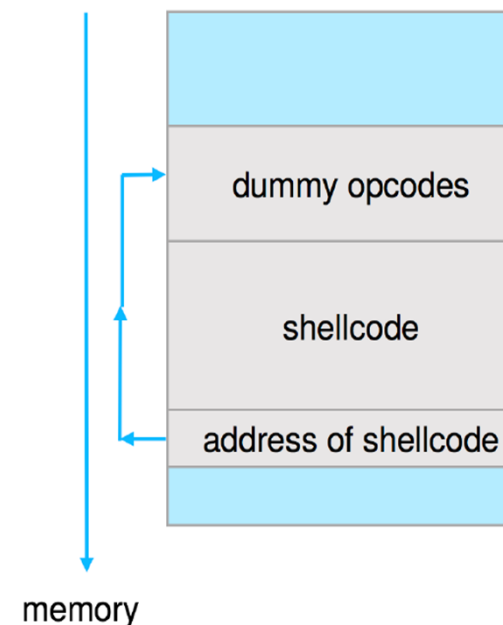
Great Programming Required?

- For the first step of determining the bug, and second step of writing exploit code, yes

- Script kiddies can run pre-written exploit code to attack a given system

- Attack code can get a shell with the processes' owner's permissions
  - Or open a network port, delete files, download a program, etc.

- Depending on bug, attack can be executed across a network using allowed connections, bypassing firewalls

- Buffer overflow can be disabled by disabling stack execution or adding bit to page table to indicate "non-executable" state
  - Available in SPARC and x86
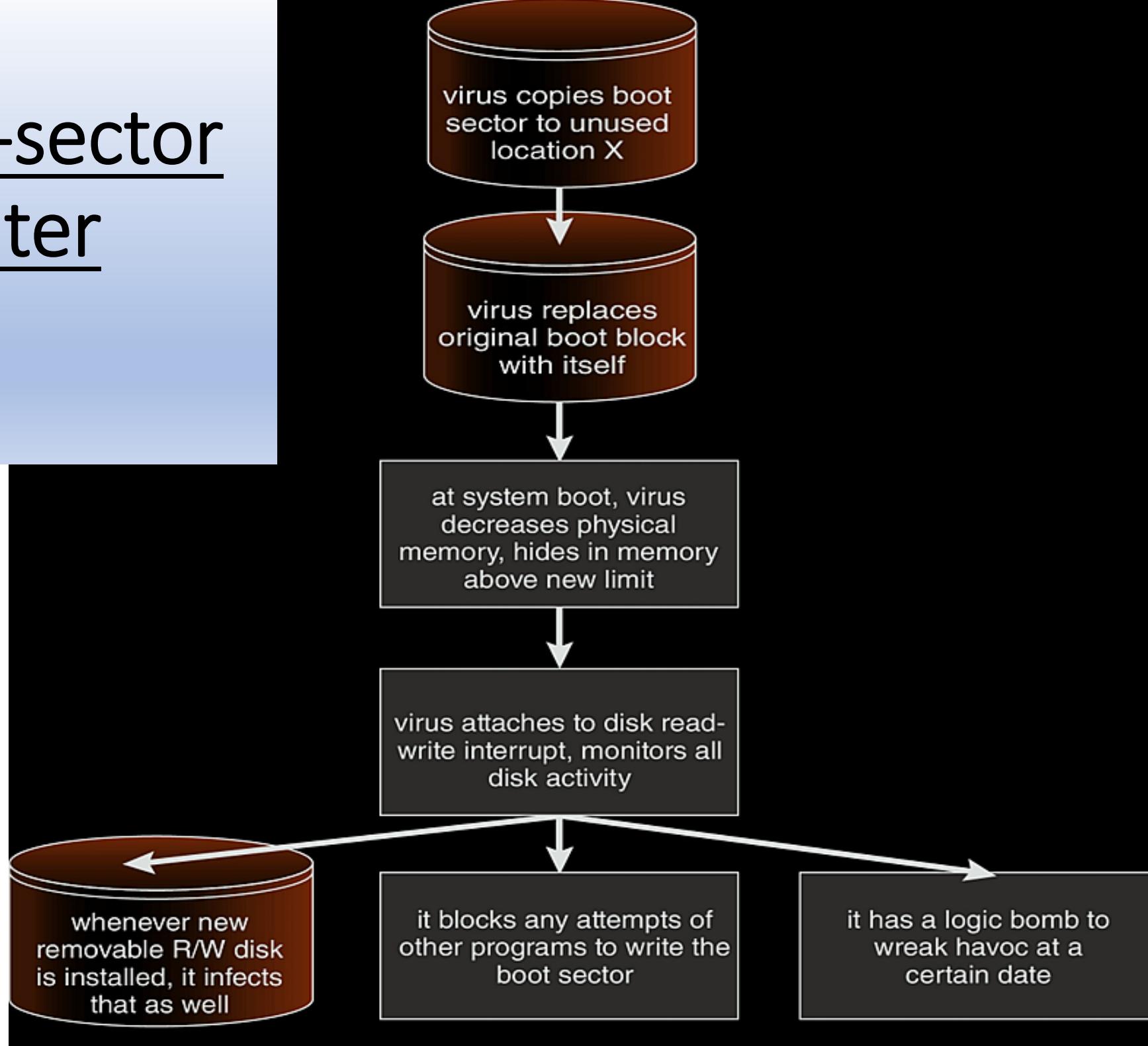 - But still have security exploits

Program Threats (Cont.)

- Viruses
    - Code fragment embedded in legitimate program
    - Self-replicating, designed to infect other computers
    - Very specific to CPU architecture, operating system, applications
    - Usually borne via email or as a macro
    - Visual Basic Macro to reformat hard drive (worm)

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

- Virus dropper inserts virus onto the system

- Many categories of viruses, literally many thousands of viruses
    - File / parasitic, Boot / memory, macro, source code, polymorphic to avoid having a virus signature, encrypted, stealth, tunneling, multipartite, armored

A Boot-sector Computer Virus

virus copies boot sector to unused location X

virus replaces original boot block with itself

at system boot, virus decreases physical memory, hides in memory above new limit

virus attaches to disk read-write interrupt, monitors all disk activity

whenever new removable R/W disk is installed, it infects that as well

it blocks any attempts of other programs to write the boot sector

it has a logic bomb to wreak havoc at a certain date

The Threat Continues

- Attacks still common, still occurring
- Attacks moved over time from science experiments to tools of organized crime
  - Targeting specific companies
  - Creating botnets to use as tool for spam and DDOS delivery
  - Keystroke logger to grab passwords, credit card numbers

- Why is Windows the target for most attacks?
  - Most common
  - Everyone is an administrator
    - Licensing required?
  - Monoculture considered harmful

Distributed denial of service (DDoS) attacks are a subclass of denial of service (DoS) attacks.
A DDoS attack involves multiple connected online devices, collectively known as a botnet, which are used to overwhelm a target website with fake traffic

Many systems run the same hardware, operating system, and application software – >> dark web ??

System and Network Threats

- Some systems "open" rather than secure by default
  - Reduce attack surface, but harder to use, more knowledge needed to administer

- Network threats harder to detect, prevent
  - Protection systems weaker
  - More difficult to have a shared secret on which to base access
  - No physical limits once system attached to internet, or on network with system attached to internet
  - Even determining location of connecting system difficult
    - IP address is only knowledge

- **Worms** – use spawn mechanism; standalone program

- Internet worm
  - Exploited UNIX networking features (remote access) and bugs in *finger* and *sendmail* programs
  - Exploited trust-relationship mechanism used by *rsh* to access friendly systems without use of password
  - Grappling hook program uploaded main worm program → 99 lines of code
  - Hooked system then uploaded main code, tried to attack connected systems
  - Also tried to break into other users accounts on local system via password guessing
  - If target system already infected, abort, except for every 7th time

Morris Worm (1988) - Similar to the fork bomb effect—crashing the machine several times. The DEC VAX machines running 4BSD, and Sun-3 systems were infected by the main body of the worm. A portable C "grappling hook" component was applied to download the main body parts, and the grappling hook could run on other systems, loading them down and making them peripheral victims.

Hackers frequently launch attacks from _zombie systems_—independent systems or devices that have been compromised by hackers but that continue to serve their owners while being used without the owners' knowledge for nefarious purposes.

System and Network Threats (Cont.)

- **Port scanning**
  - Automated attempt to connect to a range of ports on one or a range of IP addresses
  - Detection of answering service protocol
  - Detection of OS and version running on system
  - `nmap` scans all ports in a given IP range for a response
  - `nessus` has a database of protocols and bugs (and exploits) to apply against a system
  - Frequently launched from zombie systems
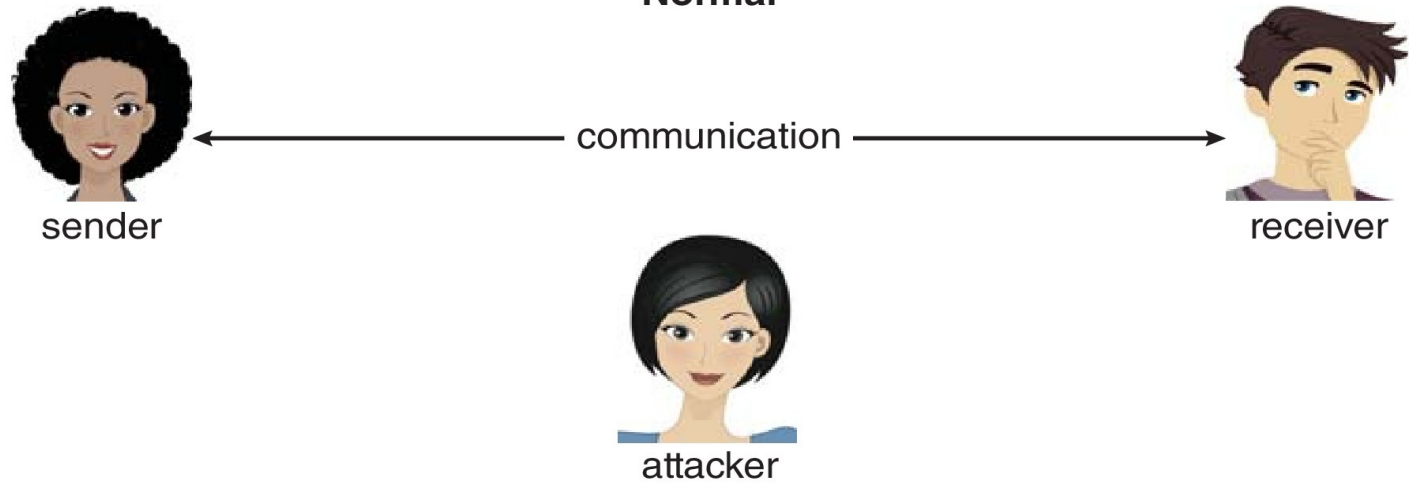   - To decrease trace-ability
- **Denial of Service**
  - Overload the targeted computer preventing it from doing any useful work
  - Distributed Denial-of-Service (DDoS) come from multiple sites at once
  - Consider the start of the IP-connection handshake (SYN)
    - How many started-connections can the OS handle?
  - Consider traffic to a web site
    - How can you tell the difference between being a target and being really popular?
  - Accidental – CS students writing bad `fork()` code
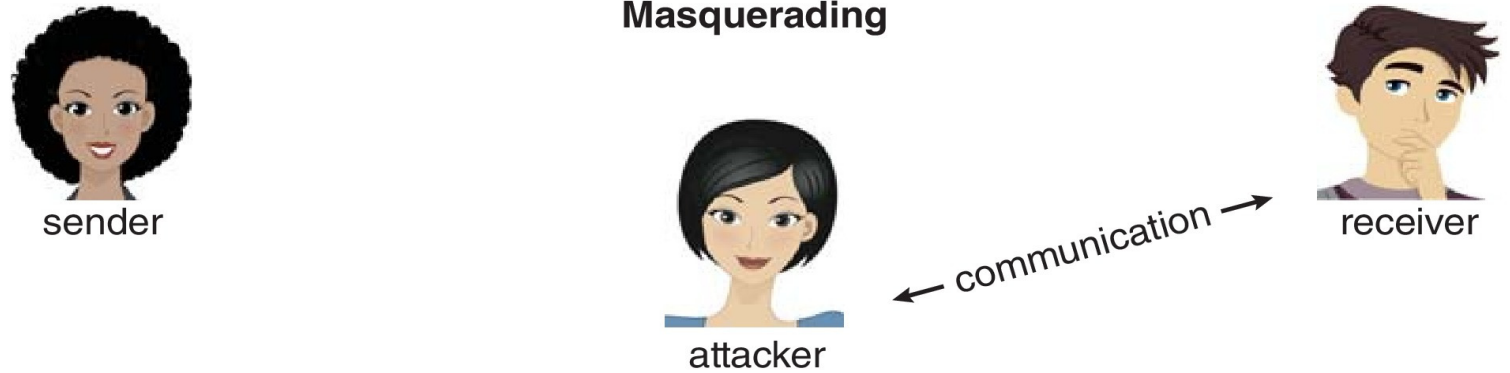 - Purposeful – extortion, punishment
- Port scanning
  - Automated tool to look for network ports accepting connections
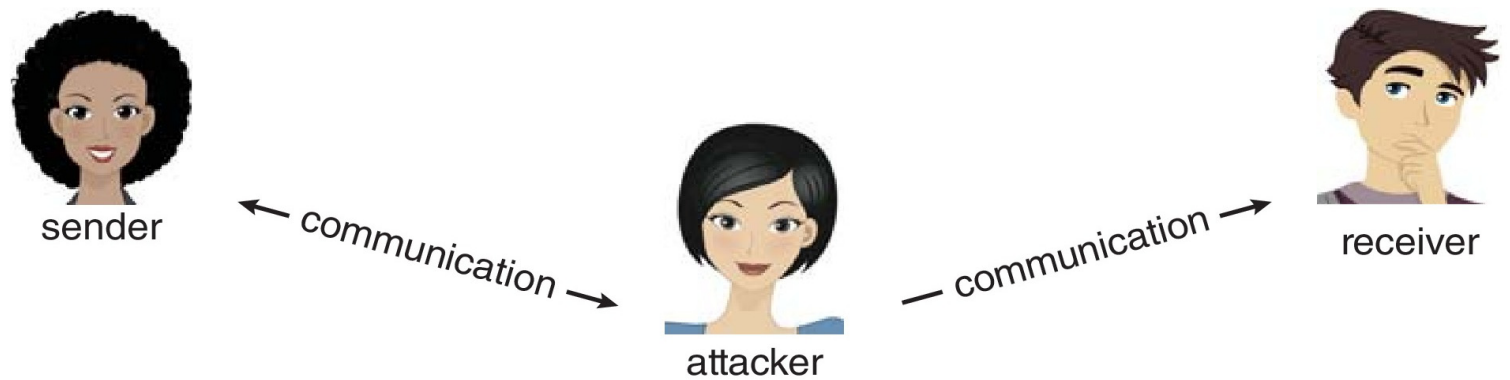 - Used for good and evil

Standard Security Attacks

Normal

sender — communication → receiver

attacker

Masquerading

sender

attacker ← communication — receiver

Man-in-the-middle

sender ← communication — attacker — communication → receiver

Cryptography as a Security Tool

- Broadest security tool available
  - Internal to a given computer, source and destination of messages can be known and protected
    - OS creates, manages, protects process IDs, communication ports
  - Source and destination of messages on network cannot be trusted without cryptography
    - Local network – IP address?
      - Consider unauthorized host added
    - WAN / Internet – how to establish authenticity
      - Not via IP address

Cryptography

- Means to constrain potential senders (*sources*) and / or receivers (*destinations*) of *messages*
  - Based on secrets (keys)
  - Enables
    - Confirmation of source
    - Receipt only by certain destination
   - Trust relationship between sender and receiver

Encryption

- Constrains the set of possible receivers of a message
- Encryption algorithm consists of
    - Set K of keys
    - Set M of Messages
    - Set C of ciphertexts (encrypted messages)
    - A function $E : K \to (M \to C)$. That is, for each $k \in K$, E_k is a function for generating ciphertexts from messages
        - Both E and E_k for any k should be efficiently computable functions
    - A function $D : K \to (C \to M)$. That is, for each $k \in K$, D_k is a function for generating messages from ciphertexts
        - Both D and D_k for any k should be efficiently computable functions
- 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 k
    - Thus, a computer holding k can decrypt ciphertexts to the plaintexts used to produce them, but a computer not holding k cannot decrypt ciphertexts
    - Since ciphertexts are generally exposed (for example, sent on the network), it is important that it be infeasible to derive k from the ciphertexts

Symmetric Encryption

- Same key used to encrypt and decrypt
  - Therefore *k* must be kept secret

- DES was most commonly used symmetric block-encryption algorithm (created by US Govt – *Data Encryption Standard*)
  - Encrypts a block of data at a time
  - Keys too short so now considered insecure

- Triple-DES considered more secure
  - Algorithm used 3 times using 2 or 3 keys
  - For example $c = E_{k3}(D_{k2}(E_{k1}(m)))$

- 2001 NIST adopted new block cipher - Advanced Encryption Standard (AES) →Keys of 128, 192, or 256 bits, works on 128 bit blocks

- RC4 is most common symmetric stream cipher, but known to have vulnerabilities (RC4 - Rivest Cipher 4 invented by Ron Rivest in 1987)
  - Encrypts/decrypts a stream of bytes (i.e., wireless transmission)
  - Key is a input to pseudo-random-bit generator
    - Generates an infinite keystream

Secure Communication over Insecure Medium
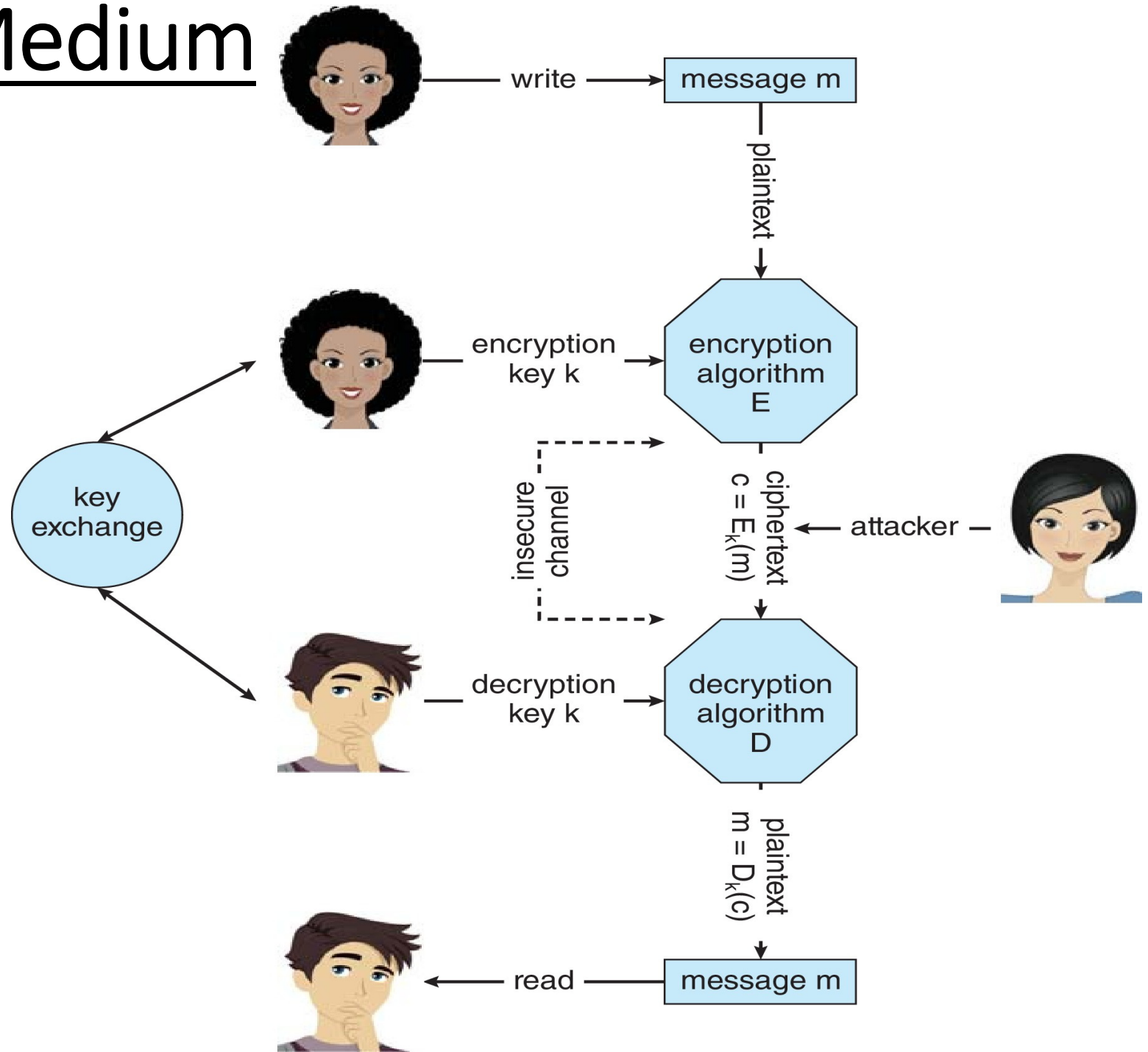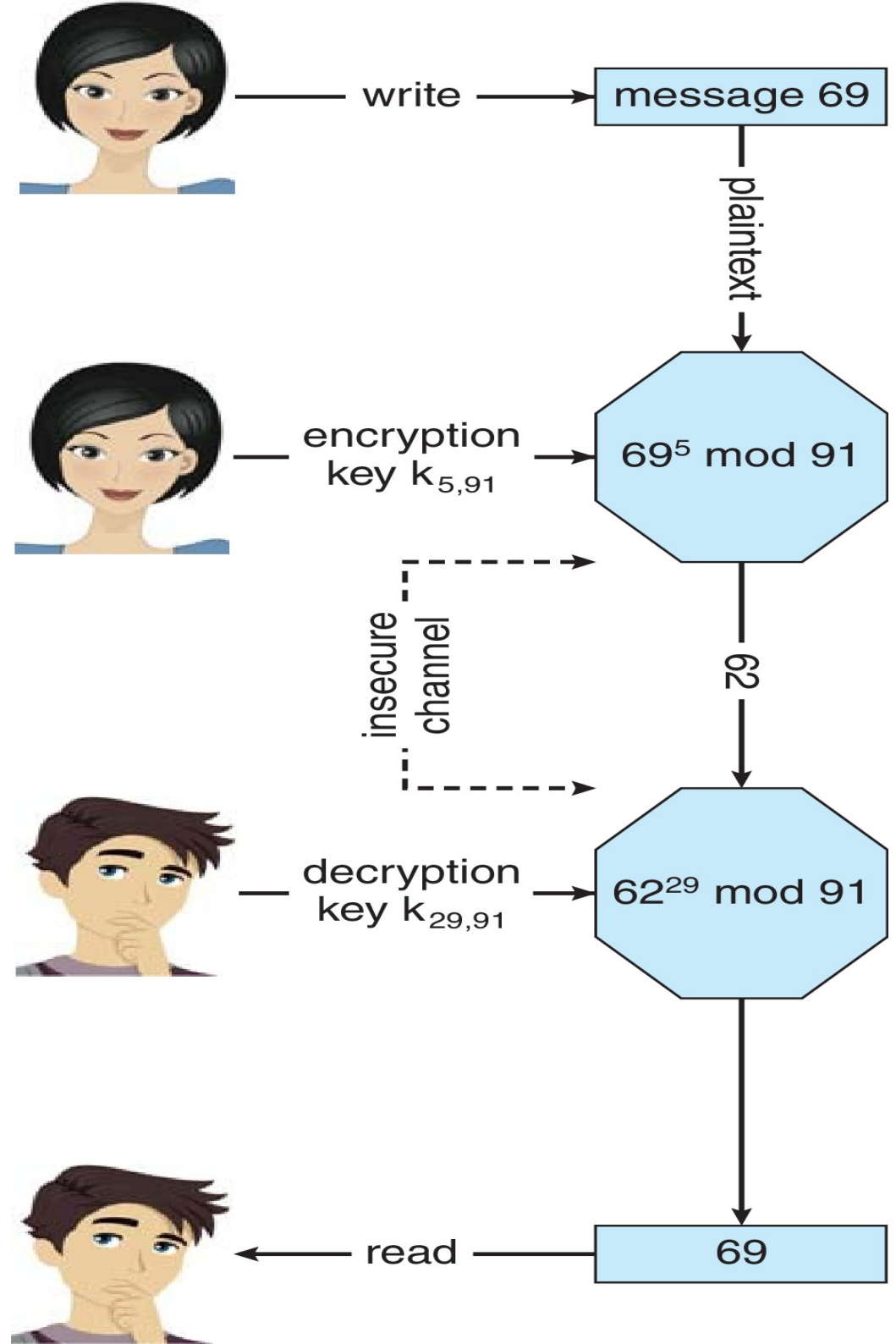
Asymmetric Encryption

- 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 block cipher
  - Efficient algorithm for testing whether or not a number is prime
  - No efficient algorithm is know for finding the prime factors of a number
- Formally, it is computationally infeasible to derive $k_{d,N}$ from $k_{e,N}$, and so k_e need not be kept secret and can be widely disseminated
  - k_e is the public key
  - 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)
  - Encryption algorithm is $E_{ke,N}(m) = m^{k_e} \bmod N$, where k_e satisfies $k_e k_d \bmod (p-1)(q-1) = 1$
  - The decryption algorithm is then $D_{kd,N}(c) = c^{k_d} \bmod N$

Asymmetric Encryption Example

- For example. make p = 7and 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 $k_e k_d$ mod 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
- 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 The Advance Encryption Standard (AES) cipher text method is a more accurate and elegant cryptographic method. According to testing results and the text files used, it has been concluded that the AES algorithm outperforms the Data Encryption Standard (DES) and RSA algorithms.

Encryption using RSA
Asymmetric Cryptography

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

Authentication

- Constraining set of potential senders of a message
  - Complementary to encryption
  - Also can prove message unmodified
- Algorithm components
  - A set K of keys
  - A set M of messages
  - A set A of authenticators
  - A function $S : K \rightarrow (M \rightarrow A)$
    - That is, for each $k \in K$, S_k is a function for generating authenticators from messages
    - Both S and S_k for any k should be efficiently computable functions
  - A function $V : K \rightarrow (M \times A \rightarrow \{\text{true, false}\})$. That is, for each $k \in K$, V_k is a function for verifying authenticators on messages
    - Both V and V_k for any k should be efficiently computable functions

Authentication (Cont.)

- For a message m, a computer can generate an authenticator $a \in A$ such that $V_k(m, a) = \texttt{true}$ only if it possesses k

- Thus, computer holding k can generate authenticators on messages so that any other computer possessing k can verify them

- Computer not holding k cannot generate authenticators on messages that can be verified using V_k

- Since authenticators are generally exposed (for example, they are sent on the network with the messages themselves), it must not be feasible to derive k from the authenticators

- Practically, if $V_k(m,a) = \textbf{true}$ then we know m has not been modified and that send of message has k
  - If we share k with only one entity, know where the message originated

Authentication – Hash Functions

- Basis of authentication

- Creates small, fixed-size block of data message digest (hash value) from m

- Hash Function H must be collision resistant on m
  - Must be infeasible to find an $m' \neq m$ such that $H(m) = H(m')$

- If $H(m) = H(m')$, then $m = m'$
  - The message has not been modified

- Common message-digest functions include MD5, which produces a 128-bit hash, and SHA-1, which outputs a 160-bit hash

- Not useful as authenticators
  - For example $H(m)$ can be sent with a message
    - But if H is known someone could modify m to m' and recompute $H(m')$ and modification not detected
    - So must authenticate $H(m)$

Authentication – Digital Signature

- Based on asymmetric keys and digital signature algorithm
- Authenticators produced are digital signatures
- Very useful – **anyone** can verify authenticity of a message
- In a digital-signature algorithm, computationally infeasible to derive k_s from k_v
  - V is a one-way function
  - Thus, k_v is the public key and k_s is the private key
- Consider the RSA digital-signature algorithm
  - Similar to the RSA encryption algorithm, but the key use is reversed
  - Digital signature of message $S_{ks}(m) = H(m)^{k_s} \bmod N$
  - The key k_s again is a pair ($\underline{?}$, N), where N is the product of two large, randomly chosen prime numbers p and q
  - Verification algorithm is $V_{kv}(m, a)$ ($a^{k_v} \bmod N = H(m)$)
    - Where k_v satisfies $k_v k_s \bmod (p - 1)(q - 1) = 1$

Authentication (Cont.)

- Why authentication if a subset of encryption?
  - Fewer computations (except for RSA digital signatures)
  - Authenticator usually shorter than message
  - Sometimes want authentication but not confidentiality
    - Signed patches et al
  - Can be basis for non-repudiation

Key Distribution

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

Authentication - MAC

- Symmetric encryption used in message-authentication code (MAC) authentication algorithm

- Cryptographic checksum generated from message using secret key
  - Can securely authenticate short values

- If used to authenticate $H(m)$ for an H that is collision resistant, then obtain a way to securely authenticate long message by hashing them first

- Note that k is needed to compute both S_k and V_k, so anyone able to compute one can compute the other

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

Man-in-the-middle Attack on Asymmetric Cryptography
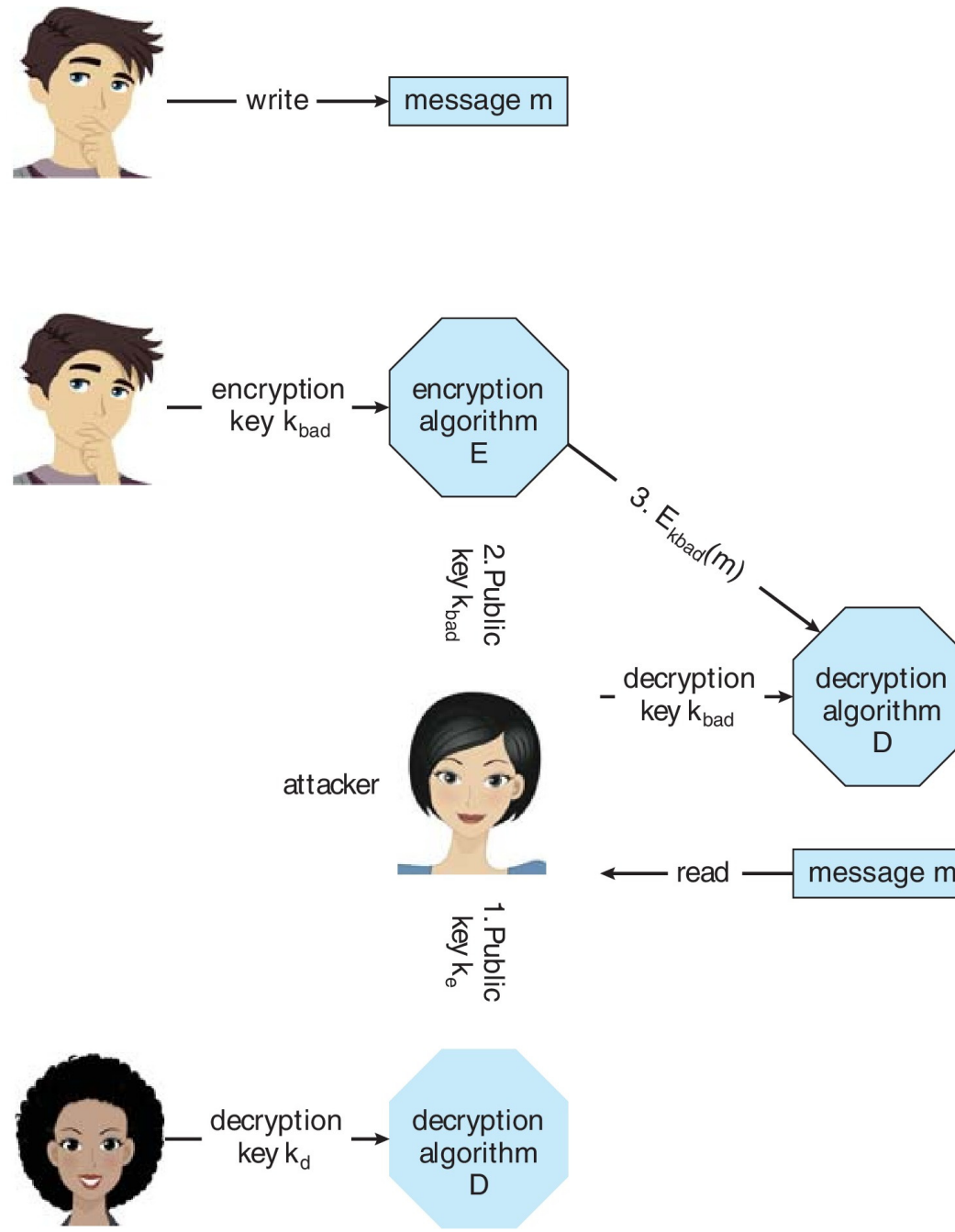
Implementation of Cryptography

- Can be done at various layers of ISO Reference Model
  - SSL at the Transport layer
  - Network layer is typically IPSec
    - IKE for key exchange
    - Basis of Virtual Private Networks (VPNs)
- Why not just at lowest level?
  - Sometimes need more knowledge than available at low levels
    - i.e., User authentication
    - i.e., e-mail delivery

OSI model

7. Application Layer

NNTP · SIP · SSI · DNS · FTP · Gopher · HTTP · NFS · NTP · SMPP · SMTP · SNMP · Telnet · Netconf · (more)

6. Presentation Layer

MIME · XDR · TLS · SSL

5. Session Layer

Named Pipes · NetBIOS · SAP · L2TP PPTP · SPDY

4. Transport Layer

TCP · UDP · SCTP · DCCP · SPX

3. Network Layer

IP (IPv4, IPv6) · ICMP · IPsec · IGMP IPX · AppleTalk

2. Data Link Layer

ATM · SDLC · HDLC · ARP · CSLIP · SLIP · GFP · PLIP · IEEE 802.3 · Frame Relay · ITU-T G.hn DLL · PPP · X.25 · Network Switch · DHCP

1. Physical Layer

EIA/TIA-232 · EIA/TIA-449 · ITU-T V-Series · I.430 · I.431 · POTS · PDH · SONET/SDH · PON · OTN · DSL · IEEE 802.3 · IEEE 802.11 · IEEE 802.15 · IEEE 802.16 · IEEE 1394 · ITU-T G.hn PHY · USB · Bluetooth · Hubs

OSI Model			
	Data unit	Layer	Function
Host layers	Data	7. Application	Network process to application
		6. Presentation	Data representation, encryption and decryption, convert machine dependent data to machine independent data
		5. Session	Interhost communication
	Segments	4. Transport	End-to-end connections and reliability, flow control
Media layers	Packet/Datagram	3. Network	Path determination and logical addressing
	Frame	2. Data Link	Physical addressing
	Bit	1. Physical	Media, signal and binary transmission

Source: http://en.wikipedia.org/wiki/OSI_model

Encryption Example - TLS

- Insertion of cryptography at one layer of the ISO network model (the transport layer)

- SSL – Secure Socket Layer (also called TLS)

- Cryptographic protocol that limits two computers to only exchange messages with each other
  - Very complicated, with many variations

- Used between web servers and browsers for secure communication (credit card numbers)

- The server is verified with a certificate assuring client is talking to correct server

- Asymmetric cryptography used to establish a secure session key (symmetric encryption) for bulk of communication during session

- Communication between each computer then uses symmetric key cryptography

User Authentication

- Crucial to identify user correctly, as protection systems depend on user ID
- User identity most often established through passwords, can be considered a special case of either keys or capabilities
- Passwords must be kept secret
  - Frequent change of passwords
  - History to avoid repeats
  - Use of "non-guessable" passwords
  - Log all invalid access attempts (but not the passwords themselves)
  - Unauthorized transfer
- Passwords may also either be encrypted or allowed to be used only once
  - Does encrypting passwords solve the exposure problem?
    - Might solve sniffing
    - Consider shoulder surfing
    - Consider Trojan horse keystroke logger
    - How are passwords stored at authenticating site?

Passwords

- Encrypt to avoid having to keep secret
  - But keep secret anyway (i.e. Unix uses superuser-only readably file `/etc/shadow`)
  - Use algorithm easy to compute but difficult to invert
  - Only encrypted password stored, never decrypted
  - Add "salt" to avoid the same password being encrypted to the same value
- One-time passwords
  - Use a function based on a seed to compute a password, both user and computer
  - Hardware device / calculator / key fob to generate the password
    - Changes very frequently
- Biometrics →Some physical attribute (fingerprint, hand scan)
- Multi-factor authentication
  - Need two or more factors for authentication
    - i.e., USB "dongle", biometric measure, and password

Passwords (Cont.)

STRONG AND EASY TO REMEMBER PASSWORDS

It is extremely important to use strong (hard to guess and hard to shoulder surf) passwords on critical systems like bank accounts. It is also important to not use the same password on lots of systems, as one less important, easily hacked system could reveal the password you use on more important systems. A good technique is to generate your password by using the first letter of each word of an easily remembered phrase using both upper and lower characters with a number or punctuation mark thrown in for good measure. For example, the phrase "My girlfriend's name is Katherine" might yield the password "Mgn.isK!". The password is hard to crack but easy for the user to remember. A more secure system would allow more characters in its passwords. Indeed, a system might also allow passwords to include the space character, so that a user could create a **passphrase** which is easy to remember but difficult to break.
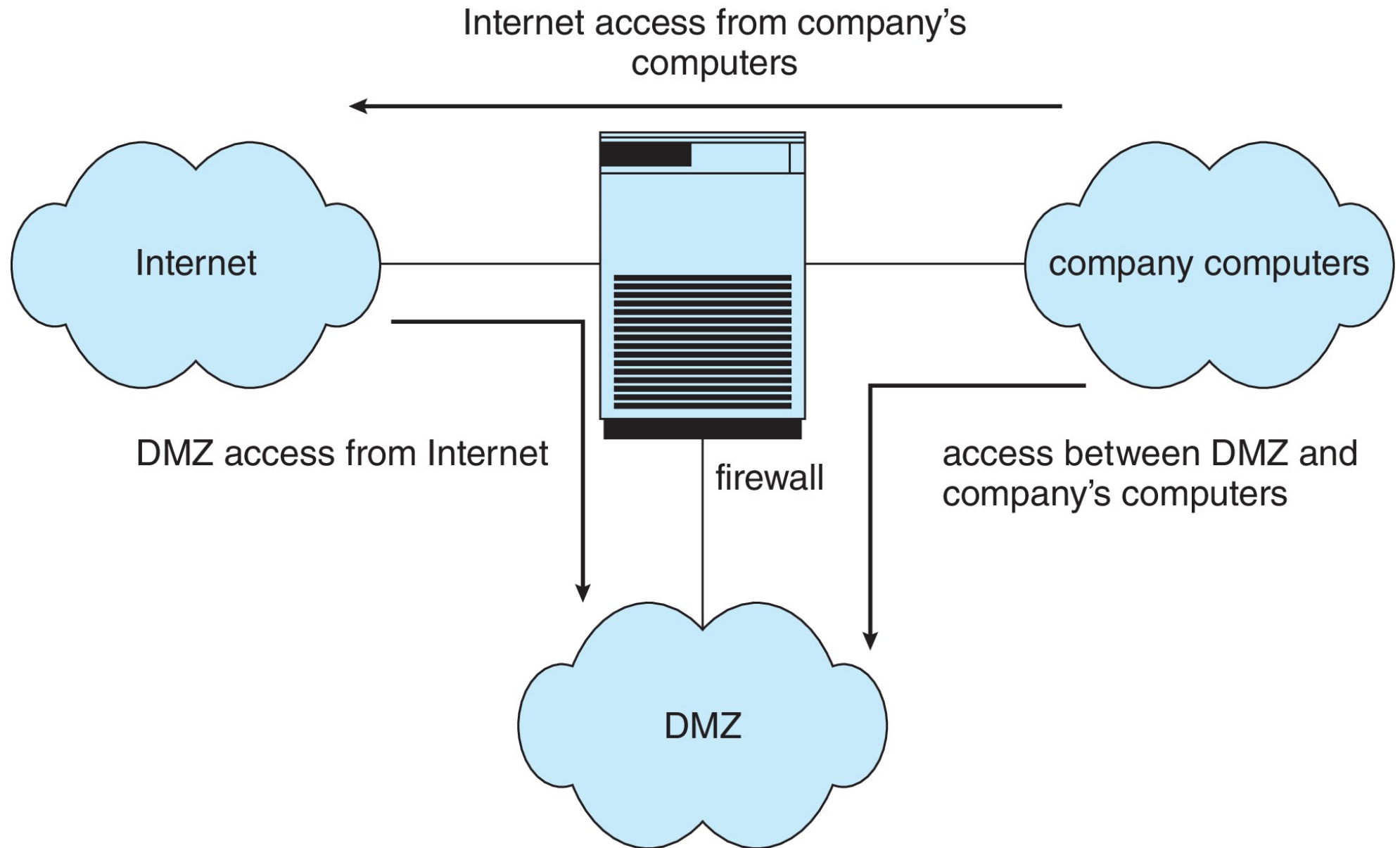
Implementing Security Defenses

- Defense in depth is most common security theory – multiple layers of security

- Security policy describes what is being secured

- Vulnerability assessment compares real state of system / network compared to security policy

- Intrusion detection endeavors to detect attempted or successful intrusions
  - Signature-based detection spots known bad patterns
  - Anomaly detection spots differences from normal behavior
    - Can detect zero-day attacks
  - False-positives and false-negatives a problem

- Virus protection
  - Searching all programs or programs at execution for known virus patterns ,or run in sandbox so can't damage system

- Auditing, accounting, and logging of all or specific system or network activities

- Practice safe computing – avoid sources of infection, download from only "good" sites, etc

Firewalling to Protect Systems and Networks

- A network firewall is placed between trusted and untrusted hosts
  - The firewall limits network access between these two security domains
- Can be tunneled or spoofed
  - Tunneling allows disallowed protocol to travel within allowed protocol (i.e., telnet inside of HTTP)
  - Firewall rules typically based on host name or IP address which can be spoofed
- Personal firewall is software layer on given host
  - Can monitor / limit traffic to and from the host
- Application proxy firewall understands application protocol and can control them (i.e., SMTP)
- System-call firewall monitors all important system calls and apply rules to them (i.e., this program can execute that system call)

Network Security Through Domain Separation Via Firewall

Internet access from company's computers

Internet

company computers

DMZ access from Internet

firewall

access between DMZ and company's computers

DMZ

Computer Security Classifications

- U.S. Department of Defense outlines four divisions of computer security: **A**, **B**, **C**, and **D**

- **D** – Minimal security

- **C** – Provides discretionary protection through auditing
  - Divided into **C1** and **C2**
    - **C1** identifies cooperating users with the same level of protection
    - **C2** allows user-level access control

- **B** – All the properties of **C**, however each object may have unique sensitivity labels
  - Divided into **B1**, **B2**, and **B3**

- **A** – Uses formal design and verification techniques to ensure security

Security Defenses Summarized

- By applying appropriate layers of defense, we can keep systems safe from all but the most persistent attackers. In summary, these layers may include the following:
    - Educate users about safe computing—don't attach devices of unknown origin to the computer, don't share passwords, use strong passwords, avoid falling for social engineering appeals, realize that an e-mail is not necessarily a private communication, and so on
    - Educate users about how to prevent phishing attacks—don't click on email attachments or links from unknown (or even known) senders; authenticate (for example, via a phone call) that a request is legitimate
    - Use secure communication when possible
    - Physically protect computer hardware
    - Configure the operating system to minimize the attack surface; disable all unused services
    - Configure system daemons, privileges applications, and services to be as secure as possible

    - Use modern hardware and software, as they are likely to have up-to-date security features
    - Keep systems and applications up to date and patched

Security Defenses Summarized (Cont.)

- Only run applications from trusted sources (such as those that are code signed)
- Enable logging and auditing; review the logs periodically, or automate alerts
- Install and use antivirus software on systems susceptible to viruses, and keep the software up to date
- Use strong passwords and passphrases, and don't record them where they could be found
- Use intrusion detection, firewalling, and other network-based protection systems as appropriate
- For important facilities, use periodic vulnerability assessments and other testing methods to test security and response to incidents
- Encrypt mass-storage devices, and consider encrypting important individual files as well
- Have a security policy for important systems and facilities, and keep it up to date

Example: Windows 10

- Security is based on user accounts
  - Each user has unique security ID
  - Login to ID creates security access token
    - Includes security ID for user, for user's groups, and special privileges
    - Every process gets copy of token
    - System checks token to determine if access allowed or denied
- Uses a subject model to ensure access security
  - A subject tracks and manages permissions for each program that a user runs
- Each object in Windows has a security attribute defined by a security descriptor
  - For example, a file has a security descriptor that indicates the access permissions for all users