Introduction to IS Security

Courtesy of William Stallings and Lawrie Brown
Computer Security: Principles and Practice,4th Edition

The NIST defines the term *computer security* as follows:

> " Measures and controls that ensure confidentiality, integrity, and availability of information system assets including hardware, software, firmware, and information being processed, stored, and communicated."

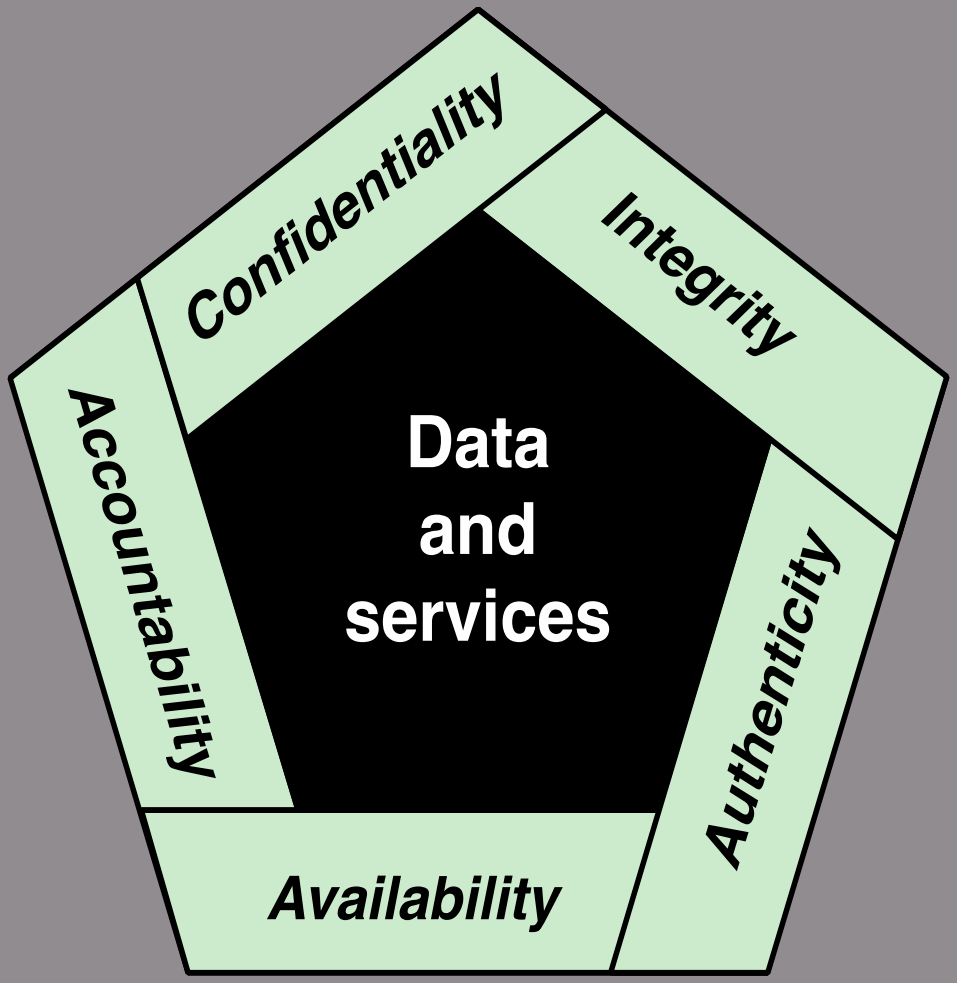


Figure 1.1 Essential Network and Computer Security Requirements

Key Security Concepts

Confidentiality

- Preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information

Integrity

- Guarding against improper information modification or destruction, including ensuring information nonrepudiation and authenticity

Availability

- Ensuring timely and reliable access to and use of information

Levels of Impact

Low

The loss could be expected to have a limited adverse effect on organizational operations, organizational assets, or individuals

Moderate

The loss could be expected to have a serious adverse effect on organizational operations, organizational assets, or individuals

High

The loss could be expected to have a severe or catastrophic adverse effect on organizational operations, organizational assets, or individuals

Computer Security Challenges

1. Computer security is not as simple as it might first appear to the novice
2. In developing a particular security mechanism or algorithm, one must always consider potential attacks on those security features
3. Procedures used to provide particular services are often counterintuitive
4. Physical and logical placement needs to be determined
5. Security mechanisms typically involve more than a particular algorithm or protocol and also require that participants be in possession of some secret information which raises questions about the creation, distribution, and protection of that secret information
6. Attackers only need to find a single weakness, while the designer must find and eliminate all weaknesses to achieve perfect security
7. Security is still too often an afterthought to be incorporated into a system after the design is complete, rather than being an integral part of the design process
8. Security requires regular and constant monitoring
9. There is a natural tendency on the part of users and system managers to perceive little benefit from security investment until a security failure occurs
10. Many users and even security administrators view strong security as an impediment to efficient and user-friendly operation of an information system or use of information

Table 1.1

Computer Security Terminology, from RFC 2828, *Internet Security Glossary*, May 2000

Adversary (threat agent)
Individual, group, organization, or government that conducts or has the intent to conduct detrimental activities.

Attack
Any kind of malicious activity that attempts to collect, disrupt, deny, degrade, or destroy information system resources or the information itself.

Countermeasure
A device or techniques that has as its objective the impairment of the operational effectiveness of undesirable or adversarial activity, or the prevention of espionage, sabotage, theft, or unauthorized access to or use of sensitive information or information systems.

Risk
A measure of the extent to which an entity is threatened by a potential circumstance or event, and typically a function of 1) the adverse impacts that would arise if the circumstance or event occurs; and 2) the likelihood of occurrence.

Security Policy
A set of criteria for the provision of security services. It defines and constrains the activities of a data processing facility in order to maintain a condition of security for systems and data.

System Resource (Asset)
A major application, general support system, high impact program, physical plant, mission critical system, personnel, equipment, or a logically related group of systems.

Threat
Any circumstance or event with the potential to adversely impact organizational operations (including mission, functions, image, or reputation), organizational assets, individuals, other organizations, or the Nation through an information system via unauthorized access, destruction, disclosure, modification of information, and/or denial of service.

Vulnerability
Weakness in an information system, system security procedures, internal controls, or implementation that could be exploited or triggered by a threat source.

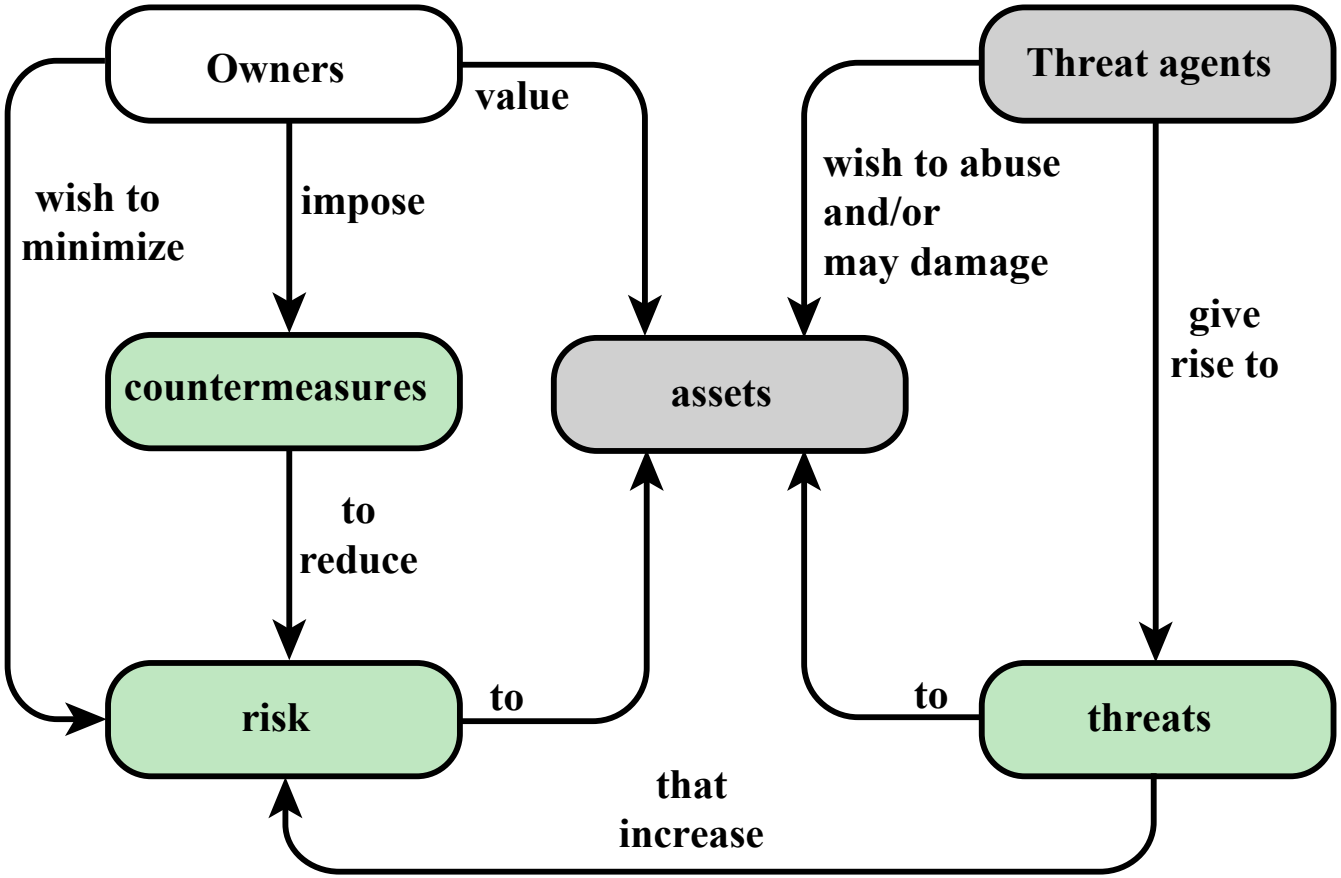
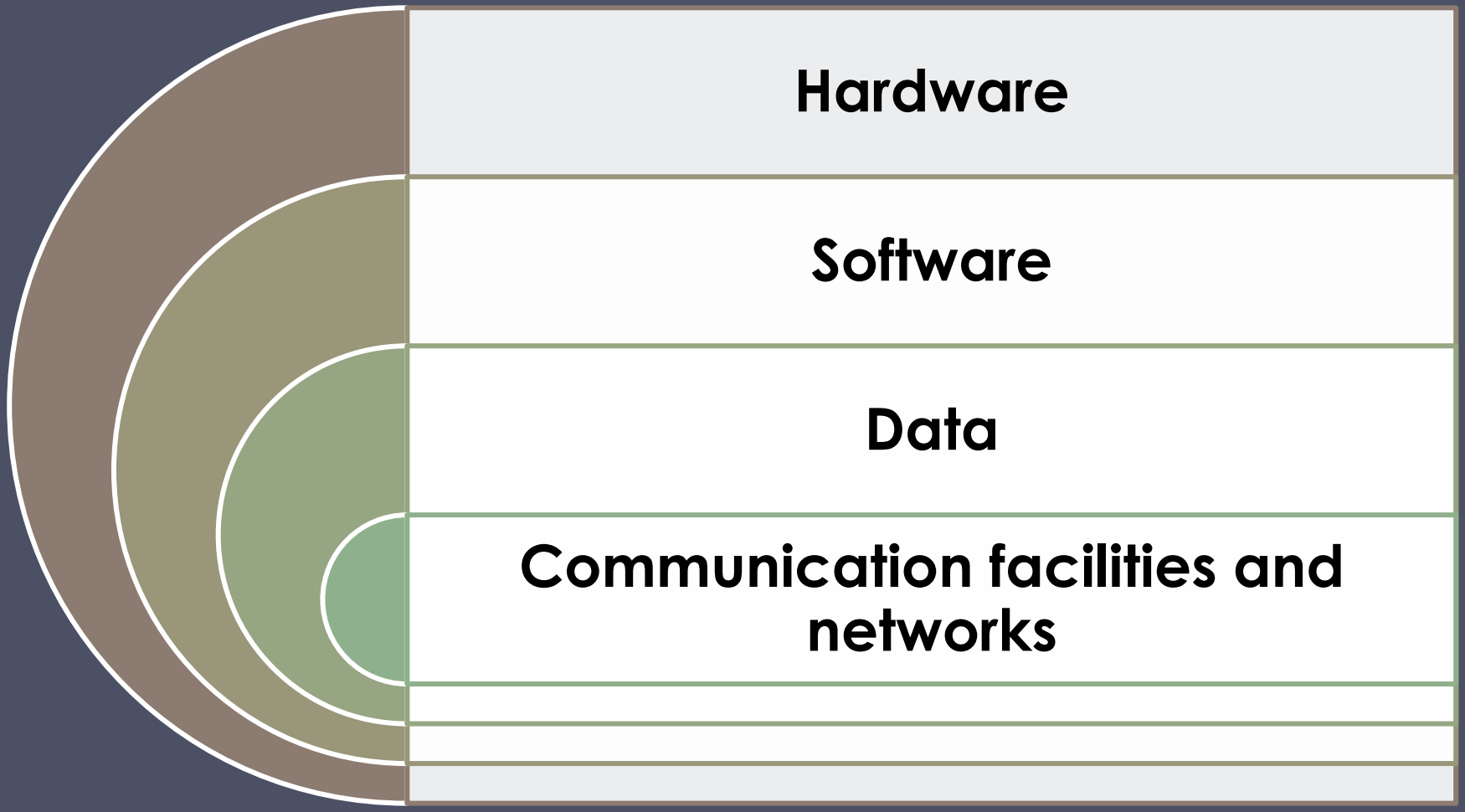


Figure 1.2 Security Concepts and Relationships

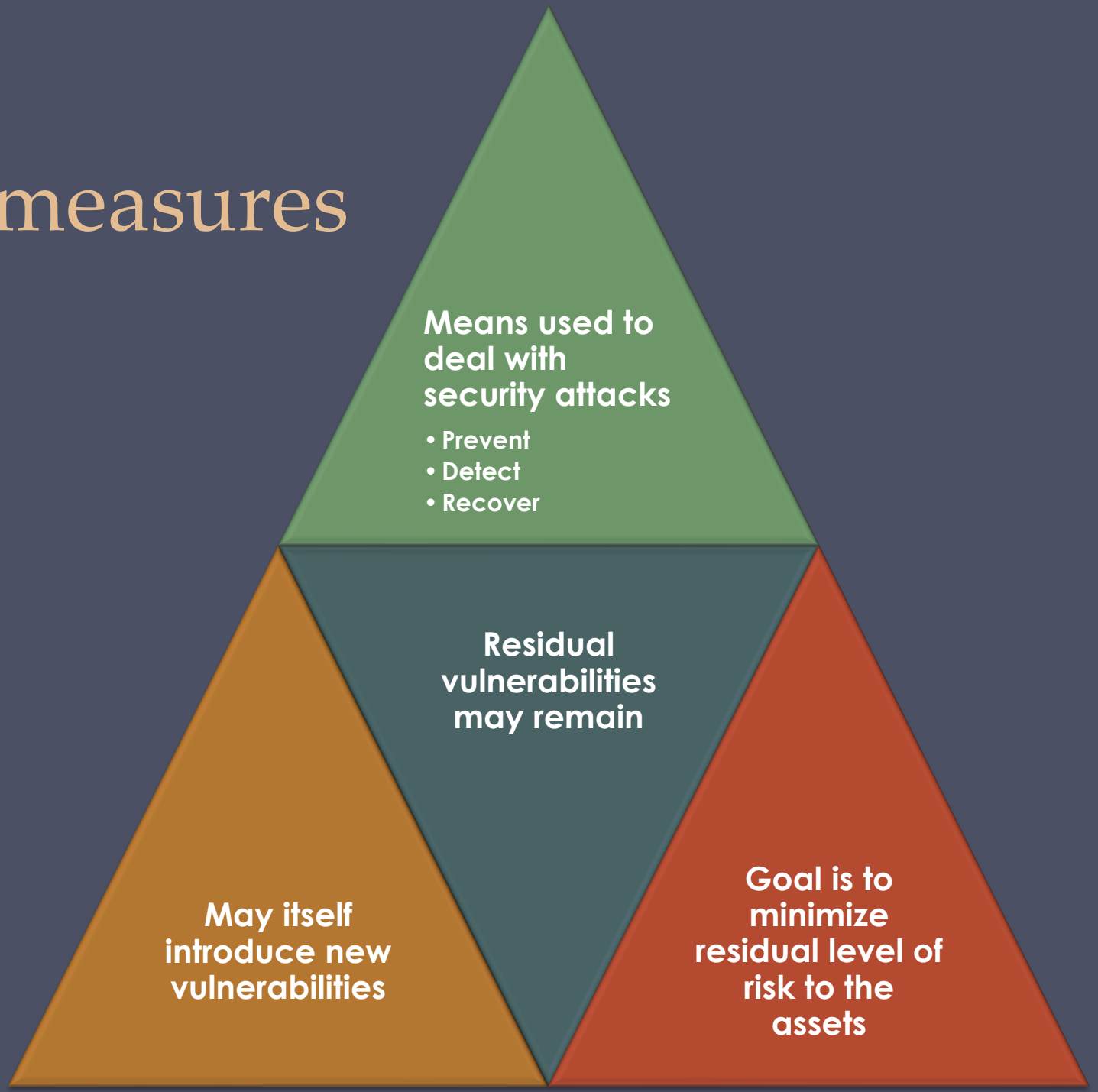
Assets of a Computer System



Vulnerabilities, Threats and Attacks

- Categories of vulnerabilities
  - Corrupted (loss of integrity)
  - Leaky (loss of confidentiality)
  - Unavailable or very slow (loss of availability)
- Threats
  - Capable of exploiting vulnerabilities
  - Represent potential security harm to an asset
- Attacks (threats carried out)
  - Passive – attempt to learn or make use of information from the system that does not affect system resources
  - Active – attempt to alter system resources or affect their operation
  - Insider – initiated by an entity inside the security parameter
  - Outsider – initiated from outside the perimeter

Countermeasures



Threat Consequence	Threat Action (Attack)
Unauthorized Disclosure A circumstance or event whereby an entity gains access to data for which the entity is not authorized.	**Exposure:** Sensitive data are directly released to an unauthorized entity. **Interception:** An unauthorized entity directly accesses sensitive data traveling between authorized sources and destinations. **Inference:** A threat action whereby an unauthorized entity indirectly accesses sensitive data (but not necessarily the data contained in the communication) by reasoning from characteristics or byproducts of communications. **Intrusion:** An unauthorized entity gains access to sensitive data by circumventing a system's security protections.
Deception A circumstance or event that may result in an authorized entity receiving false data and believing it to be true.	**Masquerade:** An unauthorized entity gains access to a system or performs a malicious act by posing as an authorized entity. **Falsification:** False data deceive an authorized entity. **Repudiation:** An entity deceives another by falsely denying responsibility for an act.
Disruption A circumstance or event that interrupts or prevents the correct operation of system services and functions.	**Incapacitation:** Prevents or interrupts system operation by disabling a system component. **Corruption:** Undesirably alters system operation by adversely modifying system functions or data. **Obstruction:** A threat action that interrupts delivery of system services by hindering system operation.
Usurpation A circumstance or event that results in control of system services or functions by an unauthorized entity.	**Misappropriation:** An entity assumes unauthorized logical or physical control of a system resource. **Misuse:** Causes a system component to perform a function or service that is detrimental to system security.

Table 1.2

Threat Consequences, and the Types of Threat Actions That Cause Each Consequence

Based on RFC 4949

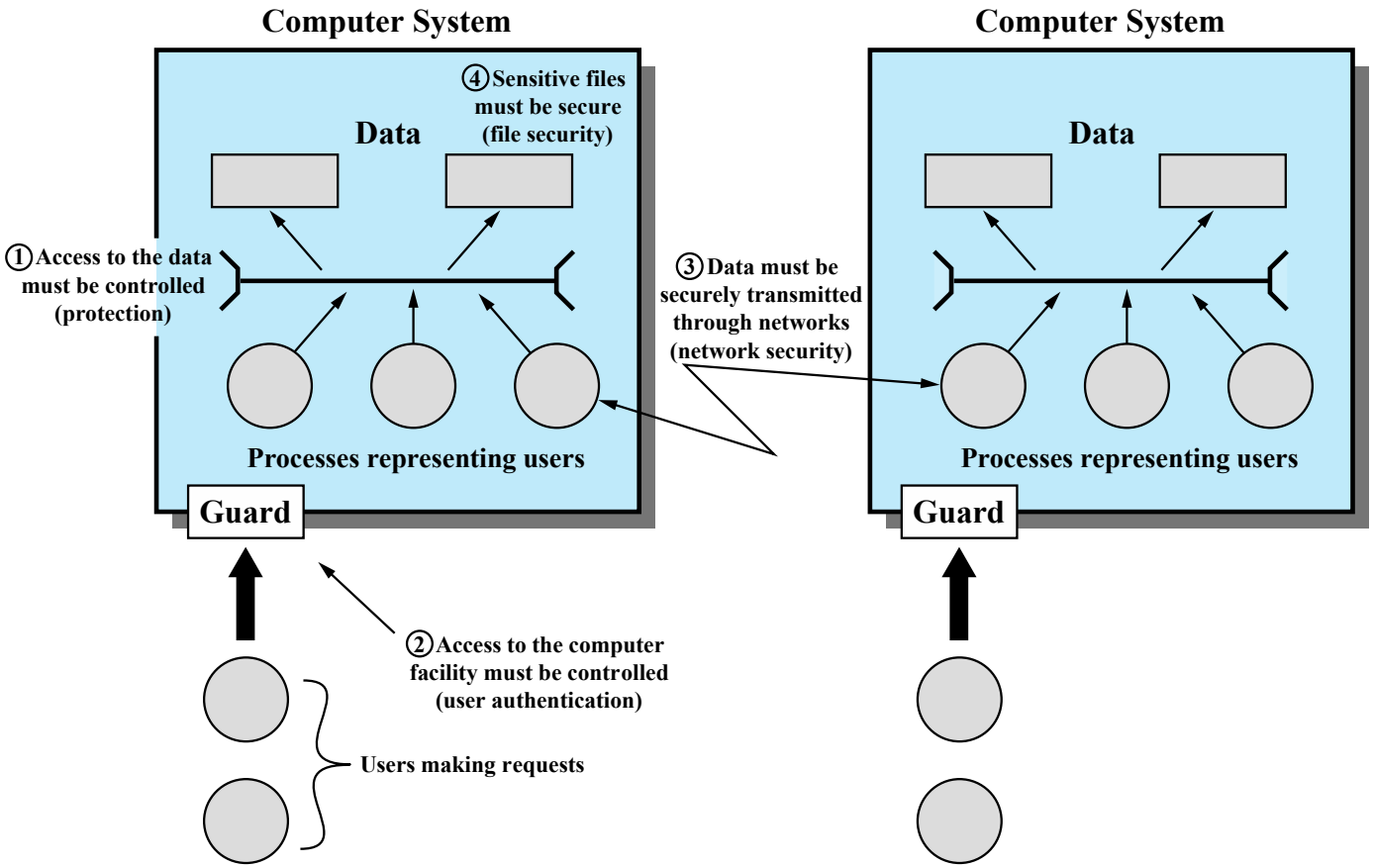


Figure 1.3 Scope of Computer Security. This figure depicts security concerns other than physical security, including control of access to computers systems, safeguarding of data transmitted over communications systems, and safeguarding of stored data.

Table 1.3
Computer and Network Assets, with Examples of Threats

	Availability	Confidentiality	Integrity
Hardware	Equipment is stolen or disabled, thus denying service.	An unencrypted CD-ROM or DVD is stolen.	
Software	Programs are deleted, denying access to users.	An unauthorized copy of software is made.	A working program is modified, either to cause it to fail during execution or to cause it to do some unintended task.
Data	Files are deleted, denying access to users.	An unauthorized read of data is performed. An analysis of statistical data reveals underlying data.	Existing files are modified or new files are fabricated.
Communication Lines and Networks	Messages are destroyed or deleted. Communication lines or networks are rendered unavailable.	Messages are read. The traffic pattern of messages is observed.	Messages are modified, delayed, reordered, or duplicated. False messages are fabricated.

Passive and Active Attacks

Passive Attack

- Attempts to learn or make use of information from the system but does not affect system resources
- Eavesdropping on, or monitoring of, transmissions
- Goal of attacker is to obtain information that is being transmitted
- Two types:
  - Release of message contents
  - Traffic analysis

Active Attack

- Attempts to alter system resources or affect their operation
- Involve some modification of the data stream or the creation of a false stream
- Four categories:
  - Replay
  - Masquerade
  - Modification of messages
  - Denial of service

Access control: Limit information system access to authorized users, processes acting on behalf of authorized users, or devices (including other information systems) and to the types of transactions and functions that authorized users are permitted to exercise.

Awareness and training: (i) Ensure that managers and users of organizational information systems are made aware of the security risks associated with their activities and of the applicable laws, regulation, and policies related to the security of organizational information systems; and (ii) ensure that personnel are adequately trained to carry out their assigned information security-related duties and responsibilities.

Audit and accountability: (i) Create, protect, and retain information system audit records to the extent needed to enable the monitoring, analysis, investigation, and reporting of unlawful, unauthorized, or inappropriate information system activity; and (ii) ensure that the actions of individual information system users can be uniquely traced to those users so they can be held accountable for their actions.

Certification, accreditation, and security assessments: (i) Periodically assess the security controls in organizational information systems to determine if the controls are effective in their application; (ii) develop and implement plans of action designed to correct deficiencies and reduce or eliminate vulnerabilities in organizational information systems; (iii) authorize the operation of organizational information systems and any associated information system connections; and (iv) monitor information system security controls on an ongoing basis to ensure the continued effectiveness of the controls.

Configuration management: (i) Establish and maintain baseline configurations and inventories of organizational information systems (including hardware, software, firmware, and documentation) throughout the respective system development life cycles; and (ii) establish and enforce security configuration settings for information technology products employed in organizational information systems.

Contingency planning: Establish, maintain, and implement plans for emergency response, backup operations, and postdisaster recovery for organizational information systems to ensure the availability of critical information resources and continuity of operations in emergency situations.

Identification and authentication: Identify information system users, processes acting on behalf of users, or devices and authenticate (or verify) the identities of those users, processes, or devices, as a prerequisite to allowing access to organizational information systems.

Incident response: (i) Establish an operational incident handling capability for organizational information systems that includes adequate preparation, detection, analysis, containment, recovery, and user response activities; and (ii) track, document, and report incidents to appropriate organizational officials and/or authorities.

Maintenance: (i) Perform periodic and timely maintenance on organizational information systems; and (ii) provide effective controls on the tools, techniques, mechanisms, and personnel used to conduct information system maintenance.

Table 1.4

Security Requirements

(FIPS 200)

Media protection: (i) Protect information system media, both paper and digital; (ii) limit access to information on information system media to authorized users; and (iii) sanitize or destroy information system media before disposal or release for reuse.

Physical and environmental protection: (i) Limit physical access to information systems, equipment, and the respective operating environments to authorized individuals; (ii) protect the physical plant and support infrastructure for information systems; (iii) provide supporting utilities for information systems; (iv) protect information systems against environmental hazards; and (v) provide appropriate environmental controls in facilities containing information systems.

Planning: Develop, document, periodically update, and implement security plans for organizational information systems that describe the security controls in place or planned for the information systems and the rules of behavior for individuals accessing the information systems.

Personnel security: (i) Ensure that individuals occupying positions of responsibility within organizations (including third-party service providers) are trustworthy and meet established security criteria for those positions; (ii) ensure that organizational information and information systems are protected during and after personnel actions such as terminations and transfers; and (iii) employ formal sanctions for personnel failing to comply with organizational security policies and procedures.

Risk assessment: Periodically assess the risk to organizational operations (including mission, functions, image, or reputation), organizational assets, and individuals, resulting from the operation of organizational information systems and the associated processing, storage, or transmission of organizational information.

Systems and services acquisition: (i) Allocate sufficient resources to adequately protect organizational information systems; (ii) employ system development life cycle processes that incorporate information security considerations; (iii) employ software usage and installation restrictions; and (iv) ensure that third-party providers employ adequate security measures to protect information, applications, and/or services outsourced from the organization.

System and communications protection: (i) Monitor, control, and protect organizational communications (i.e., information transmitted or received by organizational information systems) at the external boundaries and key internal boundaries of the information systems; and (ii) employ architectural designs, software development techniques, and systems engineering principles that promote effective information security within organizational information systems.

System and information integrity: (i) Identify, report, and correct information and information system flaws in a timely manner; (ii) provide protection from malicious code at appropriate locations within organizational information systems; and (iii) monitor information system security alerts and advisories and take appropriate actions in response.

Table 1.4

Security Requirements

(FIPS 200)

Fundamental Security Design Principles

Economy of mechanism	Fail-safe defaults	Complete mediation	Open design
Separation of privilege	Least privilege	Least common mechanism	Psychological acceptability
Isolation	Encapsulation	Modularity	Layering
Least astonishment			

Attack Surfaces

Consist of the reachable and exploitable vulnerabilities in a system

Examples:

- Open ports on outward facing Web and other servers, and code listening on those ports
- Services available on the inside of a firewall
- Code that processes incoming data, email, XML, office documents, and industry-specific custom data exchange formats
- Interfaces, SQL, and Web forms
- An employee with access to sensitive information vulnerable to a social engineering attack

Attack Surface Categories

Network Attack Surface

Vulnerabilities over an enterprise network, wide-area network, or the Internet

Included in this category are network protocol vulnerabilities, such as those used for a denial-of-service attack, disruption of communications links, and various forms of intruder attacks

Software Attack Surface

Vulnerabilities in application, utility, or operating system code

Particular focus is Web server software

Human Attack Surface

Vulnerabilities created by personnel or outsiders, such as social engineering, human error, and trusted insiders

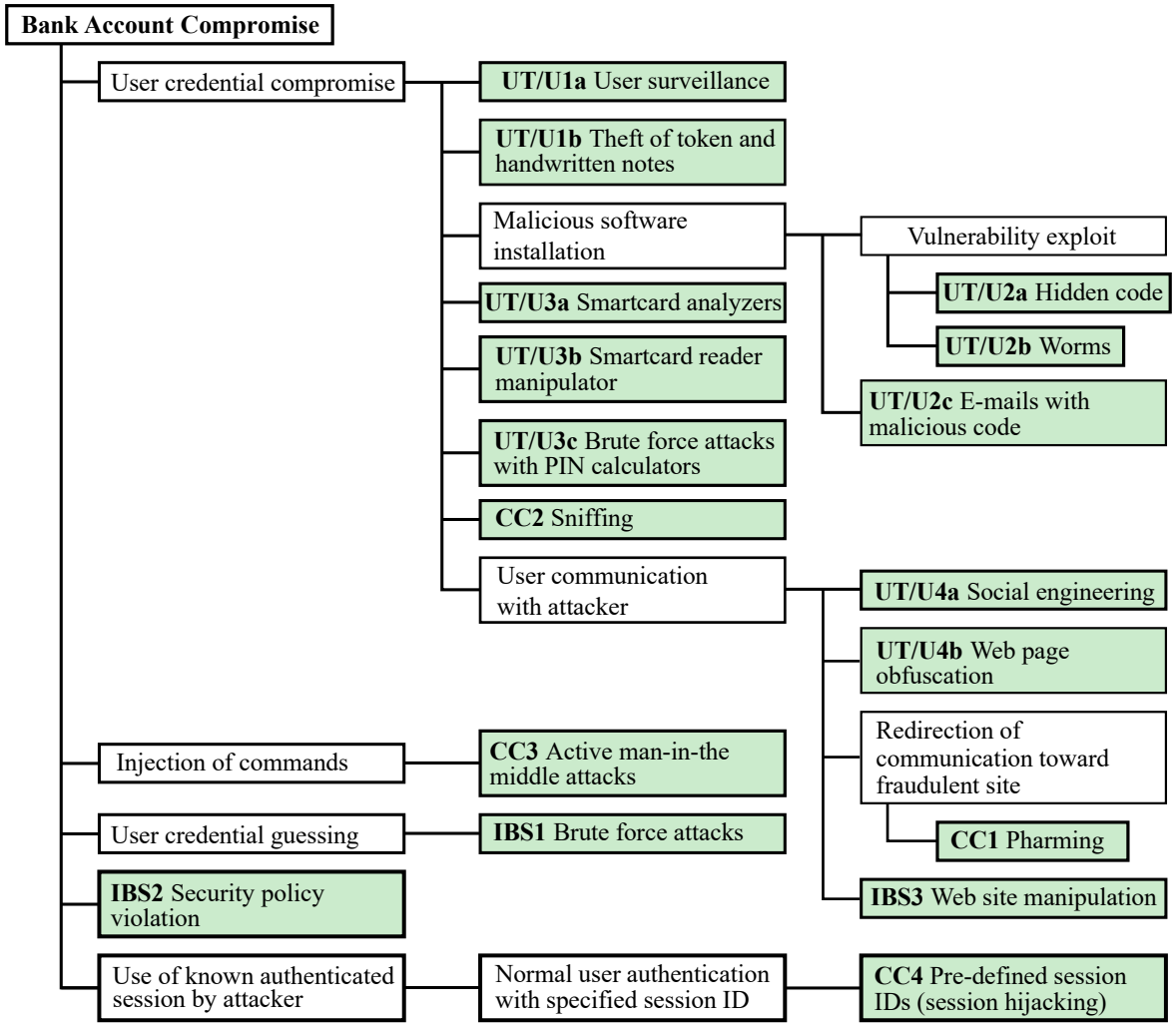
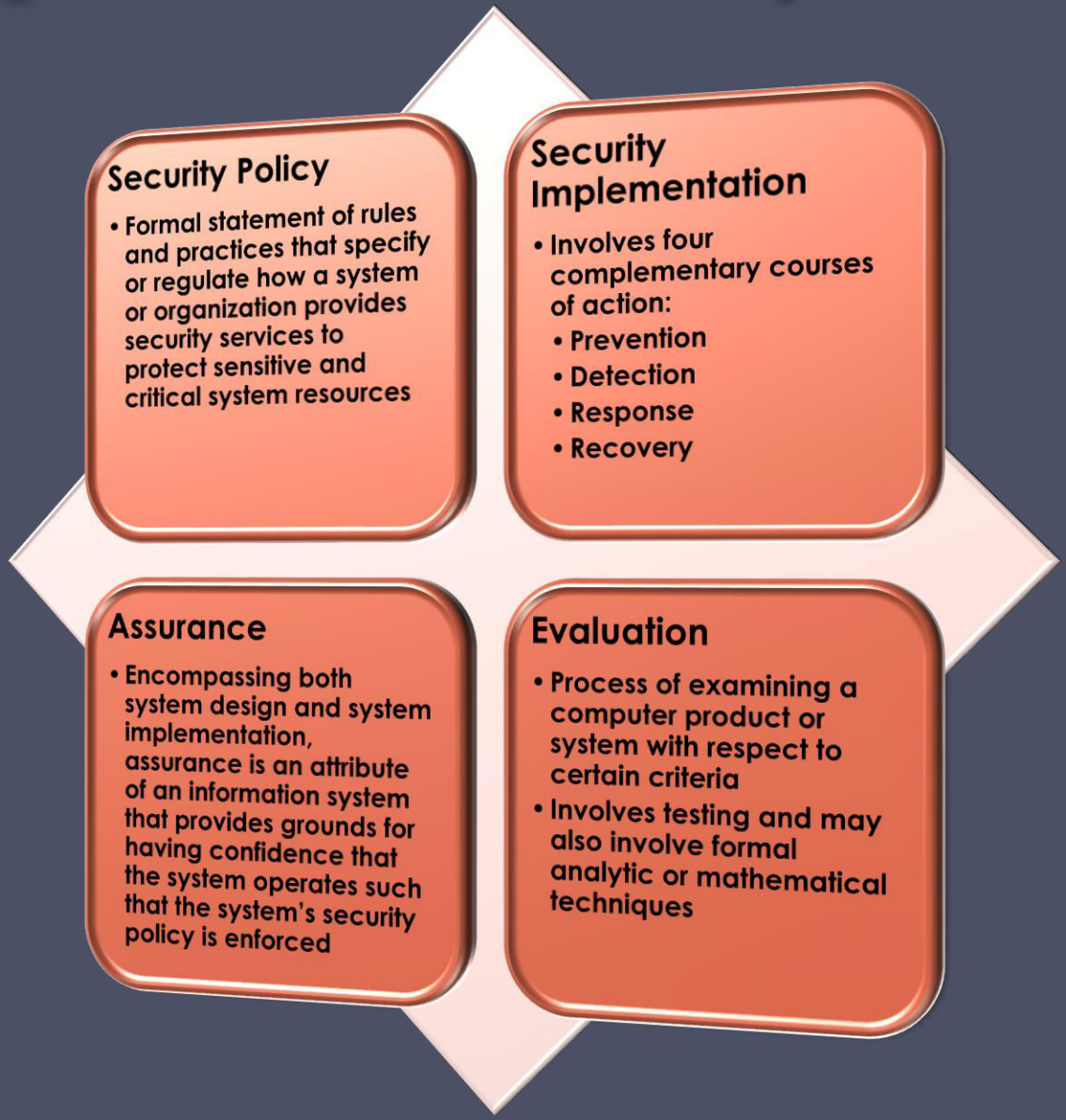


Figure 1.5 An Attack Tree for Internet Banking Authentication

Computer Security Strategy



Standards

- Standards have been developed to cover management practices and the overall architecture of security mechanisms and services
- The most important of these organizations are:
  - **National Institute of Standards and Technology (NIST)**
    - **NIST is a U.S. federal agency that deals with measurement science, standards, and technology related to U.S. government use and to the promotion of U.S. private sector innovation**
  - **Internet Society (ISOC)**
    - **ISOC is a professional membership society that provides leadership in addressing issues that confront the future of the Internet, and is the organization home for the groups responsible for Internet infrastructure standards**
  - **International Telecommunication Union (ITU-T)**
    - **ITU is a United Nations agency in which governments and the private sector coordinate global telecom networks and services**
  - **International Organization for Standardization (ISO)**
    - **ISO is a nongovernmental organization whose work results in international agreements that are published as International Standards**

Thank You!

Q & A Session

Cryptographic Tools

Courtesy of William Stallings and Lawrie Brown
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Symmetric Encryption

- The universal technique for providing confidentiality for transmitted or stored data
- Also referred to as conventional encryption or single-key encryption
- Two requirements for secure use:
  - Need a strong encryption algorithm
  - Sender and receiver must have obtained copies of the secret key in a secure fashion and must keep the key secure

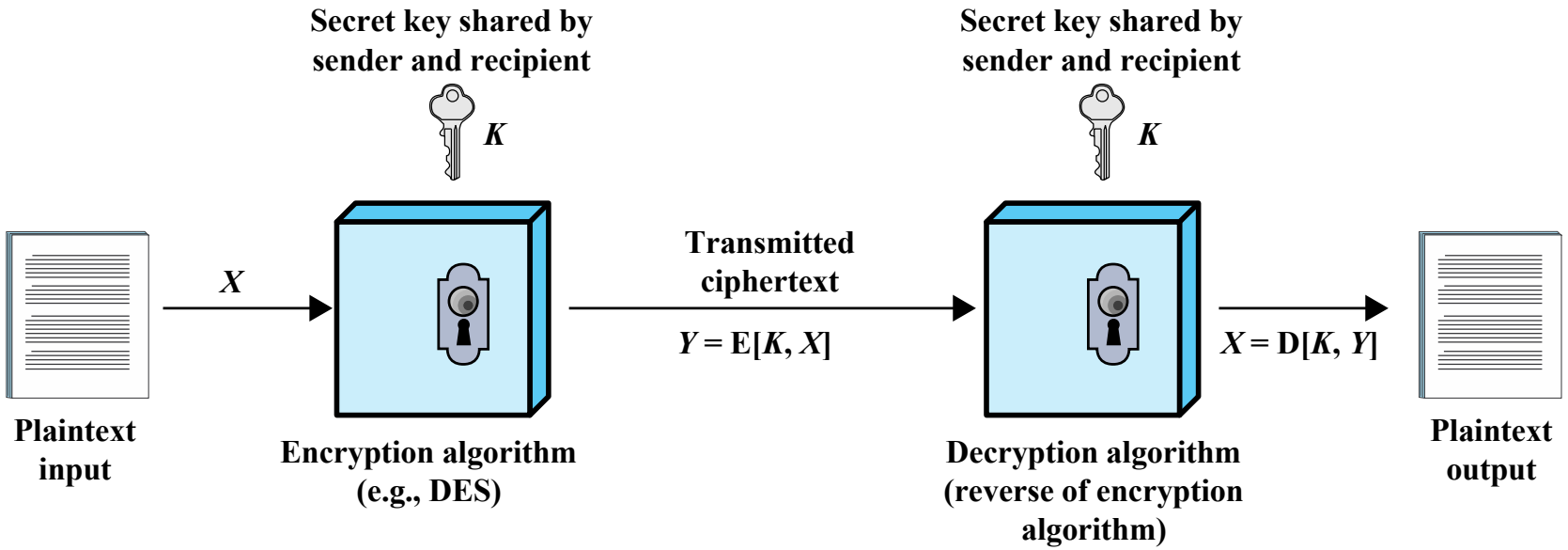


Figure 2.1 Simplified Model of Symmetric Encryption

Attacking Symmetric Encryption

Cryptanalytic Attacks

- Rely on:
  - Nature of the algorithm
  - Some knowledge of the general characteristics of the plaintext
  - Some sample plaintext-ciphertext pairs
- Exploits the characteristics of the algorithm to attempt to deduce a specific plaintext or the key being used
  - If successful all future and past messages encrypted with that key are compromised

Brute-Force Attacks

- Try all possible keys on some ciphertext until an intelligible translation into plaintext is obtained
  - On average half of all possible keys must be tried to achieve success

Table 2.1

	DES	Triple DES	AES
Plaintext block size (bits)	64	64	128
Ciphertext block size (bits)	64	64	128
Key size (bits)	56	112 or 168	128, 192, or 256

DES = Data Encryption Standard
AES = Advanced Encryption Standard

Comparison of Three Popular Symmetric Encryption Algorithms

Data Encryption Standard (DES)

- Until recently was the most widely used encryption scheme
  - FIPS PUB 46
  - Referred to as the Data Encryption Algorithm (DEA)
  - Uses 64 bit plaintext block and 56 bit key to produce a 64 bit ciphertext block
- Strength concerns:
  - Concerns about the algorithm itself
    - DES is the most studied encryption algorithm in existence
  - Concerns about the use of a 56-bit key
    - The speed of commercial off-the-shelf processors makes this key length woefully inadequate

Table 2.2

Key size (bits)	Cipher	Number of Alternative Keys	Time Required at 10^9 decryptions/s	Time Required at 10^{13} decryptions/s
56	DES	$2^{56} \approx 7.2 \times 10^{16}$	2^{55} ns = 1.125 years	1 hour
128	AES	$2^{128} \approx 3.4 \times 10^{38}$	2^{127} ns = 5.3×10^{21} years	5.3×10^{17} years
168	Triple DES	$2^{168} \approx 3.7 \times 10^{50}$	2^{167} ns = 5.8×10^{33} years	5.8×10^{29} years
192	AES	$2^{192} \approx 6.3 \times 10^{57}$	2^{191} ns = 9.8×10^{40} years	9.8×10^{36} years
256	AES	$2^{256} \approx 1.2 \times 10^{77}$	2^{255} ns = 1.8×10^{60} years	1.8×10^{56} years

Average Time Required for Exhaustive Key Search

Triple DES (3DES)

- Repeats basic DES algorithm three times using either two or three unique keys
- First standardized for use in financial applications in ANSI standard X9.17 in 1985
- Attractions:
  - 168-bit key length overcomes the vulnerability to brute-force attack of DES
  - Underlying encryption algorithm is the same as in DES
- Drawbacks:
  - Algorithm is sluggish in software
  - Uses a 64-bit block size

Advanced Encryption Standard (AES)

Needed a replacement for 3DES

3DES was not reasonable for long term use

NIST called for proposals for a new AES in 1997

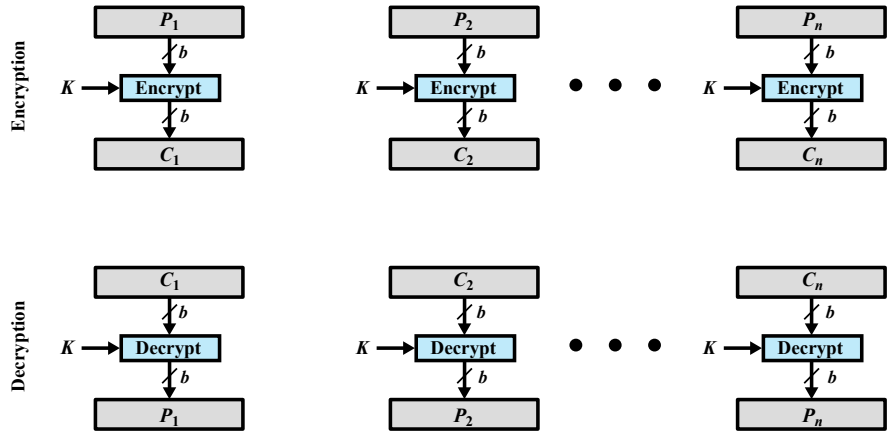
- Should have a security strength equal to or better than 3DES
- Significantly improved efficiency
- Symmetric block cipher
- 128 bit data and 128/192/256 bit keys

Selected Rijndael in November 2001

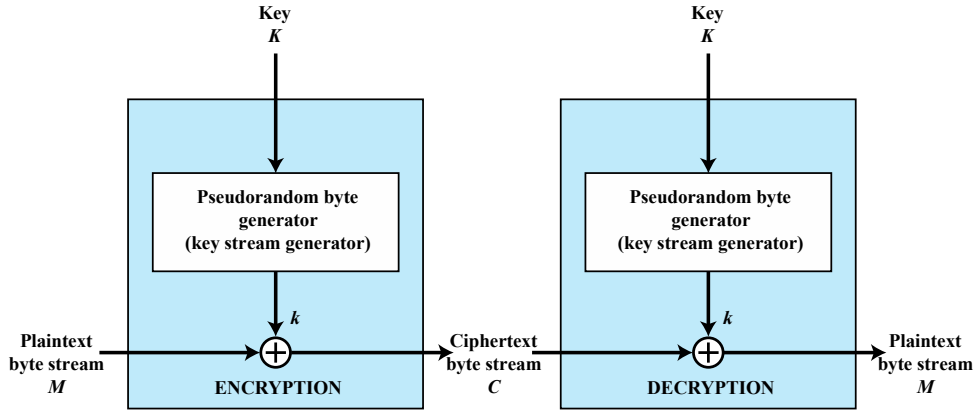
Published as FIPS 197

Practical Security Issues

- Typically symmetric encryption is applied to a unit of data larger than a single 64-bit or 128-bit block
- Electronic codebook (ECB) mode is the simplest approach to multiple-block encryption
  - Each block of plaintext is encrypted using the same key
  - Cryptanalysts may be able to exploit regularities in the plaintext
- Modes of operation
  - Alternative techniques developed to increase the security of symmetric block encryption for large sequences
  - Overcomes the weaknesses of ECB



(a) Block cipher encryption (electronic codebook mode)



(b) Stream encryption

Figure 2.2 Types of Symmetric Encryption

Block & Stream Ciphers

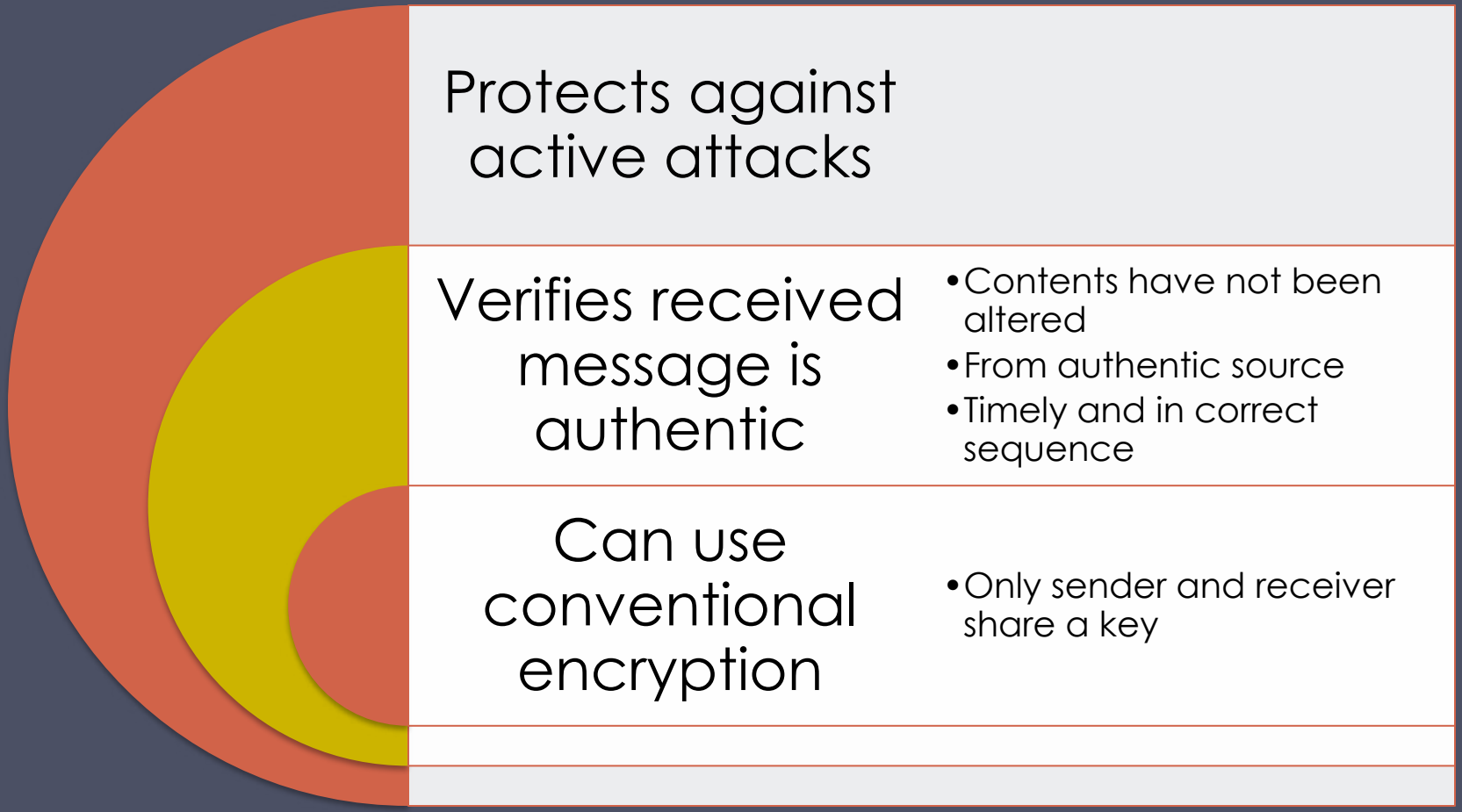
Block Cipher

- Processes the input one block of elements at a time
- Produces an output block for each input block
- Can reuse keys
- More common

Stream Cipher

- Processes the input elements continuously
- Produces output one element at a time
- Primary advantage is that they are almost always faster and use far less code
- Encrypts plaintext one byte at a time
- Pseudorandom stream is one that is unpredictable without knowledge of the input key

Message Authentication



Message Authentication Without Confidentiality

- Message encryption by itself does not provide a secure form of authentication
- It is possible to combine authentication and confidentiality in a single algorithm by encrypting a message plus its authentication tag
- Typically message authentication is provided as a separate function from message encryption
- Situations in which message authentication without confidentiality may be preferable include:
  - There are a number of applications in which the same message is broadcast to a number of destinations
  - An exchange in which one side has a heavy load and cannot afford the time to decrypt all incoming messages
  - Authentication of a computer program in plaintext is an attractive service
- Thus, there is a place for both authentication and encryption in meeting security requirements

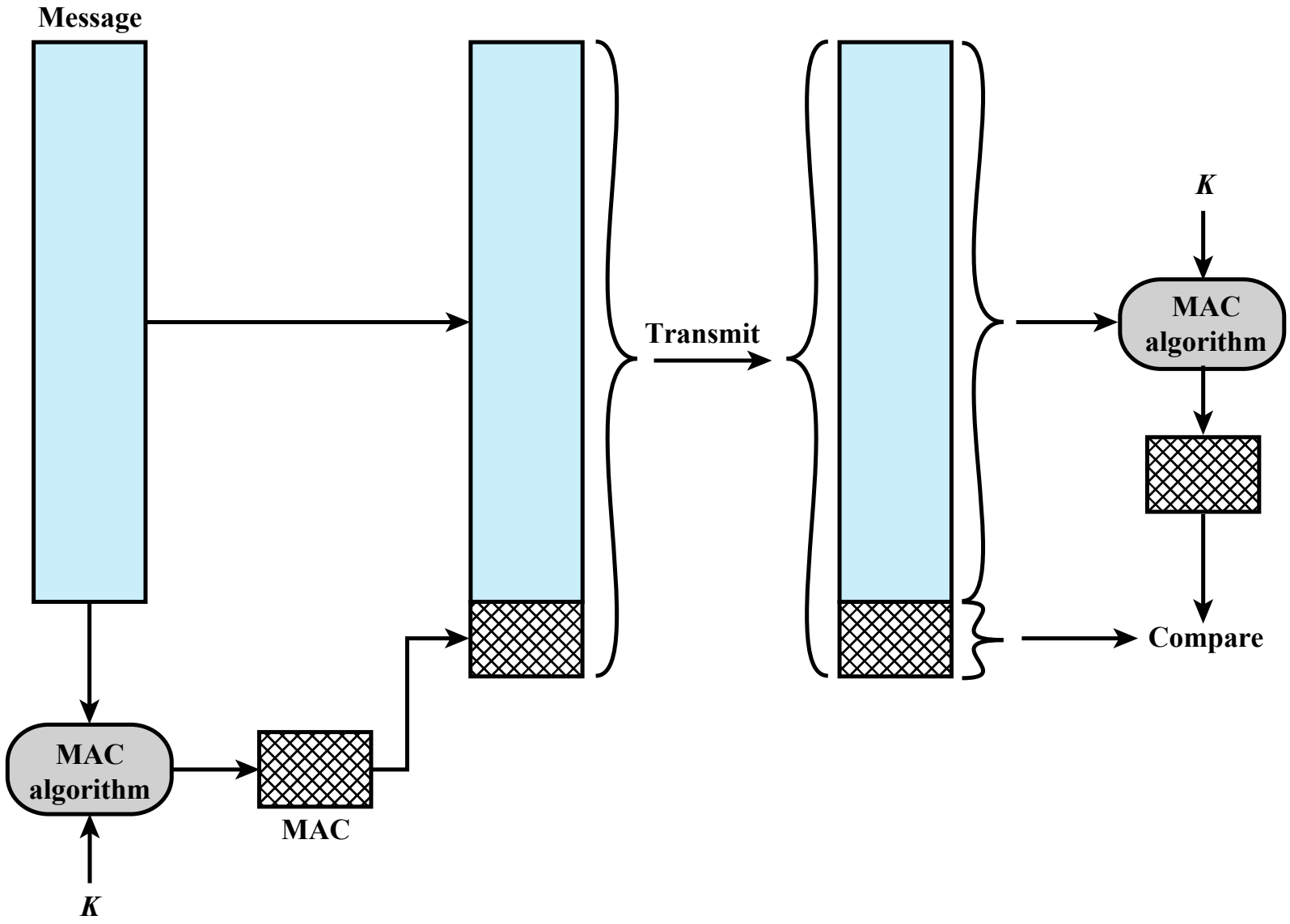
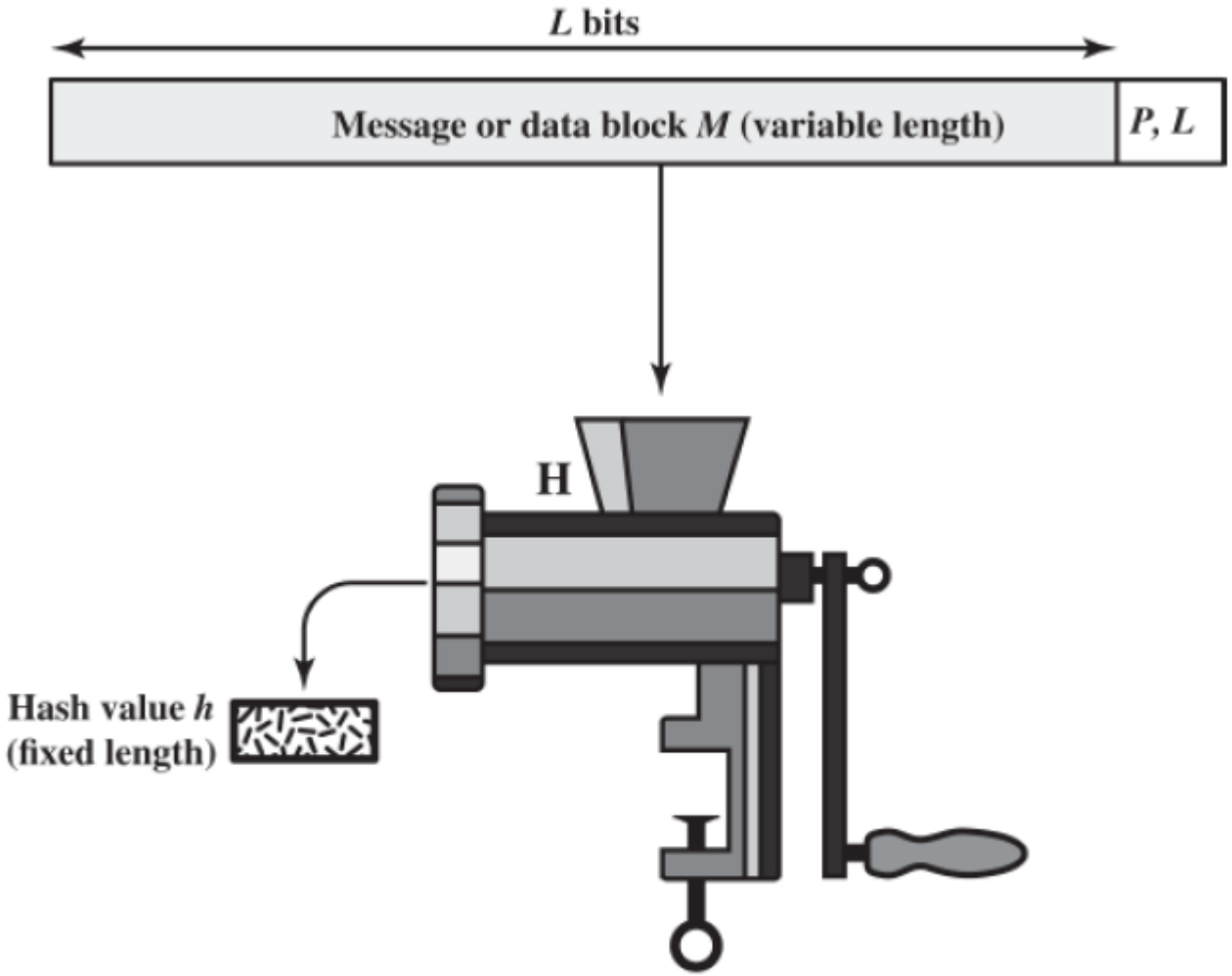


Figure 2.3 Message Authentication Using a Message Authentication Code (MAC).



P, *L* = padding plus length field

Figure 2.4 Cryptographic Hash Function; h=H(M)

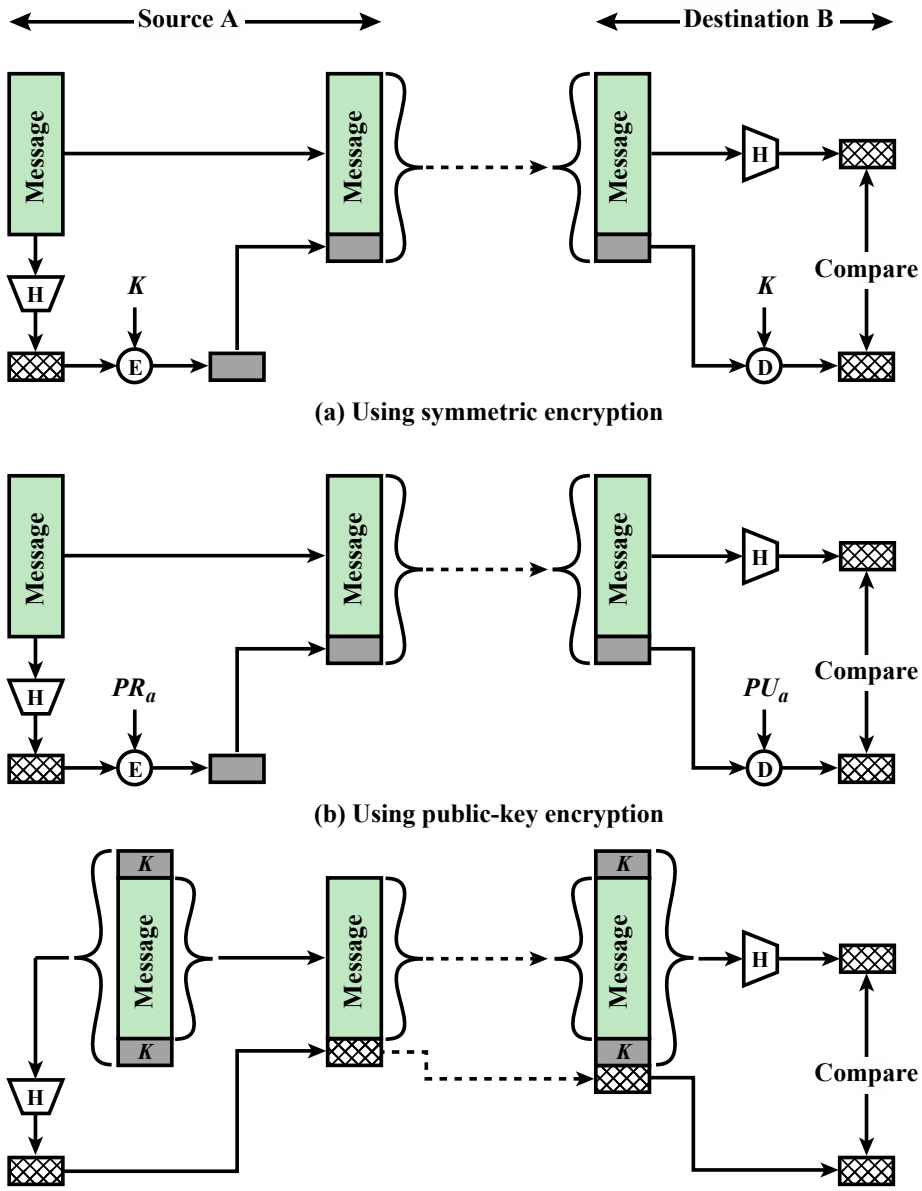


Figure 2.5 Message Authentication Using a One-Way Hash Function.

To be useful for message authentication, a hash function H must have the following properties:

- Can be applied to a block of data of any size
- Produces a fixed-length output
- H(x) is relatively easy to compute for any given x
- One-way or pre-image resistant
  - Computationally infeasible to find x such that H(x) = h
- Computationally infeasible to find $y \neq x$ such that H(y) = H(x)
- Collision resistant or strong collision resistance
  - Computationally infeasible to find any pair (x,y) such that H(x) = H(y)

Security of Hash Functions

There are two approaches to attacking a secure hash function:

- **Cryptanalysis**
  - Exploit logical weaknesses in the algorithm
- **Brute-force attack**
  - Strength of hash function depends solely on the length of the hash code produced by the algorithm

SHA most widely used hash algorithm

Additional secure hash function applications:

- **Passwords**
  - Hash of a password is stored by an operating system
- **Intrusion detection**
  - Store H(F) for each file on a system and secure the hash values

Public-Key Encryption Structure

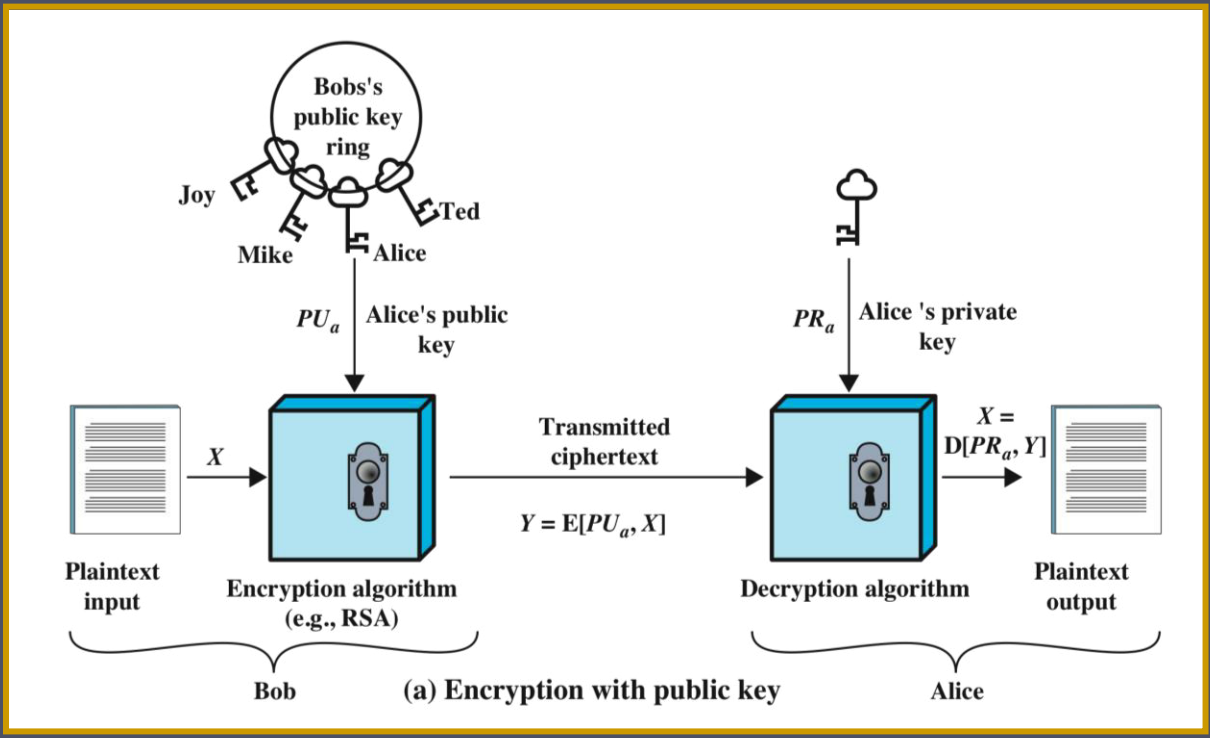
Publicly proposed by Diffie and Hellman in 1976

Based on mathematical functions

Asymmetric

- Uses two separate keys
- Public key and private key
- Public key is made public for others to use

Some form of protocol is needed for distribution



- **Plaintext**
  - Readable message or data that is fed into the algorithm as input
- **Encryption algorithm**
  - Performs transformations on the plaintext
- **Public and private key**
  - Pair of keys, one for encryption, one for decryption
- **Ciphertext**
  - Scrambled message produced as output
- **Decryption key**
  - Produces the original plaintext

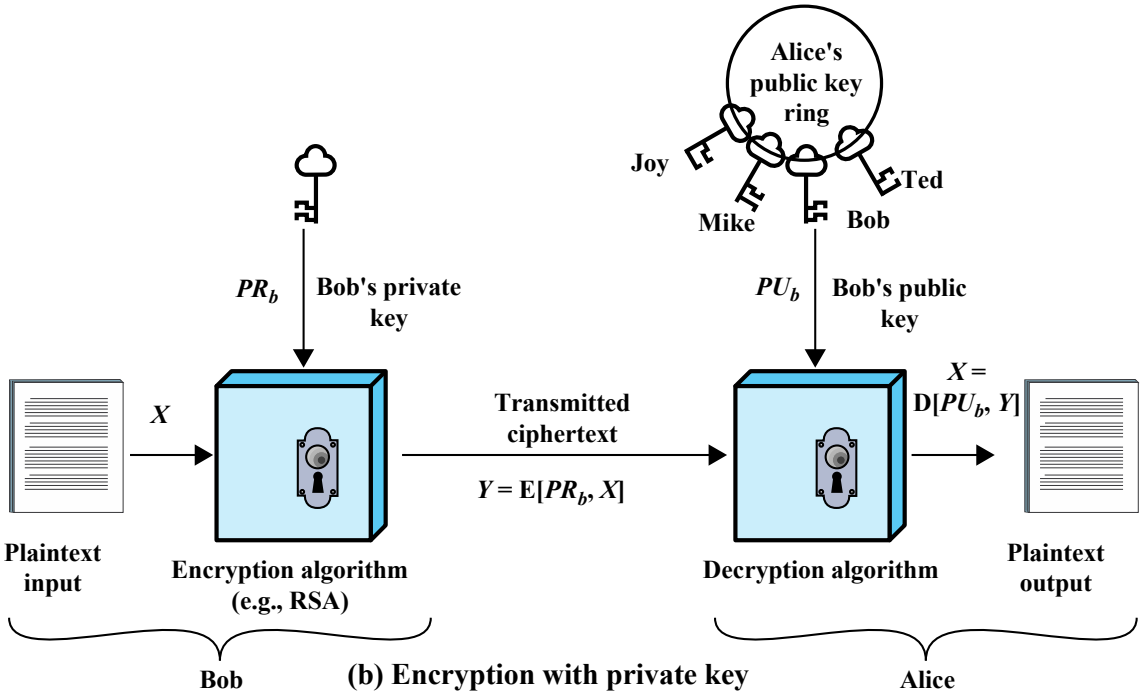


Figure 2.6 Public-Key Cryptography

- User encrypts data using his or her own private key
- Anyone who knows the corresponding public key will be able to decrypt the message

Table 2.3

Applications for Public-Key Cryptosystems

Algorithm	Digital Signature	Symmetric Key Distribution	Encryption of Secret Keys
RSA	Yes	Yes	Yes
Diffie-Hellman	No	Yes	No
DSS	Yes	No	No
Elliptic Curve	Yes	Yes	Yes

Requirements for Public-Key Cryptosystems

Computationally easy to create key pairs

Computationally easy for sender knowing public key to encrypt messages

Computationally easy for receiver knowing private key to decrypt ciphertext

Computationally infeasible for opponent to determine private key from public key

Computationally infeasible for opponent to otherwise recover original message

Useful if either key can be used for each role

Asymmetric Encryption Algorithms

RSA (Rivest, Shamir, Adleman)	Developed in 1977	Most widely accepted and implemented approach to public-key encryption	Block cipher in which the plaintext and ciphertext are integers between 0 and n-1 for some n.
Diffie-Hellman key exchange algorithm	Enables two users to securely reach agreement about a shared secret that can be used as a secret key for subsequent symmetric encryption of messages	Limited to the exchange of the keys	
Digital Signature Standard (DSS)	Provides only a digital signature function with SHA-1	Cannot be used for encryption or key exchange	
Elliptic curve cryptography (ECC)	Security like RSA, but with much smaller keys		

Digital Signatures

- NIST FIPS PUB 186-4 defines a digital signature as:

  "The result of a cryptographic transformation of data that, when properly implemented, provides a mechanism for verifying origin authentication, data integrity and signatory non-repudiation."

- Thus, a digital signature is a data-dependent bit pattern, generated by an agent as a function of a file, message, or other form of data block

- FIPS 186-4 specifies the use of one of three digital signature algorithms:
  - Digital Signature Algorithm (DSA)
  - RSA Digital Signature Algorithm
  - Elliptic Curve Digital Signature Algorithm (ECDSA)

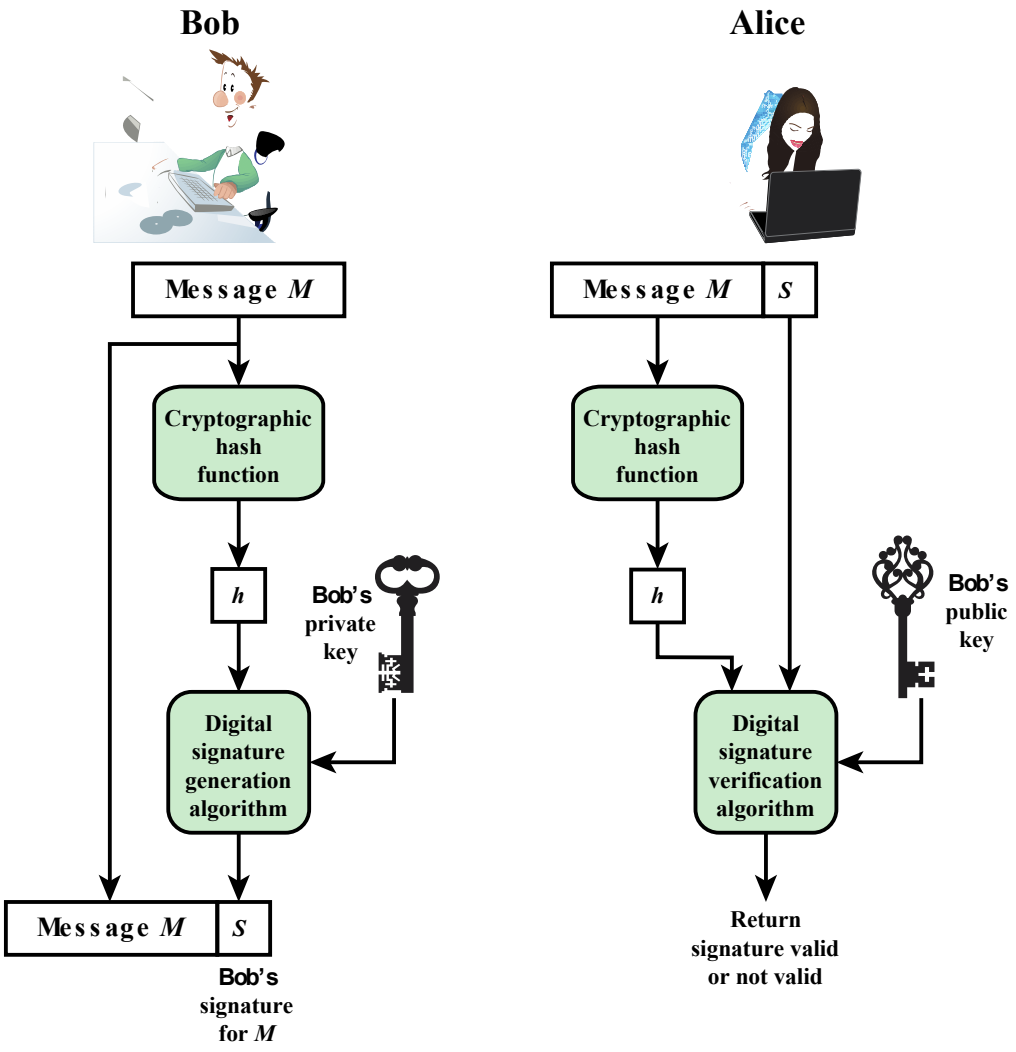


Figure 2.7 Simplified Depiction of Essential Elements of Digital Signature Process

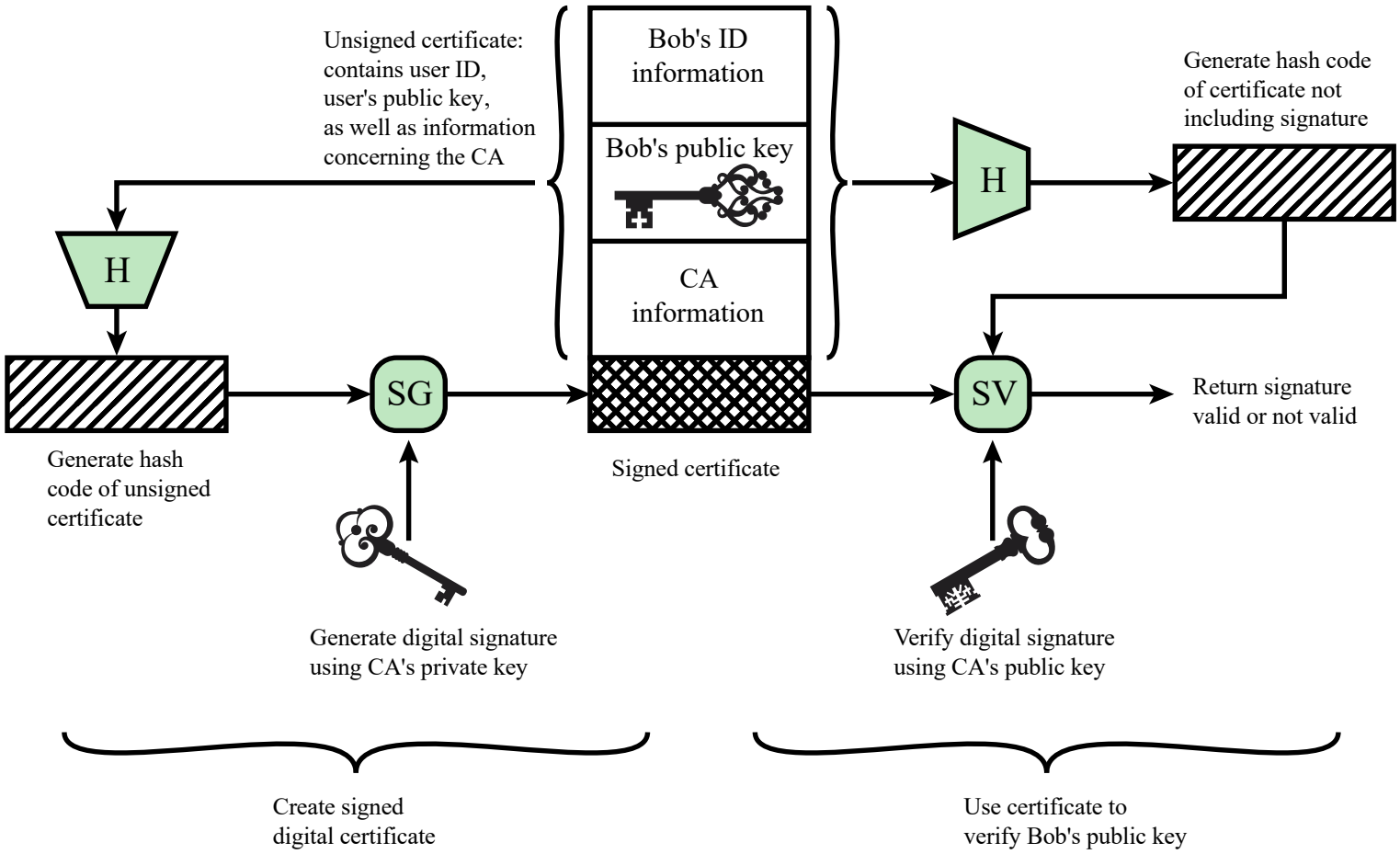
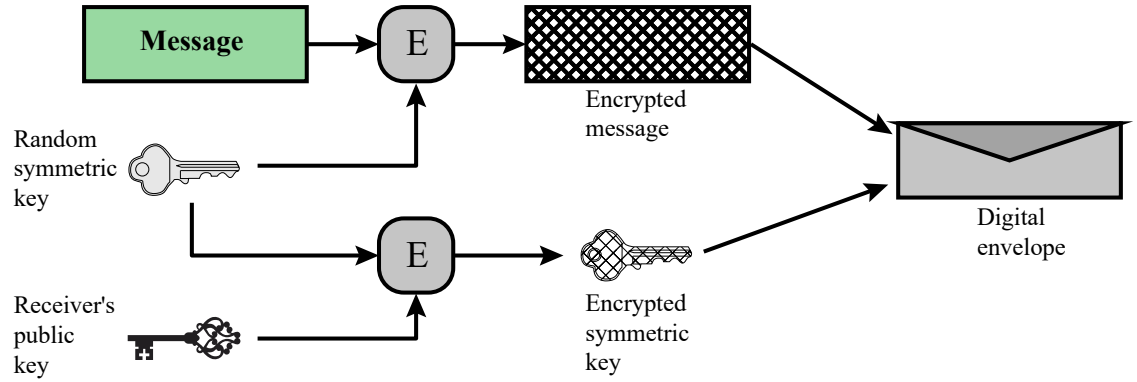
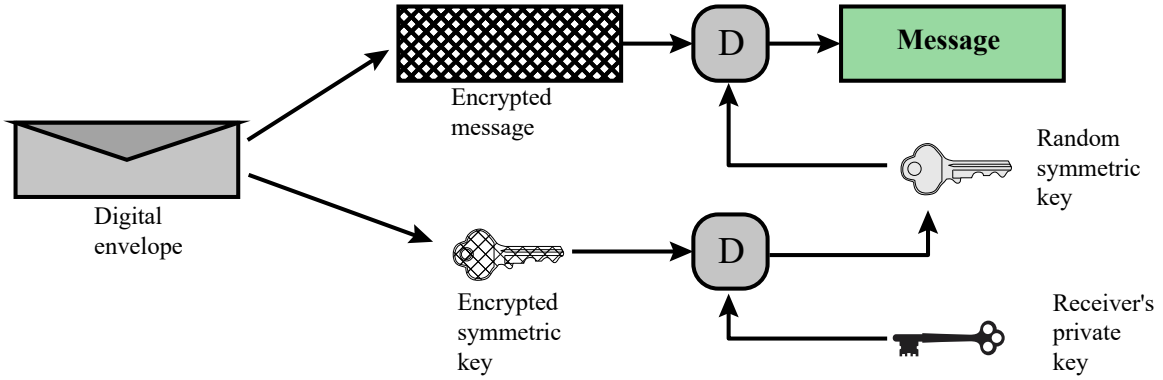


Figure 2.8 Public-Key Certificate Use



(a) Creation of a digital envelope



(b) Opening a digital envelope

Figure 2.9 Digital Envelopes

Random Numbers

Uses include generation of:

- Keys for public-key algorithms
- Stream key for symmetric stream cipher
- Symmetric key for use as a temporary session key or in creating a digital envelope
- Handshaking to prevent replay attacks
- Session key

Random Number Requirements

Randomness

- Criteria:
  - Uniform distribution
    - Frequency of occurrence of each of the numbers should be approximately the same
  - Independence
    - No one value in the sequence can be inferred from the others

Unpredictability

- Each number is statistically independent of other numbers in the sequence
- Opponent should not be able to predict future elements of the sequence on the basis of earlier elements

Random versus Pseudorandom

Cryptographic applications typically make use of algorithmic techniques for random number generation

- Algorithms are deterministic and therefore produce sequences of numbers that are not statistically random

Pseudorandom numbers are:

- Sequences produced that satisfy statistical randomness tests
- Likely to be predictable

True random number generator (TRNG):

- Uses a nondeterministic source to produce randomness
- Most operate by measuring unpredictable natural processes
  - e.g. radiation, gas discharge, leaky capacitors
- Increasingly provided on modern processors

Practical Application: Encryption of Stored Data

Common to encrypt transmitted data

Much less common for stored data

- There is often little protection beyond domain authentication and operating system access controls
- Data are archived for indefinite periods
- Even though erased, until disk sectors are reused data are recoverable

Approaches to encrypt stored data:

- Use a commercially available encryption package
- Back-end appliance
- Library based tape encryption
- Background laptop/PC data encryption

Thank You!

Q & A Session

User Authentication

Courtesy of William Stallings and Lawrie Brown
Computer Security: Principles and Practice,4th Edition

NIST SP 800-63-3 (*Digital Authentication Guideline,* October 2016) defines digital user authentication as:

"The process of establishing confidence in user identities that are presented electronically to an information system."

Table 3.1 Identification and Authentication Security Requirements (SP 800-171)

	Basic Security Requirements:
1	Identify information system users, processes acting on behalf of users, or devices.
2	Authenticate (or verify) the identities of those users, processes, or devices, as a prerequisite to allowing access to organizational information systems.
	Derived Security Requirements:
3	Use multifactor authentication for local and network access to privileged accounts and for network access to non-privileged accounts.
4	Employ replay-resistant authentication mechanisms for network access to privileged and non-privileged accounts.
5	Prevent reuse of identifiers for a defined period.
6	Disable identifiers after a defined period of inactivity.
7	Enforce a minimum password complexity and change of characters when new passwords are created.
8	Prohibit password reuse for a specified number of generations.
9	Allow temporary password use for system logons with an immediate change to a permanent password.
10	Store and transmit only cryptographically-protected passwords.
11	Obscure feedback of authentication information.

(Table can be found on page 65 in the textbook)

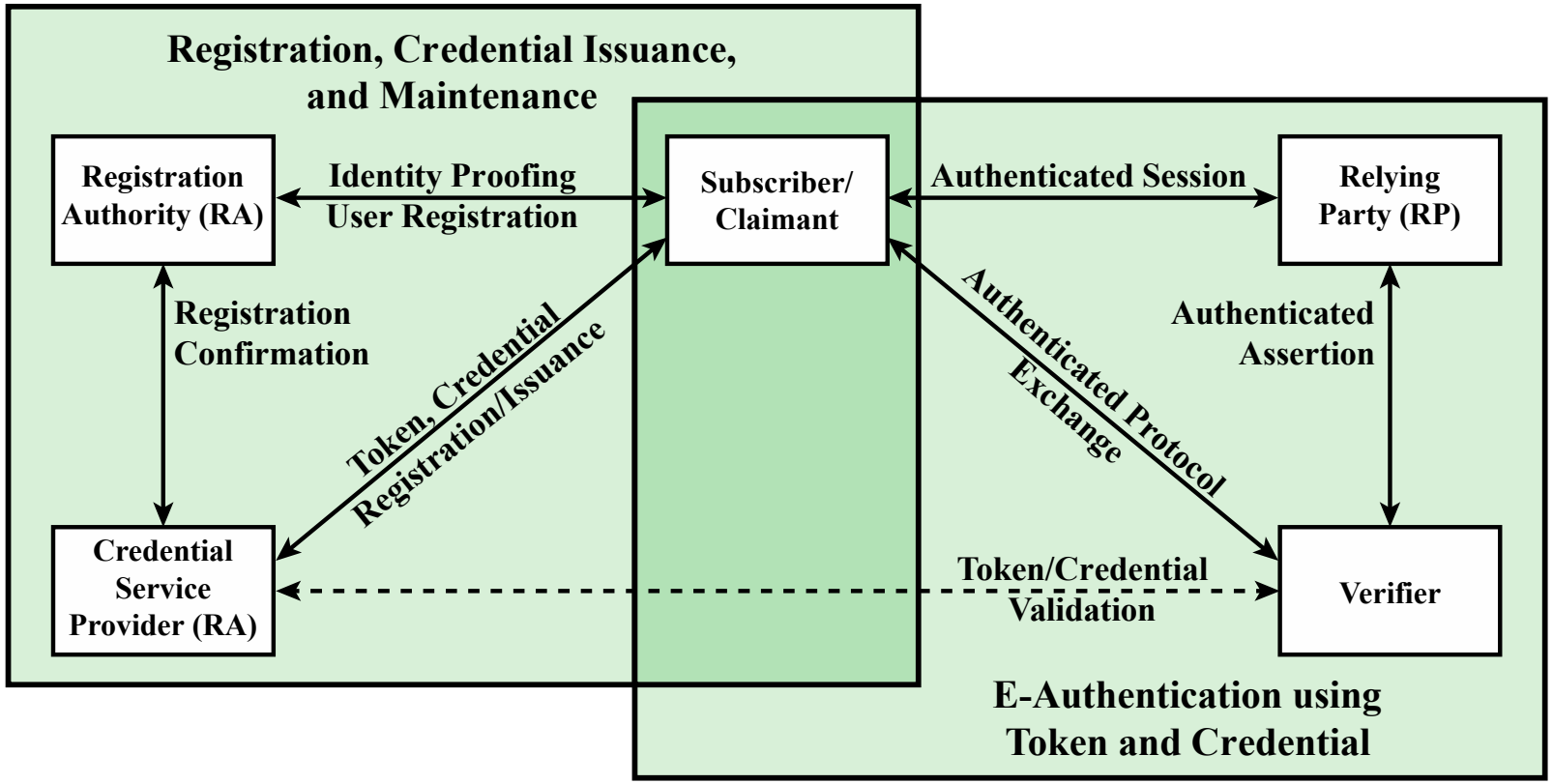


Figure 3.1 The NIST SP 800-63-2 E-Authentication Architectural Model

The four means of authenticating user identity are based on:

Something the individual knows

- Password, PIN, answers to prearranged questions

Something the individual possesses (token)

- Smartcard, electronic keycard, physical key

Something the individual is (static biometrics)

- Fingerprint, retina, face

Something the individual does (dynamic biometrics)

- Voice pattern, handwriting, typing rhythm

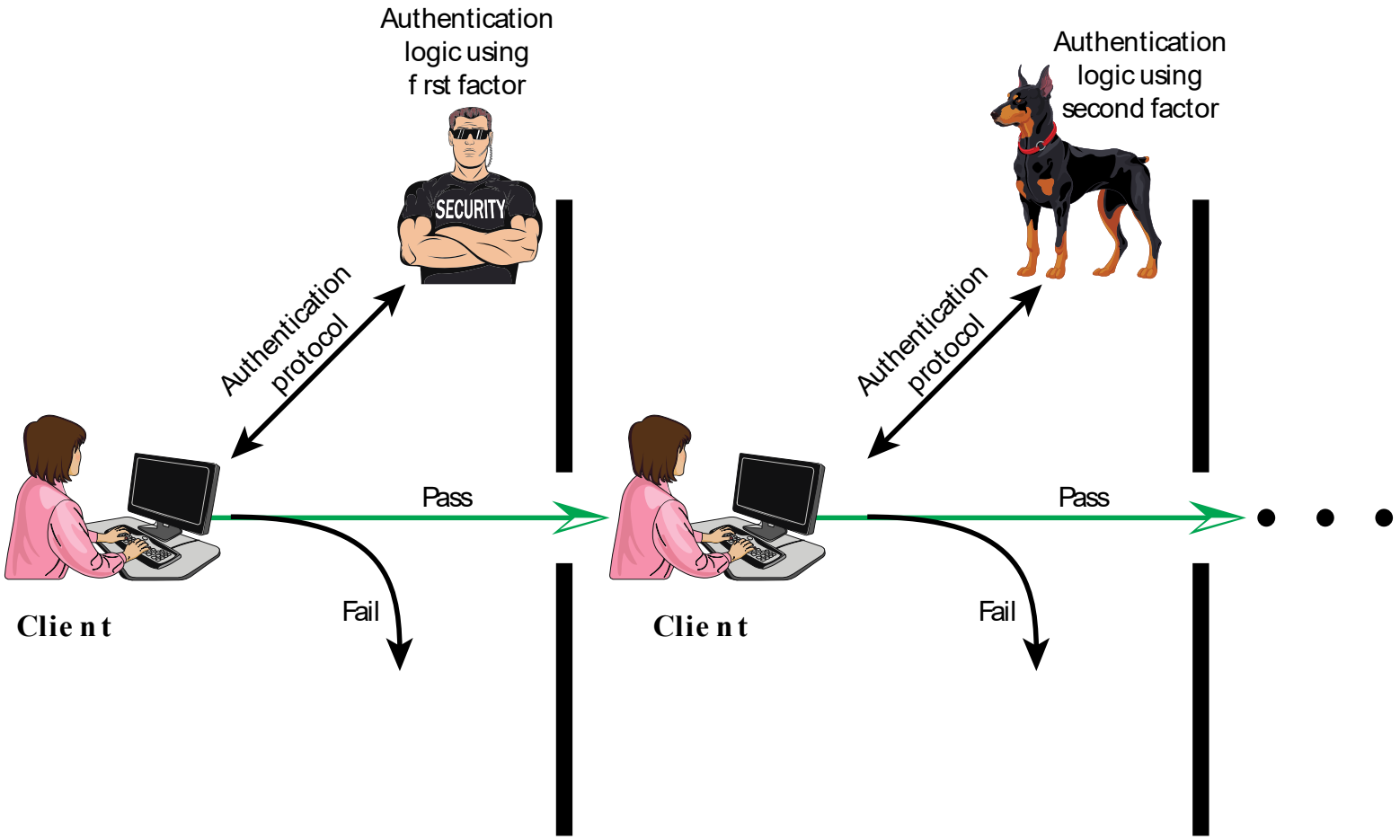
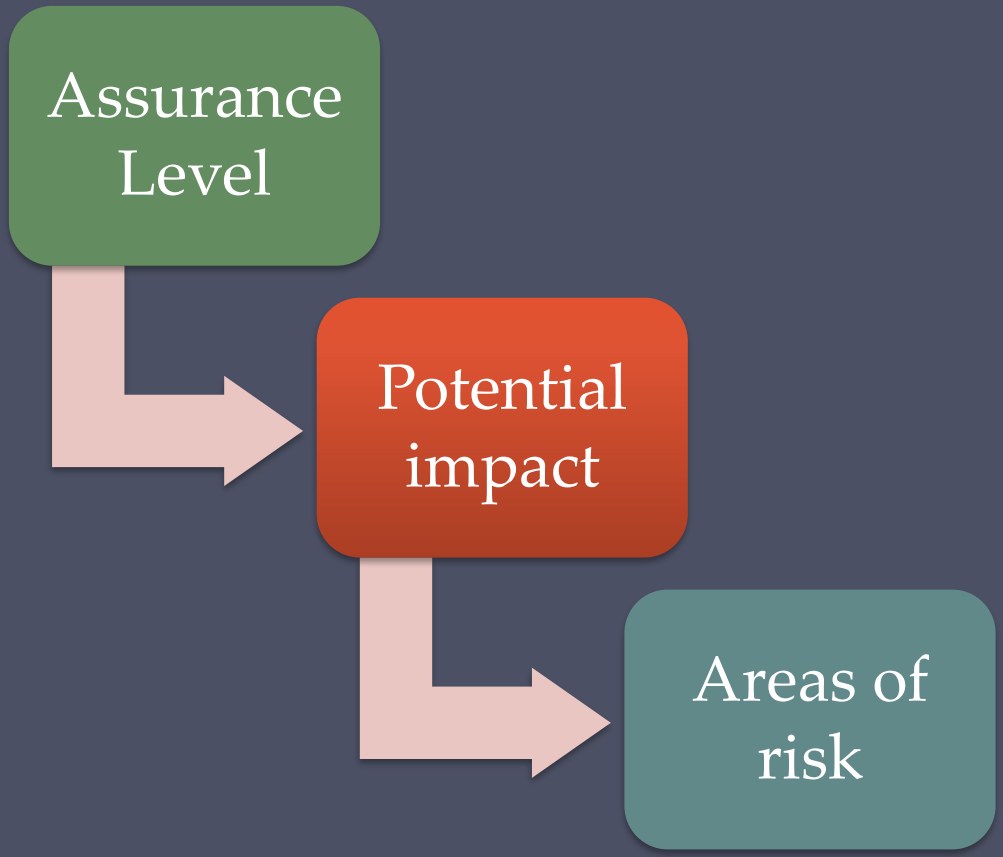


Figure 3.2 Multifactor Authentication

Risk Assessment for User Authentication

- There are three separate concepts:



Assurance Level

Describes an organization's degree of certainty that a user has presented a credential that refers to his or her identity

More specifically is defined as:

The degree of confidence in the vetting process used to establish the identity of the individual to whom the credential was issued

The degree of confidence that the individual who uses the credential is the individual to whom the credential was issued

Four levels of assurance

Level 1

- Little or no confidence in the asserted identity's validity

Level 2

- Some confidence in the asserted identity's validity

Level 3

- High confidence in the asserted identity's validity

Level 4

- Very high confidence in the asserted identity's validity

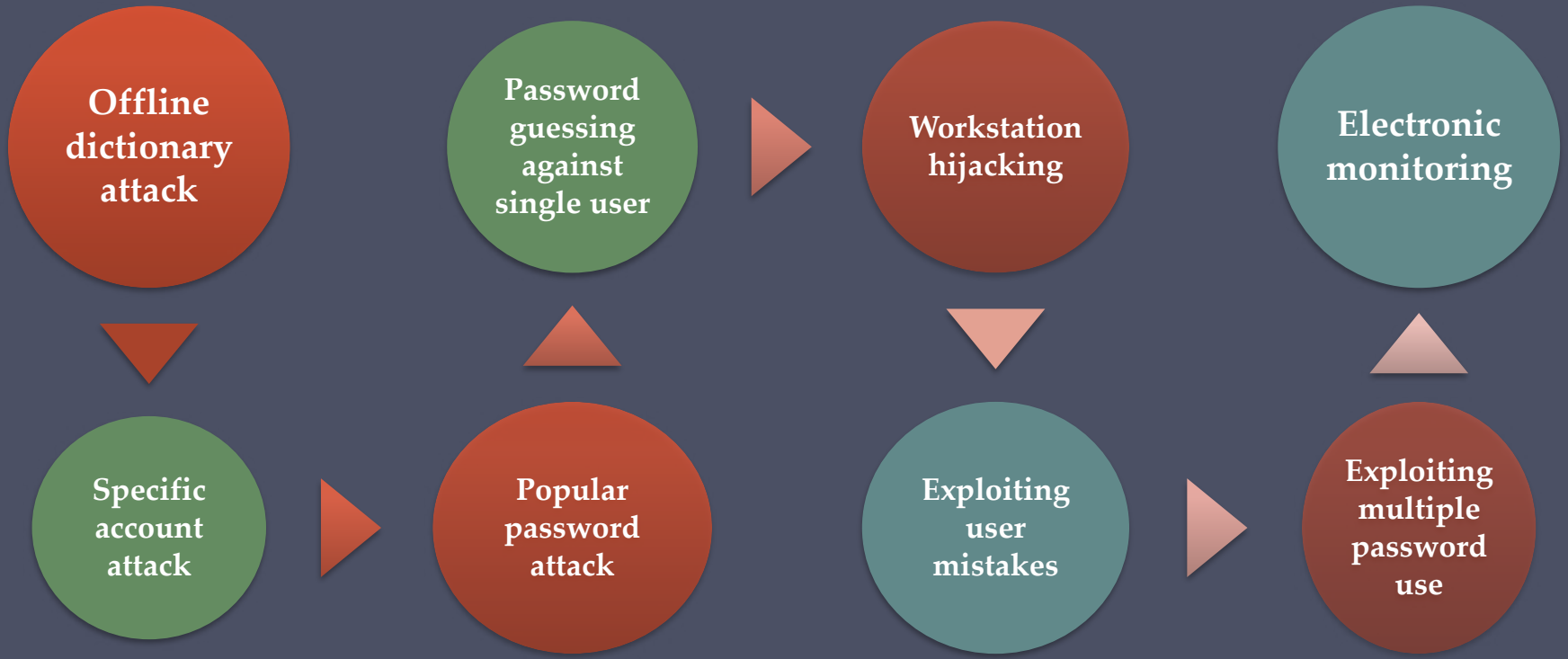
Potential Impact

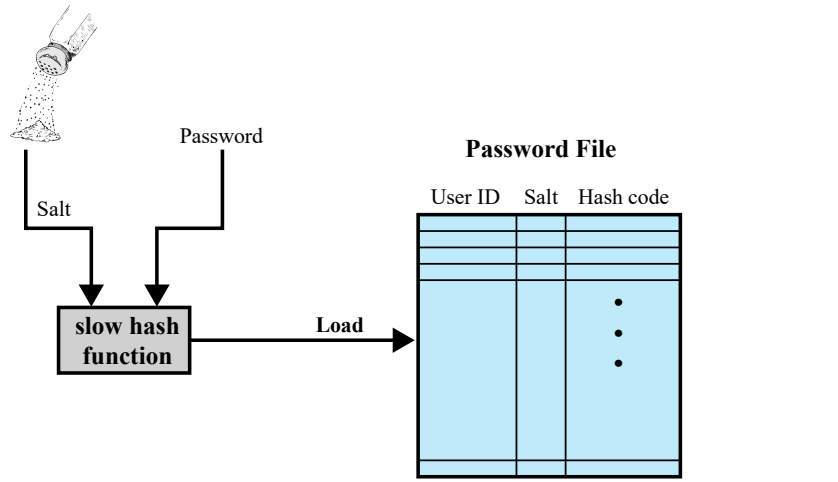
- FIPS 199 defines three levels of potential impact on organizations or individuals should there be a breach of security:
  - Low
    - An authentication error could be expected to have a limited adverse effect on organizational operations, organizational assets, or individuals
  - Moderate
    - An authentication error could be expected to have a serious adverse effect
  - High
    - An authentication error could be expected to have a severe or catastrophic adverse effect

Password-Based Authentication

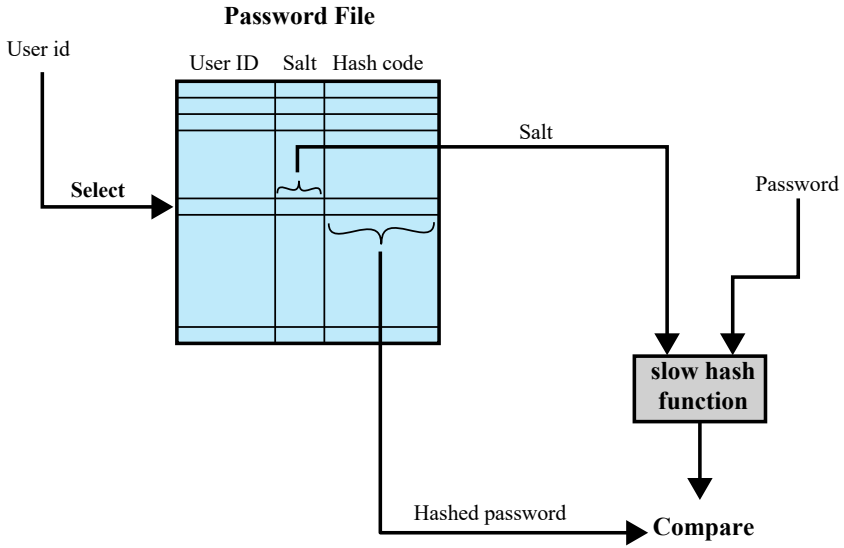
- Widely used line of defense against intruders
  - User provides name/login and password
  - System compares password with the one stored for that specified login
- The user ID:
  - Determines that the user is authorized to access the system
  - Determines the user's privileges
  - Is used in discretionary access control

Password Vulnerabilities





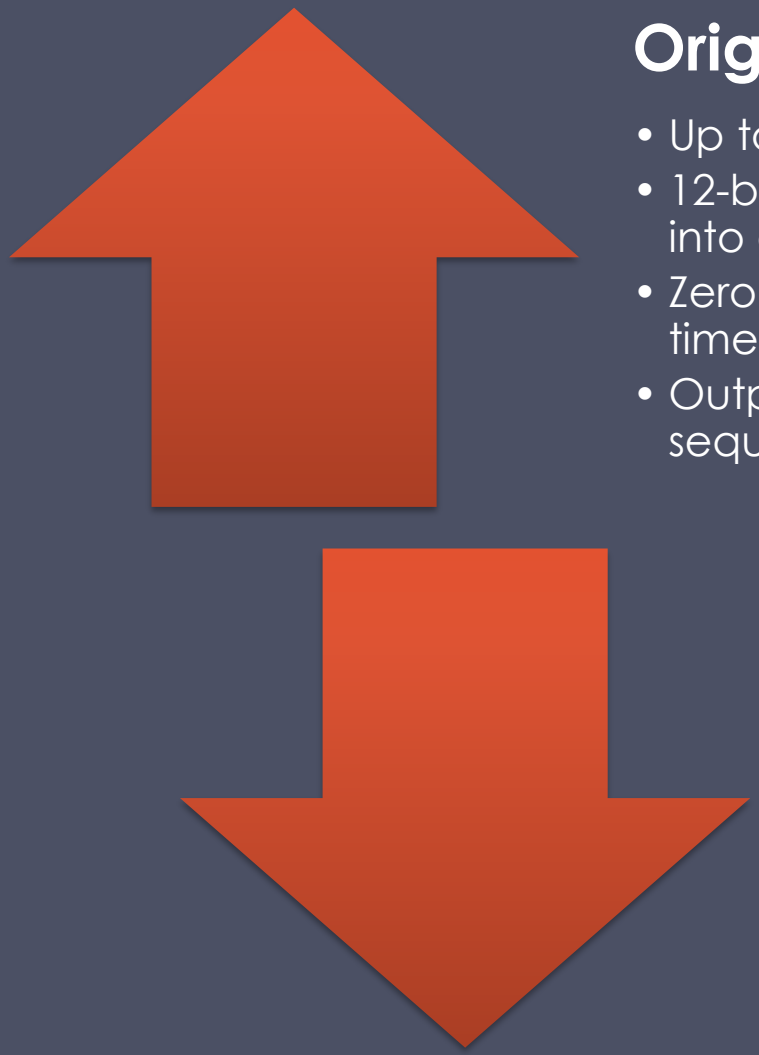
(a) Loading a new password



(b) Verifying a password

Figure 3.3 UNIX Password Scheme

UNIX Implementation



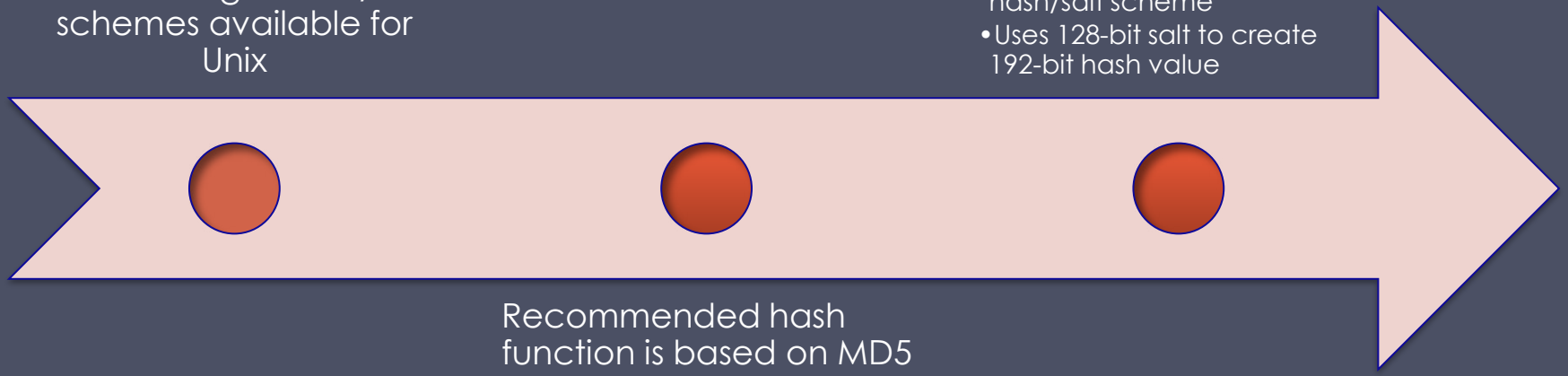
Original scheme

- Up to eight printable characters in length
- 12-bit salt used to modify DES encryption into a one-way hash function
- Zero value repeatedly encrypted 25 times
- Output translated to 11 character sequence

Now regarded as inadequate

- Still often required for compatibility with existing account management software or multivendor environments

Improved Implementations



Much stronger hash/salt schemes available for Unix

Recommended hash function is based on MD5

- Salt of up to 48-bits
- Password length is unlimited
- Produces 128-bit hash
- Uses an inner loop with 1000 iterations to achieve slowdown

OpenBSD uses Blowfish block cipher based hash algorithm called Bcrypt

- Most secure version of Unix hash/salt scheme
- Uses 128-bit salt to create 192-bit hash value

Password Cracking

Dictionary attacks

- Develop a large dictionary of possible passwords and try each against the password file
- Each password must be hashed using each salt value and then compared to stored hash values

Rainbow table attacks

- Pre-compute tables of hash values for all salts
- A mammoth table of hash values
- Can be countered by using a sufficiently large salt value and a sufficiently large hash length

Password crackers exploit the fact that people choose easily guessable passwords

- Shorter password lengths are also easier to crack

John the Ripper

- Open-source password cracker first developed in in 1996
- Uses a combination of brute-force and dictionary techniques

Modern Approaches

- Complex password policy
  - Forcing users to pick stronger passwords
- However password-cracking techniques have also improved
  - The processing capacity available for password cracking has increased dramatically
  - The use of sophisticated algorithms to generate potential passwords
  - Studying examples and structures of actual passwords in use

Password File Access Control

Can block offline guessing attacks by denying access to encrypted passwords

- Make available only to privileged users
- Shadow password file

Vulnerabilities

- Weakness in the OS that allows access to the file
- Accident with permissions making it readable
- Users with same password on other systems
- Access from backup media
- Sniff passwords in network traffic

Password Selection Strategies

User education

Users can be told the importance of using hard to guess passwords and can be provided with guidelines for selecting strong passwords

Computer generated passwords

Users have trouble remembering them

Reactive password checking

System periodically runs its own password cracker to find guessable passwords

Complex password policy

User is allowed to select their own password, however the system checks to see if the password is allowable, and if not, rejects it

Goal is to eliminate guessable passwords while allowing the user to select a password that is memorable

Proactive Password Checking

- Rule enforcement
  - Specific rules that passwords must adhere to
- Password checker
  - Compile a large dictionary of passwords not to use
- Bloom filter
  - Used to build a table based on hash values
  - Check desired password against this table

Tokens: Table 3.3

Card Type	Defining Feature	Example
Embossed	Raised characters only, on front	Old credit card
Magnetic stripe	Magnetic bar on back, characters on front	Bank card
Memory	Electronic memory inside	Prepaid phone card
Smart Contact Contactless	Electronic memory and processor inside Electrical contacts exposed on surface Radio antenna embedded inside	Biometric ID card

Types of Cards Used as Tokens

Memory Cards

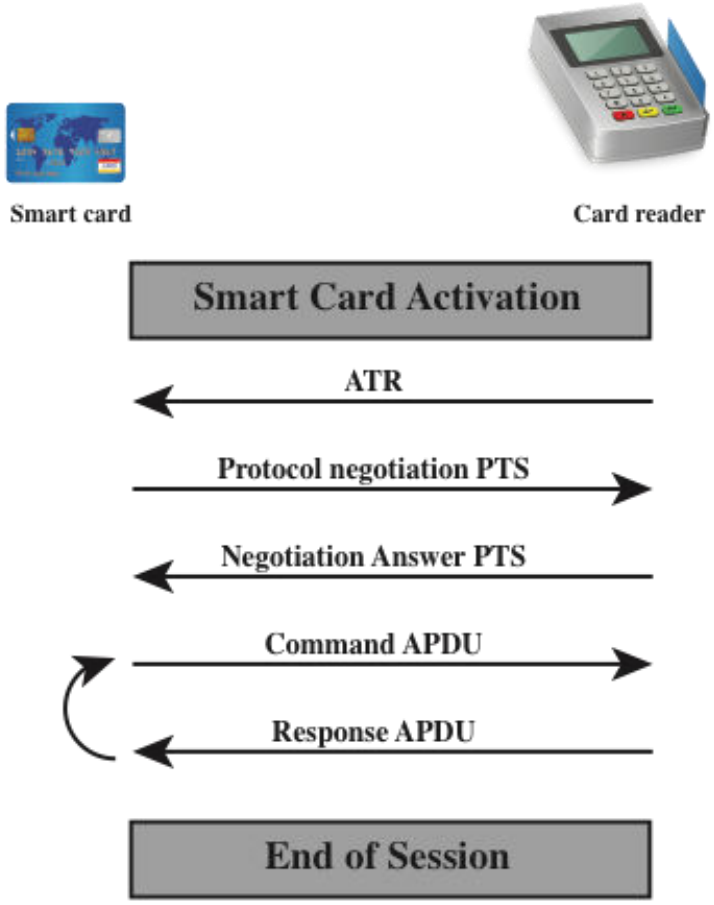
- Can store but do not process data
- The most common is the magnetic stripe card
- Can include an internal electronic memory
- Can be used alone for physical access
  - Hotel room
  - ATM
- Provides significantly greater security when combined with a password or PIN
- Drawbacks of memory cards include:
  - Requires a special reader
  - Loss of token
  - User dissatisfaction

Smart Tokens

- Physical characteristics:
  - Include an embedded microprocessor
  - A smart token that looks like a bank card
  - Can look like calculators, keys, small portable objects
- User interface:
  - Manual interfaces include a keypad and display for human/token interaction
- Electronic interface
  - A smart card or other token requires an electronic interface to communicate with a compatible reader/writer
  - Contact and contactless interfaces
- Authentication protocol:
  - Classified into three categories:
    - Static
    - Dynamic password generator
    - Challenge-response

Smart Cards

- Most important category of smart token
  - Has the appearance of a credit card
  - Has an electronic interface
  - May use any of the smart token protocols
- Contain:
  - An entire microprocessor
    - Processor
    - Memory
    - I/O ports
- Typically include three types of memory:
  - Read-only memory (ROM)
    - Stores data that does not change during the card's life
  - Electrically erasable programmable ROM (EEPROM)
    - Holds application data and programs
  - Random access memory (RAM)
    - Holds temporary data generated when applications are executed



APDU = application protocol data unit
ATR = Answer to reset
PTS = Protocol type selection

Figure 3.6 Smart Card/Reader Exchange

Electronic Identity Cards (eID)

Use of a smart card as a national identity card for citizens

Can serve the same purposes as other national ID cards, and similar cards such as a driver's license, for access to government and commercial services

Can provide stronger proof of identity and can be used in a wider variety of applications

In effect, is a smart card that has been verified by the national government as valid and authentic

Most advanced deployment is the German card *neuer Personalausweis*

Has human-readable data printed on its surface

- Personal data
- Document number
- Card access number (CAN)
- Machine readable zone (MRZ)

Table 3.4

Electronic Functions and Data for eID Cards

Function	Purpose	PACE Password	Data	Uses
ePass (mandatory)	Authorized offline inspection systems read the data	CAN or MRZ	Face image; two fingerprint images (optional), MRZ data	Offline biometric identity verification reserved for government access
eID (activation optional	Online applications read the data or acess functions as authorized	eID PIN	Family and given names; artistic name and doctoral degree: date and place of birth; address and community ID; expiration date	Identification; age verification; community ID verification; restricted identification (pseudonym); revocation query
	Offline inspection systems read the data and update the address and community ID	CAN or MRZ		
eSign (certificate optional	A certification authority installs the signature certificate online	eID PIN	Signature key; X.509 certificate	Electronic signature creation
	Citizens make electronic signature with eSign PIN	CAN		

CAN = card access number
MRZ = machine readable zone
PACE = password authenticated connection establishment
PIN = personal identification number

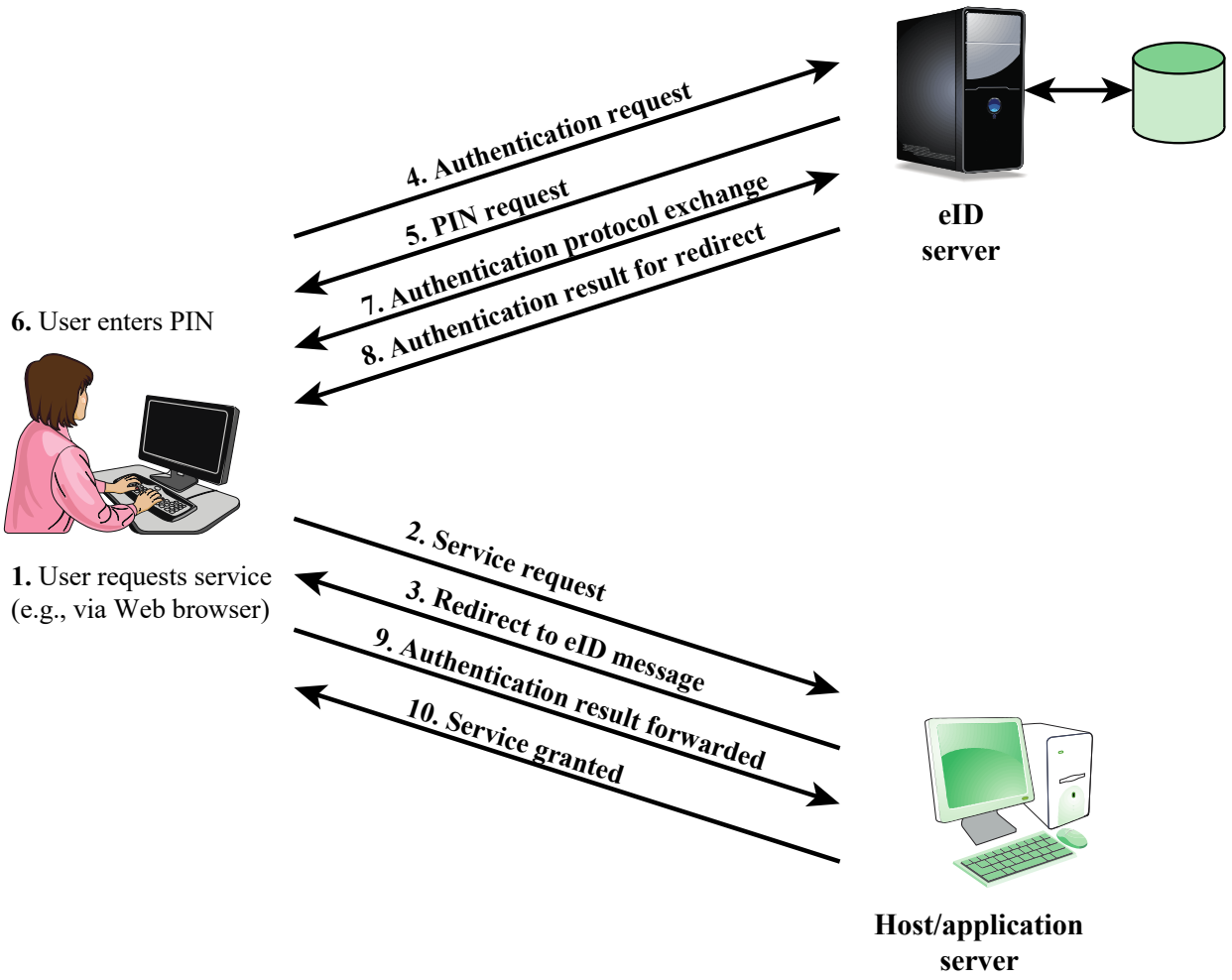


Figure 3.7 User Authentication with eID

Password Authenticated Connection Establishment (PACE)

Ensures that the contactless RF chip in the eID card cannot be read without explicit access control

For online applications, access is established by the user entering the 6-digit PIN (which should only be known to the holder of the card)

For offline applications, either the MRZ printed on the back of the card or the six-digit card access number (CAN) printed on the front is used

Biometric Authentication

- Attempts to authenticate an individual based on unique physical characteristics
- Based on pattern recognition
- Is technically complex and expensive when compared to passwords and tokens
- Physical characteristics used include:
  - Facial characteristics
  - Fingerprints
  - Hand geometry
  - Retinal pattern
  - Iris
  - Signature
  - Voice

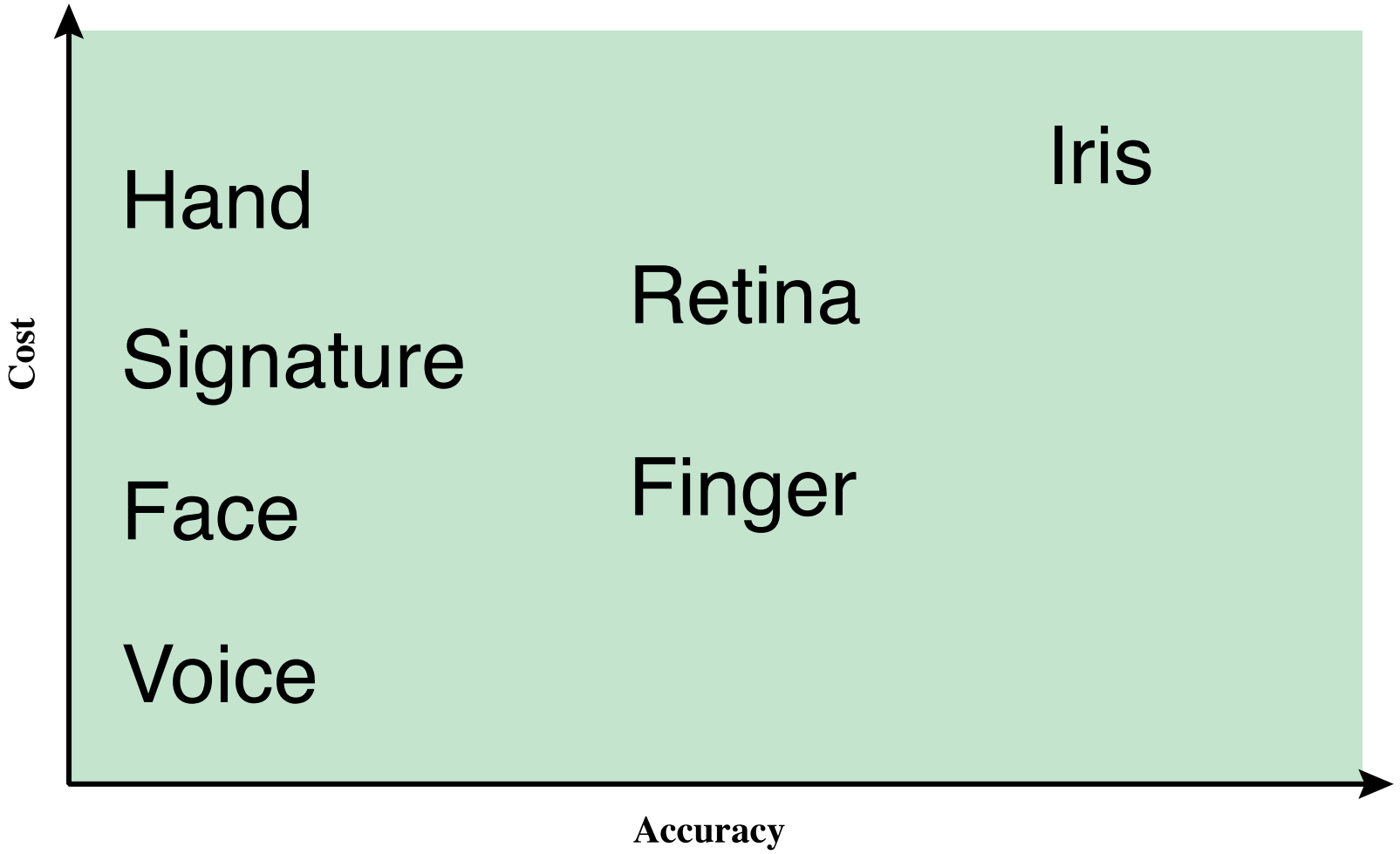


Figure 3.8 Cost Versus Accuracy of Various Biometric Characteristics in User Authentication Schemes.

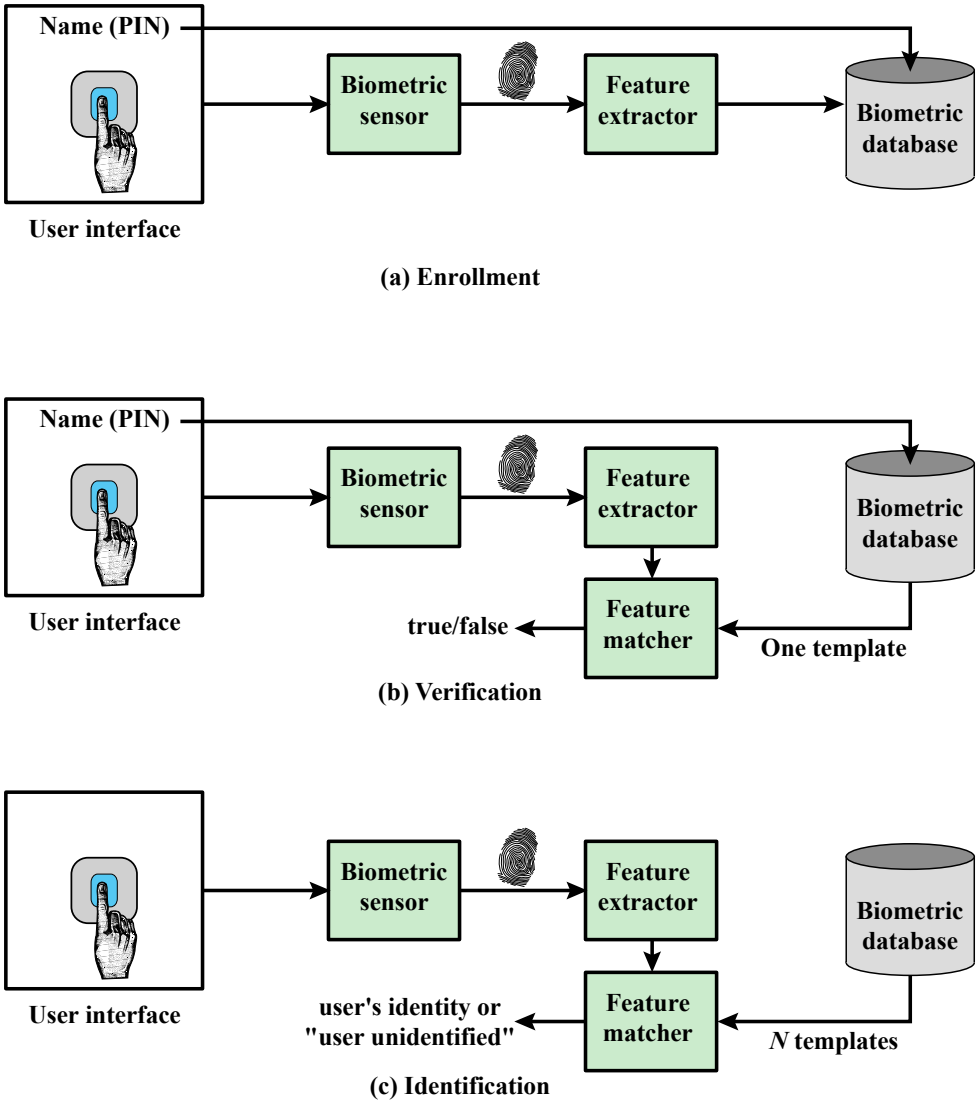


Figure 3.9 A Generic Biometric System. Enrollment creates an association between a user and the user's biometric characteristics. Depending on the application, user authentication either involves verifying that a claimed user is the actual user or identifying an unknown user.

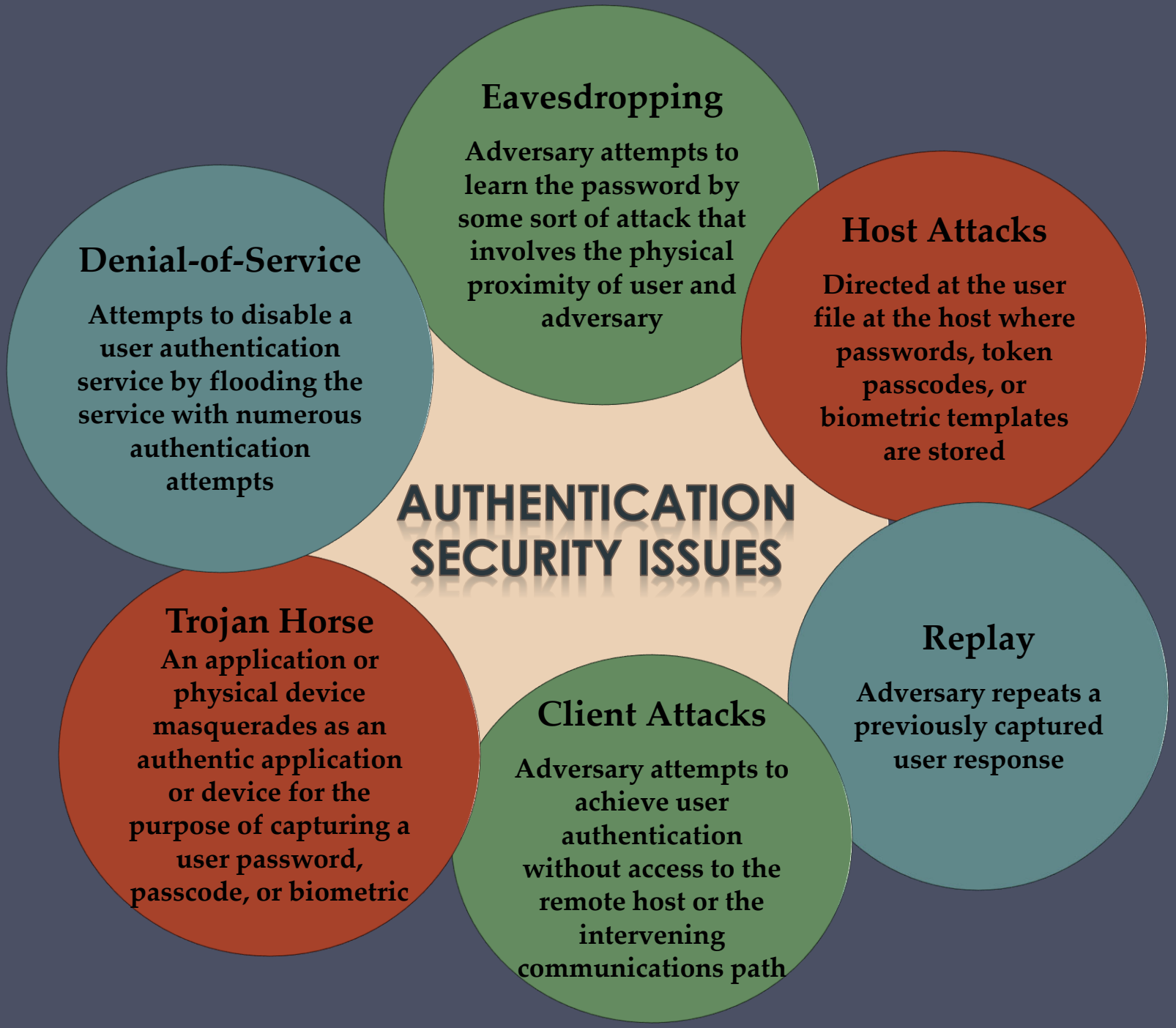
Remote User Authentication

- Authentication over a network, the Internet, or a communications link is more complex
- Additional security threats such as:
  - Eavesdropping, capturing a password, replaying an authentication sequence that has been observed
- Generally rely on some form of a challenge-response protocol to counter threats

Attacks	Authenticators	Examples	Typical defenses
Client attack	Password	Guessing, exhaustive search	Large entropy; limited attempts
	Token	Exhaustive search	Large entropy; limited attempts, theft of object requires presence
	Biometric	False match	Large entropy; limited attempts
Host attack	Password	Plaintext theft, dictionary/exhaustive search	Hashing; large entropy; protection of password database
	Token	Passcode theft	Same as password; 1-time passcode
	Biometric	Template theft	Capture device authentication; challenge response
Eavesdropping, theft, and copying	Password	"Shoulder surfing"	User diligence to keep secret; administrator diligence to quickly revoke compromised passwords; multifactor authentication
	Token	Theft, counterfeiting hardware	Multifactor authentication; tamper resistant/evident token
	Biometric	Copying (spoofing) biometric	Copy detection at capture device and capture device authentication
Replay	Password	Replay stolen password response	Challenge-response protocol
	Token	Replay stolen passcode response	Challenge-response protocol; 1-time passcode
	Biometric	Replay stolen biometric template response	Copy detection at capture device and capture device authentication via challenge-response protocol
Trojan horse	Password, token, biometric	Installation of rogue client or capture device	Authentication of client or capture device within trusted security perimeter
Denial of service	Password, token, biometric	Lockout by multiple failed authentications	Multifactor with token

Table 3.5

Some Potential Attacks, Susceptible Authenticators, and Typical Defenses


AUTHENTICATION SECURITY ISSUES
Eavesdropping
Adversary attempts to learn the password by some sort of attack that involves the physical proximity of user and adversary
Host Attacks
Directed at the user file at the host where passwords, token passcodes, or biometric templates are stored
Denial-of-Service
Attempts to disable a user authentication service by flooding the service with numerous authentication attempts
Replay
Adversary repeats a previously captured user response
Trojan Horse
An application or physical device masquerades as an authentic application or device for the purpose of capturing a user password, passcode, or biometric
Client Attacks
Adversary attempts to achieve user authentication without access to the remote host or the intervening communications path

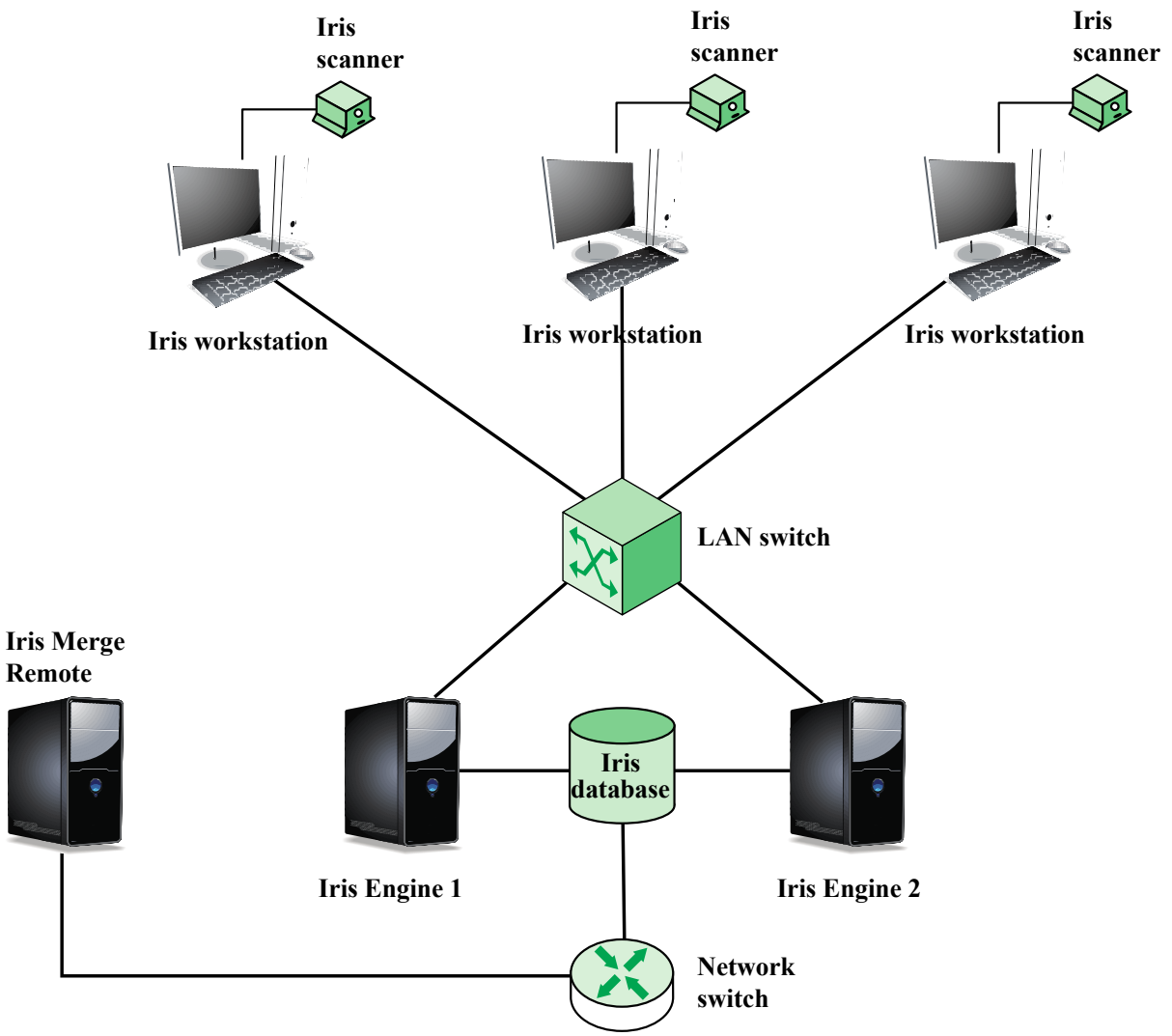
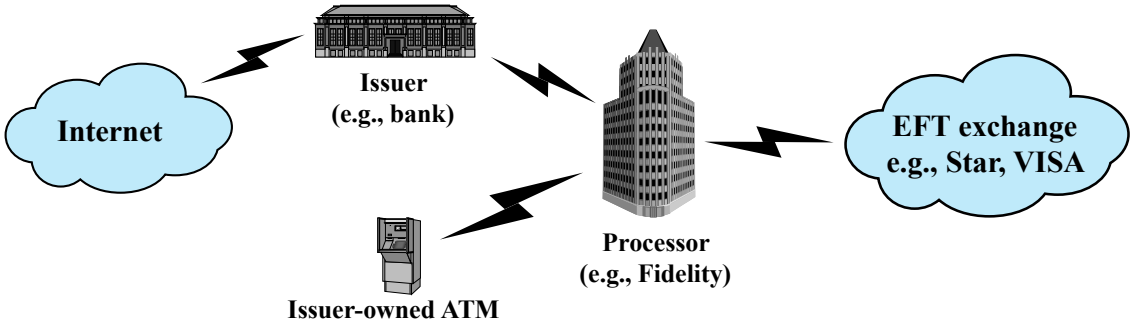
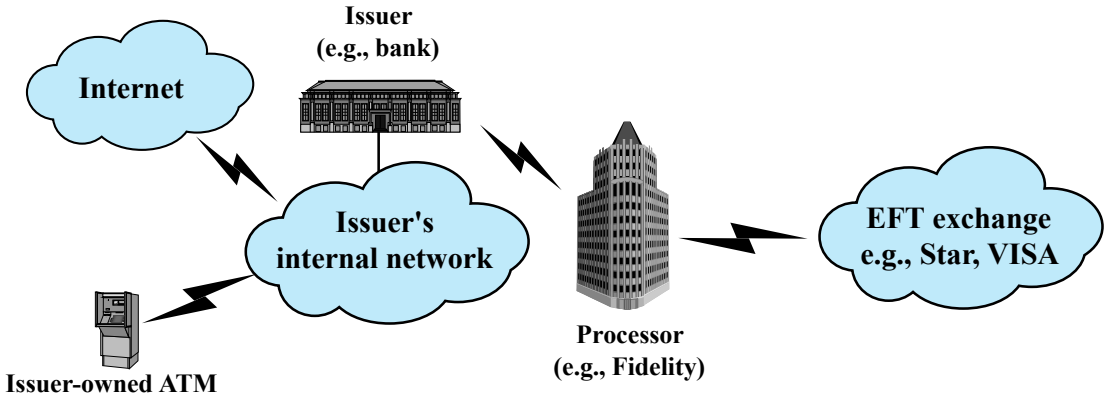


Figure 3.14 General Iris Scan Site Architecture for UAE System



(a) Point-to-point connection to processor



(b) Shared connection to processor

Figure 3.15 ATM Architectures. Most small to mid-sized issuers of debit cards contract processors to provide core data processing and electronic funds transfer (EFT) services. The bank's ATM machine may link directly to the processor or to the bank.

Case Study: ATM Security Problems

Thank You!

Q & A Session

Firewalls and Intrusion Prevention Systems

Courtesy of William Stallings and Lawrie Brown
Computer Security: Principles and Practice,4th Edition

The Need For Firewalls

- Internet connectivity is essential
  - However it creates a threat
- Effective means of protecting LANs
- Inserted between the premises network and the Internet to establish a controlled link
  - Can be a single computer system or a set of two or more systems working together
- Used as a perimeter defense
  - Single choke point to impose security and auditing
  - Insulates the internal systems from external networks

Firewall Characteristics

Design goals

All traffic from inside to outside, and vice versa, must pass through the firewall

Only authorized traffic as defined by the local security policy will be allowed to pass

The firewall itself is immune to penetration

Firewall Access Policy

- A critical component in the planning and implementation of a firewall is specifying a suitable access policy
  - This lists the types of traffic authorized to pass through the firewall
  - Includes address ranges, protocols, applications and content types
- This policy should be developed from the organization's information security risk assessment and policy
- Should be developed from a broad specification of which traffic types the organization needs to support
  - Then refined to detail the filter elements which can then be implemented within an appropriate firewall topology

Firewall Filter Characteristics

- Characteristics that a firewall access policy could use to filter traffic include:

IP address and protocol values

This type of filtering is used by packet filter and stateful inspection firewalls

Typically used to limit access to specific services

Application protocol

This type of filtering is used by an application-level gateway that relays and monitors the exchange of information for specific application protocols

User identity

Typically for inside users who identify themselves using some form of secure authentication technology

Network activity

Controls access based on considerations such as the time or request, rate of requests, or other activity patterns

Firewall Capabilities And Limits

Capabilities:

- Defines a single choke point
- Provides a location for monitoring security events
- Convenient platform for several Internet functions that are not security related
- Can serve as the platform for IPSec

Limitations:

- Cannot protect against attacks bypassing firewall
- May not protect fully against internal threats
- Improperly secured wireless LAN can be accessed from outside the organization
- Laptop, PDA, or portable storage device may be infected outside the corporate network then used internally

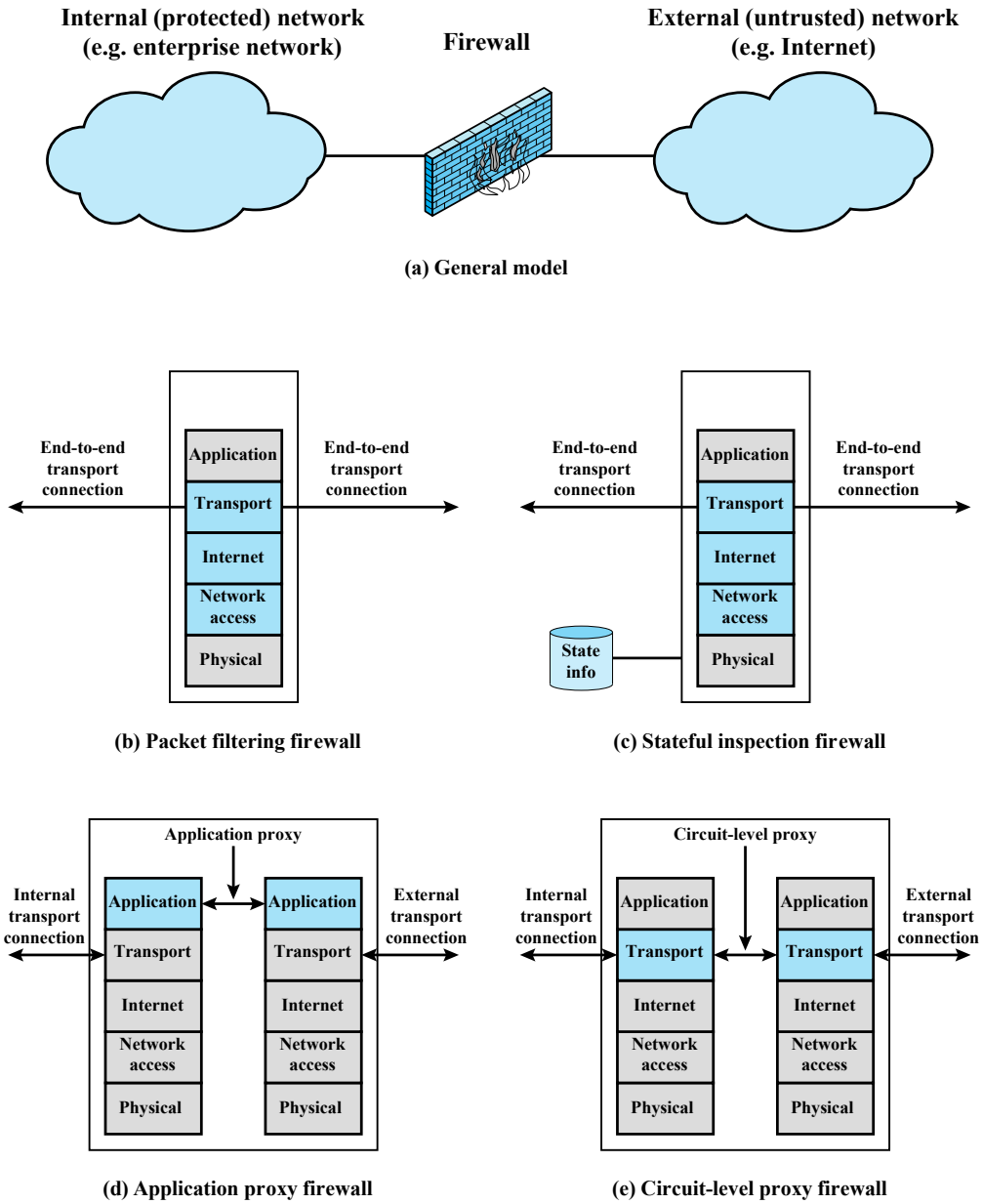


Figure 9.1 Types of Firewalls

Packet Filtering Firewall

- Applies rules to each incoming and outgoing IP packet
  - Typically a list of rules based on matches in the IP or TCP header
  - Forwards or discards the packet based on rules match

Filtering rules are based on information contained in a network packet
• Source IP address • Destination IP address • Source and destination transport-level address • IP protocol field • Interface

- Two default policies:
  - Discard - prohibit unless expressly permitted
    - More conservative, controlled, visible to users
  - Forward - permit unless expressly prohibited
    - Easier to manage and use but less secure

Table 9.1
Packet-Filtering Examples

Rule	Direction	Src address	Dest addresss	Protocol	Dest port	Action
1	In	External	Internal	TCP	25	Permit
2	Out	Internal	External	TCP	>1023	Permit
3	Out	Internal	External	TCP	25	Permit
4	In	External	Internal	TCP	>1023	Permit
5	Either	Any	Any	Any	Any	Deny

Packet Filter Advantages And Weaknesses

- Advantages
  - Simplicity
  - Typically transparent to users and are very fast
- Weaknesses
  - Cannot prevent attacks that employ application specific vulnerabilities or functions
  - Limited logging functionality
  - Do not support advanced user authentication
  - Vulnerable to attacks on TCP/IP protocol bugs
  - Improper configuration can lead to breaches

Stateful Inspection Firewall

Tightens rules for TCP traffic by creating a directory of outbound TCP connections

- There is an entry for each currently established connection
- Packet filter allows incoming traffic to high numbered ports only for those packets that fit the profile of one of the entries in this directory

Reviews packet information but also records information about TCP connections

- Keeps track of TCP sequence numbers to prevent attacks that depend on the sequence number
- Inspects data for protocols like FTP, IM and SIPS commands

Table 9.2
Example Stateful Firewall Connection State Table

Source Address	Source Port	Destination Address	Destination Port	Connection State
192.168.1.100	1030	210.9.88.29	80	Established
192.168.1.102	1031	216.32.42.123	80	Established
192.168.1.101	1033	173.66.32.122	25	Established
192.168.1.106	1035	177.231.32.12	79	Established
223.43.21.231	1990	192.168.1.6	80	Established
219.22.123.32	2112	192.168.1.6	80	Established
210.99.212.18	3321	192.168.1.6	80	Established
24.102.32.23	1025	192.168.1.6	80	Established
223.21.22.12	1046	192.168.1.6	80	Established

Application-Level Gateway

- Also called an application proxy
- Acts as a relay of application-level traffic
  - User contacts gateway using a TCP/IP application
  - User is authenticated
  - Gateway contacts application on remote host and relays TCP segments between server and user
- Must have proxy code for each application
  - May restrict application features supported
- Tend to be more secure than packet filters
- Disadvantage is the additional processing overhead on each connection

Circuit-Level Gateway

Circuit level proxy

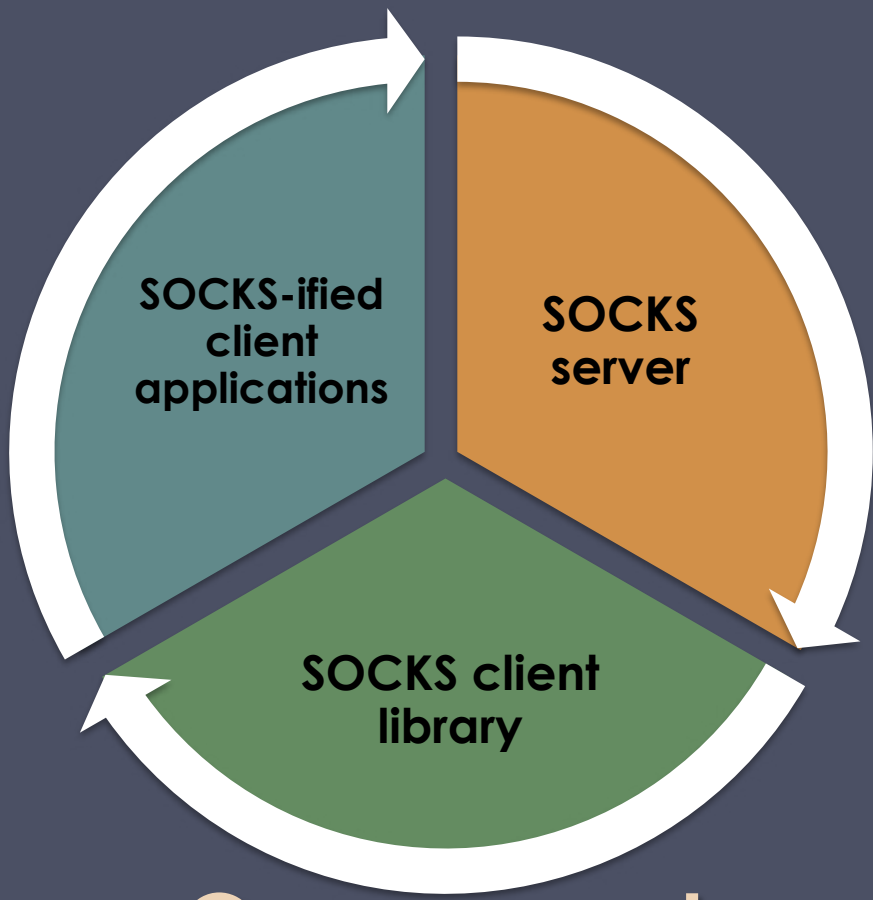
- Sets up two TCP connections, one between itself and a TCP user on an inner host and one on an outside host
- Relays TCP segments from one connection to the other without examining contents
- Security function consists of determining which connections will be allowed

Typically used when inside users are trusted

- May use application-level gateway inbound and circuit-level gateway outbound
- Lower overheads

SOCKS Circuit-Level Gateway

- SOCKS v5 defined in RFC1928
- Designed to provide a framework for client-server applications in TCP/UDP domains to conveniently and securely use the services of a network firewall
- Client application contacts SOCKS server, authenticates, sends relay request
  - Server evaluates and either establishes or denies the connection



Components

Bastion Hosts

- System identified as a critical strong point in the network's security
- Serves as a platform for an application-level or circuit-level gateway
- Common characteristics:
  - Runs secure O/S, only essential services
  - May require user authentication to access proxy or host
  - Each proxy can restrict features, hosts accessed
  - Each proxy is small, simple, checked for security
  - Each proxy is independent, non-privileged
  - Limited disk use, hence read-only code

Host-Based Firewalls

- Used to secure an individual host
- Available in operating systems or can be provided as an add-on package
- Filter and restrict packet flows
- Common location is a server

Advantages:

- Filtering rules can be tailored to the host environment
- Protection is provided independent of topology
- Provides an additional layer of protection

Personal Firewall

- Controls traffic between a personal computer or workstation and the Internet or enterprise network
- For both home or corporate use
- Typically is a software module on a personal computer
- Can be housed in a router that connects all of the home computers to a DSL, cable modem, or other Internet interface
- Typically much less complex than server-based or stand-alone firewalls
- Primary role is to deny unauthorized remote access
- May also monitor outgoing traffic to detect and block worms and malware activity

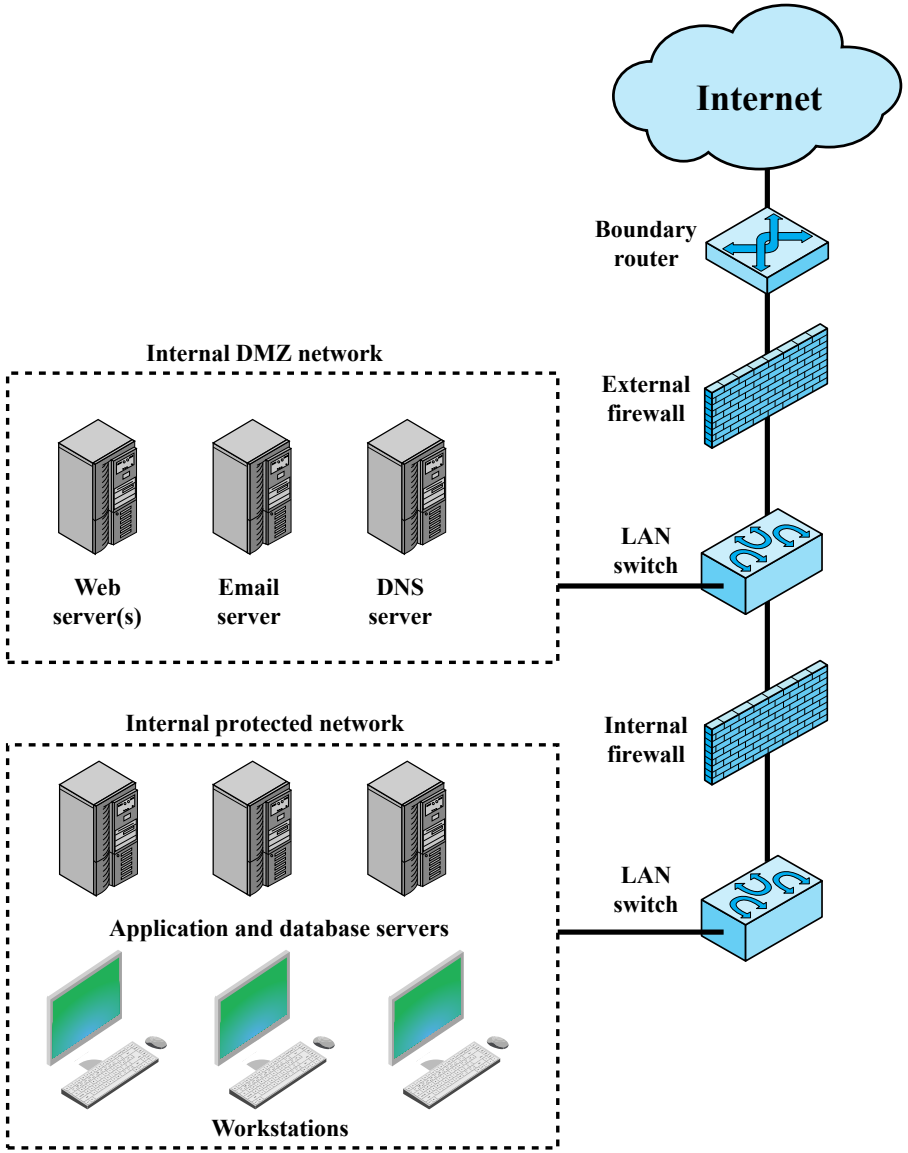


Figure 9.2 Example Firewall Configuration

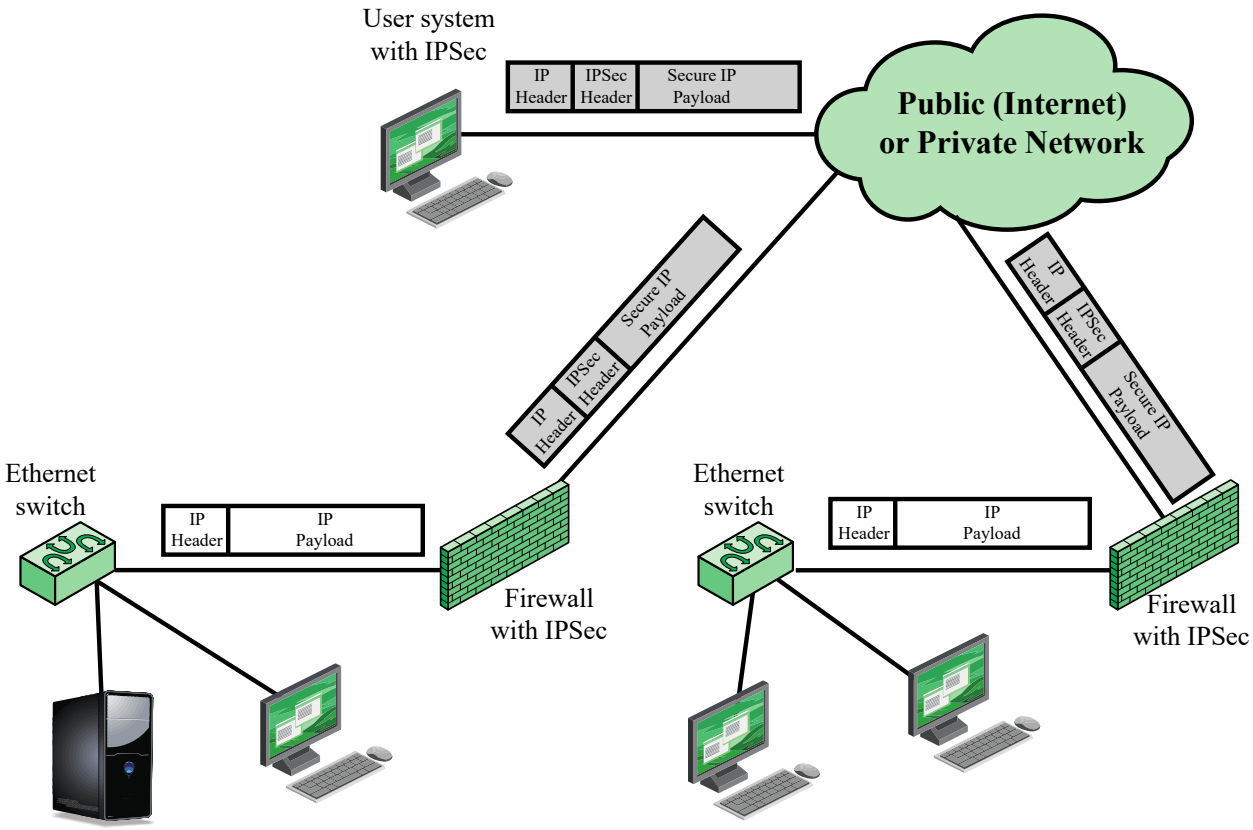


Figure 9.3 A VPN Security Scenario

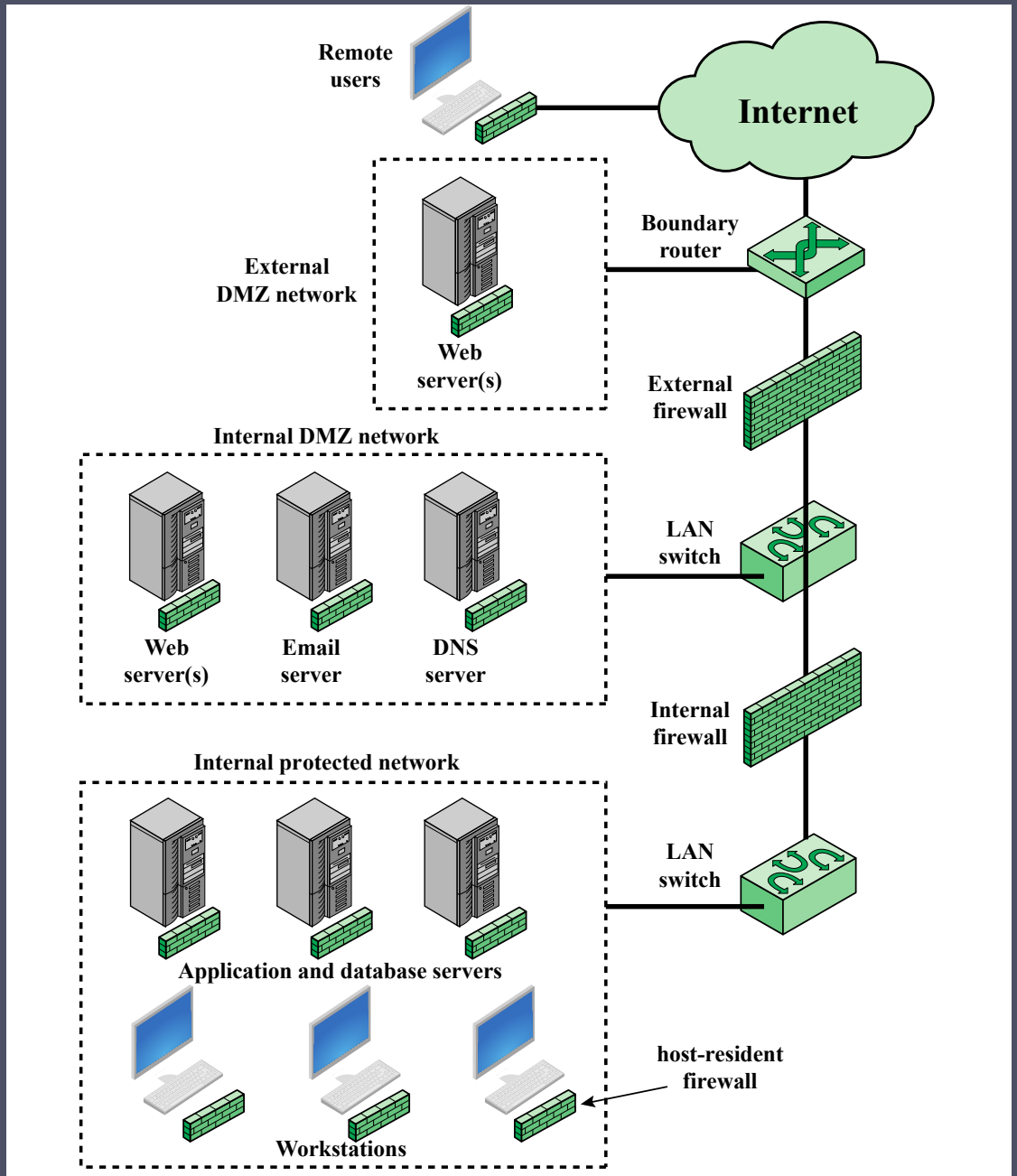


Figure 9.4 Example Distributed Firewall Configuration

Firewall Topologies

Host-resident firewall	• Includes personal firewall software and firewall software on servers
Screening router	• Single router between internal and external networks with stateless or full packet filtering
Single bastion inline	• Single firewall device between an internal and external router
Single bastion T	• Has a third network interface on bastion to a DMZ where externally visible servers are placed
Double bastion inline	• DMZ is sandwiched between bastion firewalls
Double bastion T	• DMZ is on a separate network interface on the bastion firewall
Distributed firewall configuration	• Used by large businesses and government organizations

Intrusion Prevention Systems (IPS)

- Also known as Intrusion Detection and Prevention System (IDPS)
- Is an extension of an IDS that includes the capability to attempt to block or prevent detected malicious activity
- Can be host-based, network-based, or distributed/hybrid
- Can use anomaly detection to identify behavior that is not that of legitimate users, or signature/heuristic detection to identify known malicious behavior can block traffic as a firewall does, but makes use of the types of algorithms developed for IDSs to determine when to do so

Host-Based IPS (HIPS)

- Can make use of either signature/heuristic or anomaly detection techniques to identify attacks
  - Signature: focus is on the specific content of application network traffic, or of sequences of system calls, looking for patterns that have been identified as malicious
  - Anomaly: IPS is looking for behavior patterns that indicate malware
- Examples of the types of malicious behavior addressed by a HIPS include:
  - Modification of system resources
  - Privilege-escalation exploits
  - Buffer-overflow exploits
  - Access to e-mail contact list
  - Directory traversal

HIPS

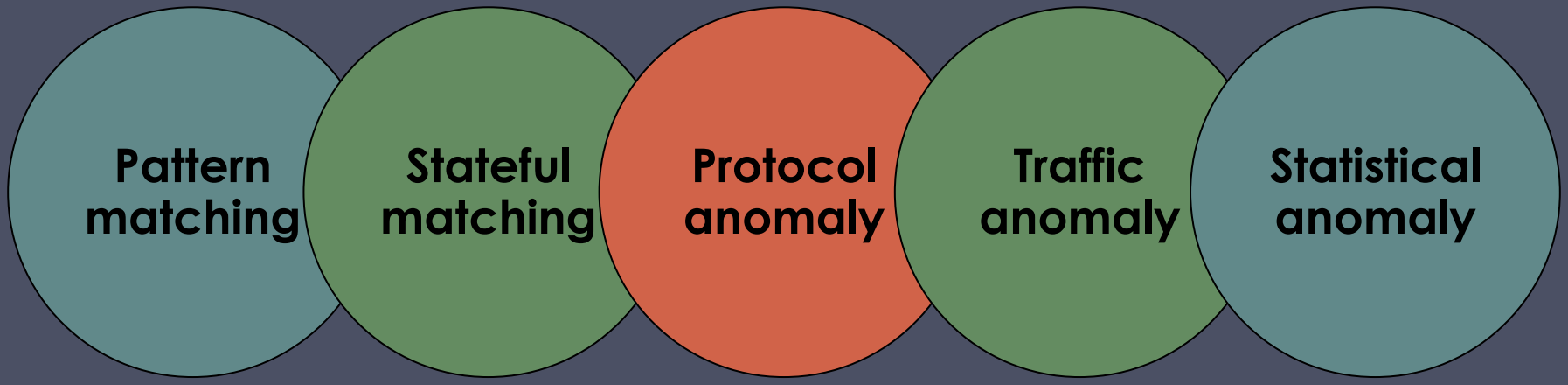
- Capability can be tailored to the specific platform
- A set of general purpose tools may be used for a desktop or server system
- Some packages are designed to protect specific types of servers, such as Web servers and database servers
  - In this case the HIPS looks for particular application attacks
- Can use a sandbox approach
  - Sandboxes are especially suited to mobile code such as Java applets and scripting languages
  - HIPS quarantines such code in an isolated system area then runs the code and monitors its behavior
- Areas for which a HIPS typically offers desktop protection:
  - System calls
  - File system access
  - System registry settings
  - Host input/output

The Role of HIPS

- Many industry observers see the enterprise endpoint, including desktop and laptop systems, as now the main target for hackers and criminals
  - Thus security vendors are focusing more on developing endpoint security products
  - Traditionally, endpoint security has been provided by a collection of distinct products, such as antivirus, antispyware, antispam, and personal firewalls
- Approach is an effort to provide an integrated, single-product suite of functions
  - Advantages of the integrated HIPS approach are that the various tools work closely together, threat prevention is more comprehensive, and management is easier
- A prudent approach is to use HIPS as one element in a defense-in-depth strategy that involves network-level devices, such as either firewalls or network-based IPSs

Network-Based IPS (NIPS)

- Inline NIDS with the authority to modify or discard packets and tear down TCP connections
- Makes use of signature/heuristic detection and anomaly detection
- May provide flow data protection
  - Requires that the application payload in a sequence of packets be reassembled
- Methods used to identify malicious packets:



Digital Immune System

- Comprehensive defense against malicious behavior caused by malware
- Developed by IBM and refined by Symantec
- Motivation for this development includes the rising threat of Internet-based malware, the increasing speed of its propagation provided by the Internet, and the need to acquire a global view of the situation
- Success depends on the ability of the malware analysis system to detect new and innovative malware strains

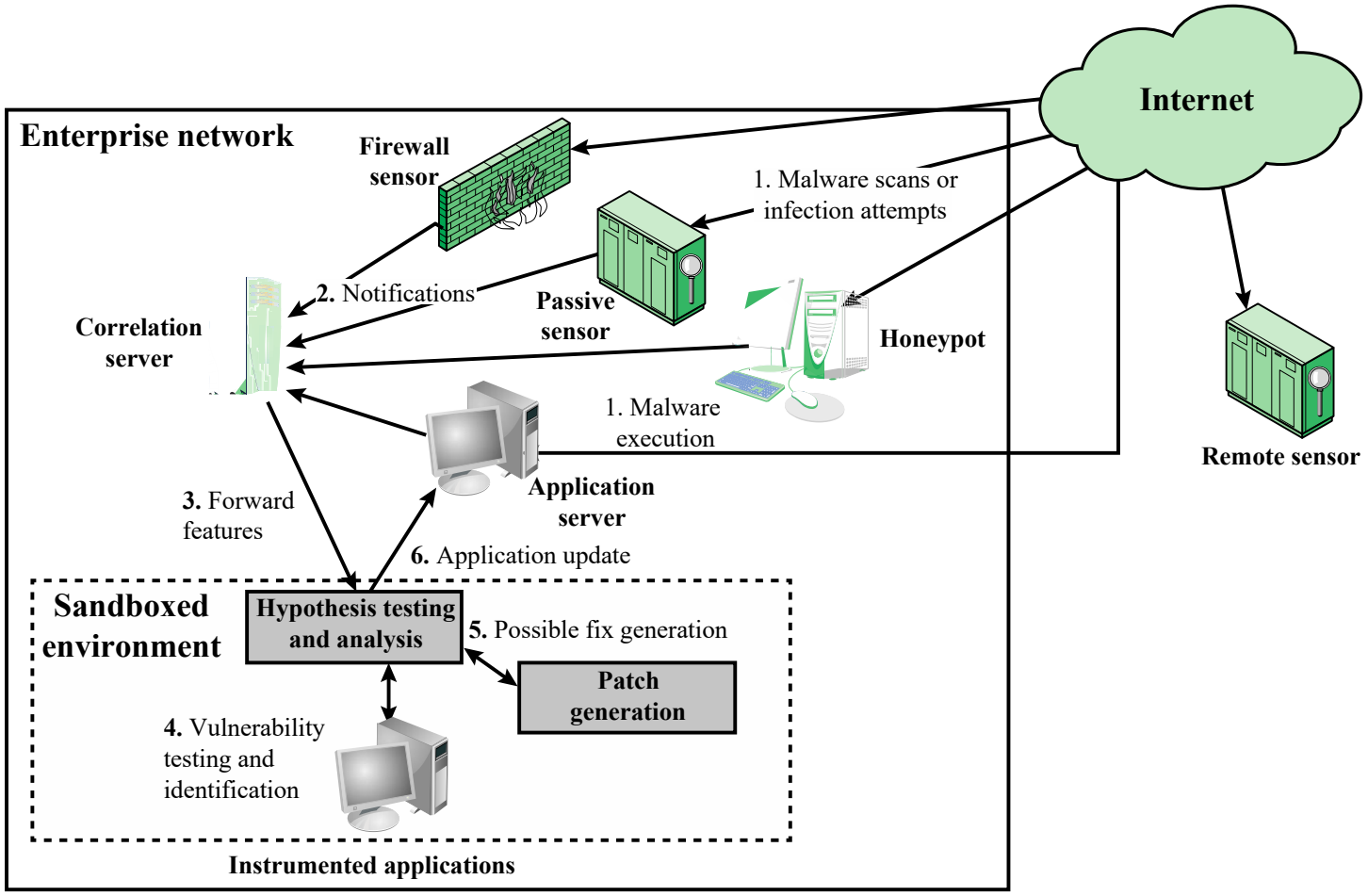
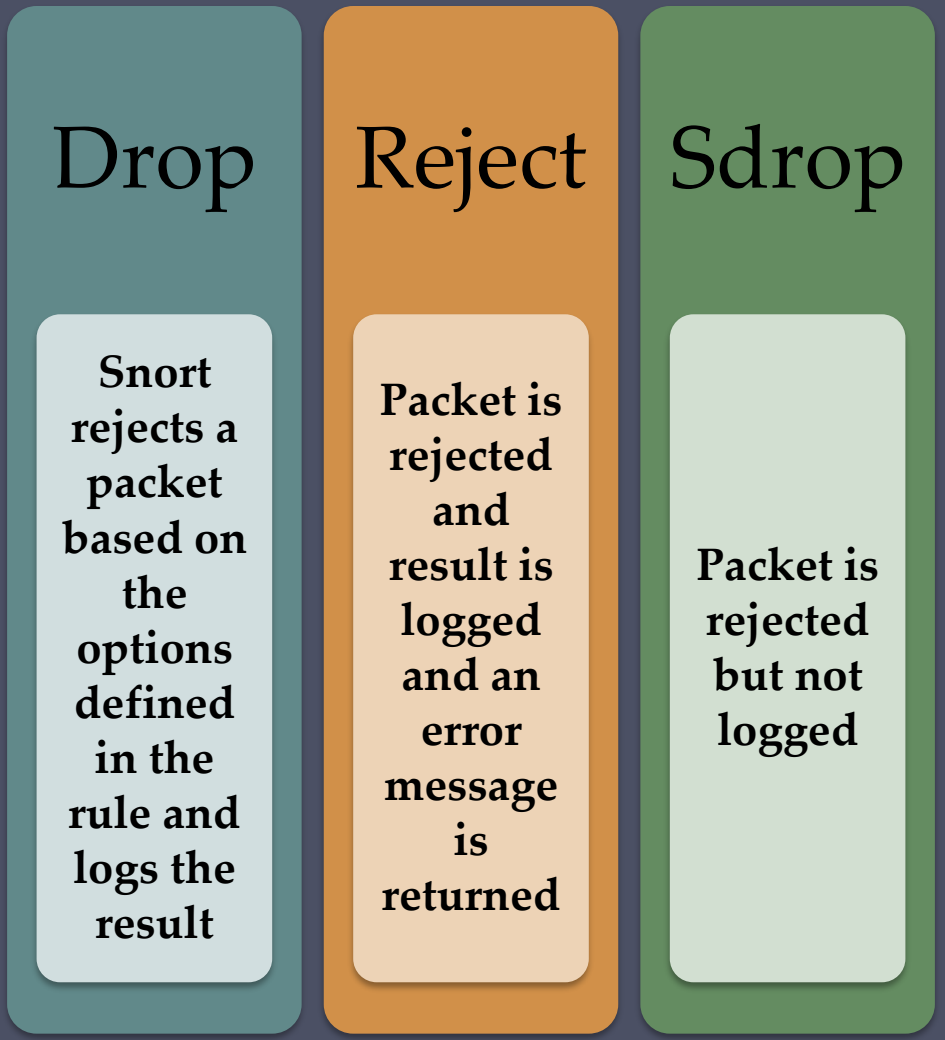


Figure 9.5 Placement of Malware Monitors (adapted from [SIDI05])

Snort Inline

- Enables Snort to function as an intrusion prevention system
- Includes a replace option which allows the Snort user to modify packets rather than drop them
  - Useful for a honeypot implementation
  - Attackers see the failure but cannot figure out why it occurred



Thank You!

Q & A Session

Software Security

Courtesy of William Stallings and Lawrie Brown
Computer Security: Principles and Practice,4th Edition

What is Software Security?

- The degree to which software protects information and system resources, providing access only to authorized users as intended.
- It encompasses practices:
  - Threat modeling
  - Secure coding
  - Security testing
  - Vulnerability management applied throughout the software development life cycle.

What is Software Security? …

- Goal:
  - To prevent, detect, and recover from attacks and unintended weaknesses that could compromise confidentiality, integrity, and availability of software systems and data.
- Software security seeks to build in protections proactively rather than reacting to threats.
- It involves vigilance across requirements, design, coding, testing, deployment, and maintenance.

Security Flaws

- Critical Web application security flaws include five related to insecure software code
  - Unvalidated input
  - Cross-site scripting
  - Buffer overflow
  - Injection flaws
  - Improper error handling
- These flaws occur as a consequence of insufficient checking and validation of data and error codes in programs
- Awareness of these issues is a critical initial step in writing more secure program code
- Emphasis should be placed on the need for software developers to address these known areas of concern

Reducing Software Vulnerabilities

- The NIST report NISTIR 8151 presents a range of approaches to reduce the number of software vulnerabilities
- It recommends:
  - Stopping vulnerabilities before they occur by using improved methods for specifying and building software
  - Finding vulnerabilities before they can be exploited by using better and more efficient testing techniques
  - Reducing the impact of vulnerabilities by building more resilient architectures

Software Security, Quality and Reliability

- Software quality and reliability:
  - Concerned with the accidental failure of program as a result of some theoretically random, unanticipated input, system interaction, or use of incorrect code
  - Improve using structured design and testing to identify and eliminate as many bugs as possible from a program
  - Concern is not how many bugs, but how often they are triggered

- Software security:
  - Attacker chooses probability distribution, specifically targeting bugs that result in a failure that can be exploited by the attacker
  - Triggered by inputs that differ dramatically from what is usually expected
  - Unlikely to be identified by common testing approaches

Defensive Programming

- Designing and implementing software so that it continues to function even when under attack
- Requires attention to all aspects of program execution, environment, and type of data it processes
- Software is able to detect erroneous conditions resulting from some attack
- Also referred to as secure programming
- Key rule is to never assume anything, check all assumptions and handle any possible error states

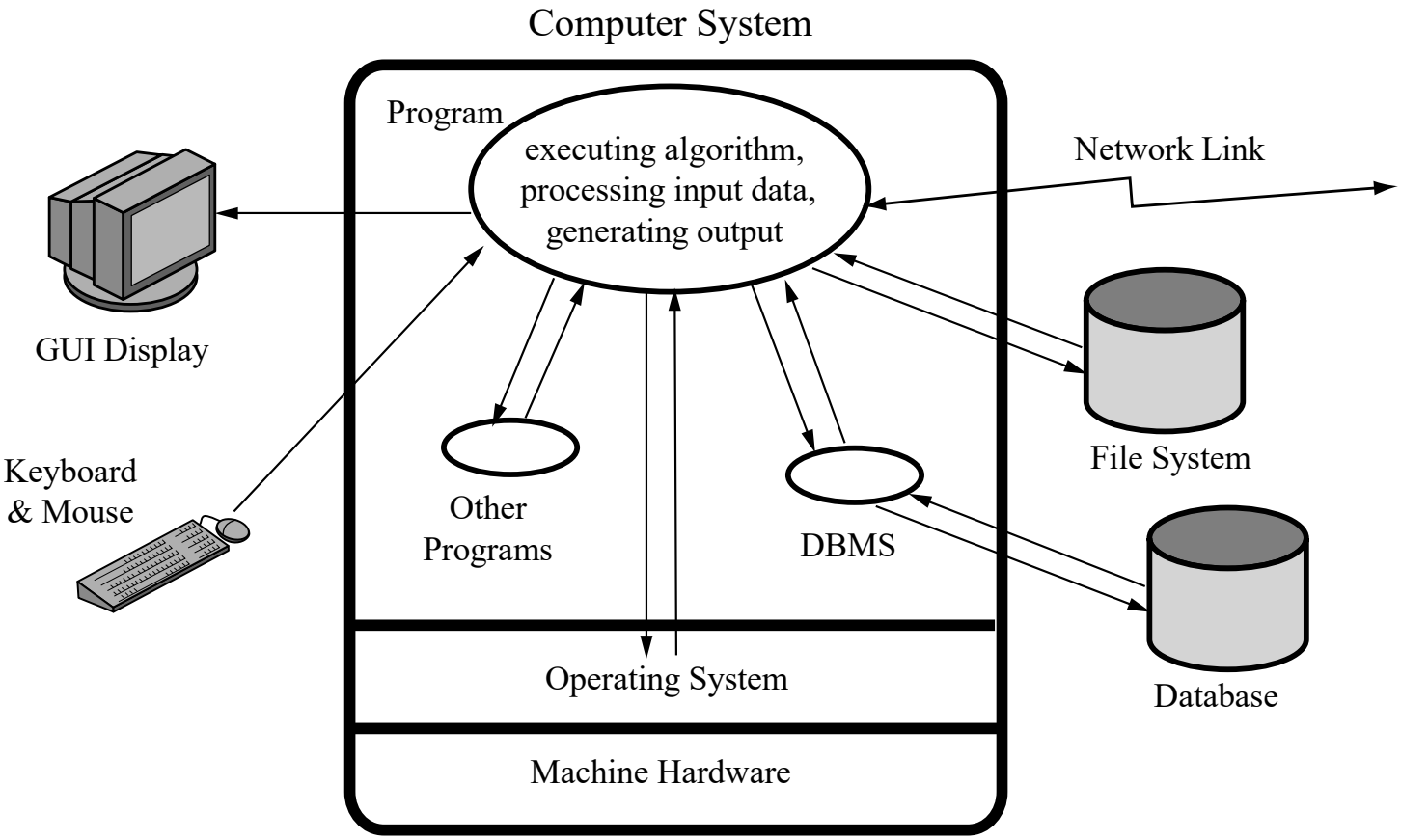


Figure 11.1 Abstract View of Program

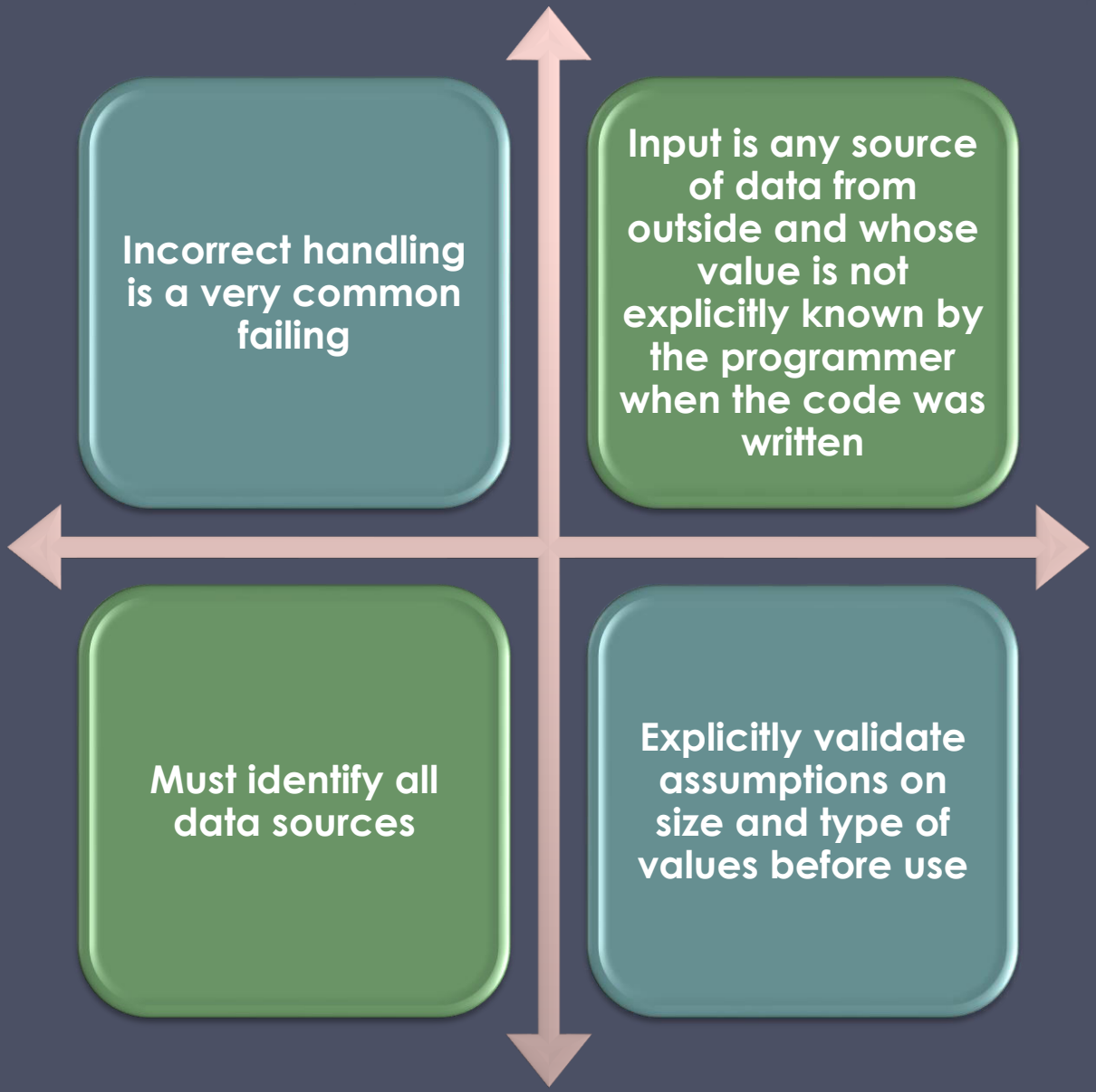
Defensive Programming

- Programmers often make assumptions about the type of inputs a program will receive and the environment it executes in
  - Assumptions need to be validated by the program and all potential failures handled gracefully and safely
- Requires a changed mindset to traditional programming practices
  - Programmers have to understand how failures can occur and the steps needed to reduce the chance of them occurring in their programs
- Conflicts with business pressures to keep development times as short as possible to maximize market advantage

Security by Design

- Security and reliability are common design goals in most engineering disciplines
- Software development not as mature
- Recent years have seen increasing efforts to improve secure software development processes
- Software Assurance Forum for Excellence in Code (SAFECode)
  - Develop publications outlining industry best practices for software assurance and providing practical advice for implementing proven methods for secure software development

Handling Program Input



Input Size & Buffer Overflow

- Programmers often make assumptions about the maximum expected size of input
  - Allocated buffer size is not confirmed
  - Resulting in buffer overflow
- Testing may not identify vulnerability
  - Test inputs are unlikely to include large enough inputs to trigger the overflow
- Safe coding treats all input as dangerous

Interpretation of Program Input

- Program input may be binary or text
  - Binary interpretation depends on encoding and is usually application specific
- There is an increasing variety of character sets being used
  - Care is needed to identify just which set is being used and what characters are being read
- Failure to validate may result in an exploitable vulnerability
- 2014 Heartbleed OpenSSL bug is a recent example of a failure to check the validity of a binary input value

Injection Attacks

- Flaws relating to invalid handling of input data, specifically when program input data can accidentally or deliberately influence the flow of execution of the program

Most often occur in scripting languages

- Encourage reuse of other programs and system utilities where possible to save coding effort
- Often used as Web CGI scripts

Cross Site Scripting (XSS) Attacks

Attacks where input provided by one user is subsequently output to another user

Commonly seen in scripted Web applications

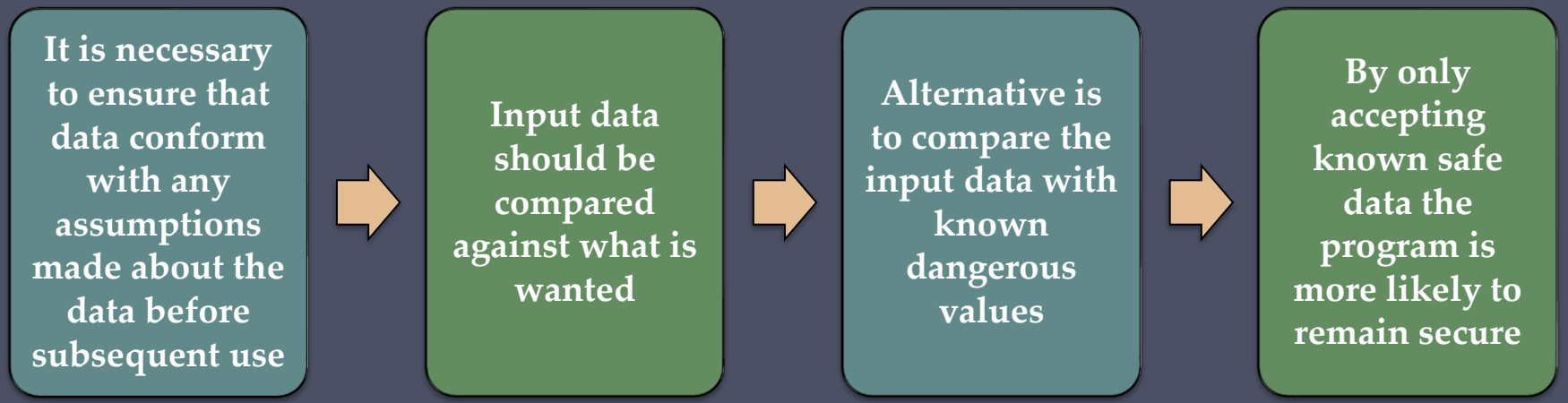
- Vulnerability involves the inclusion of script code in the HTML content
- Script code may need to access data associated with other pages
- Browsers impose security checks and restrict data access to pages originating from the same site

Exploit assumption that all content from one site is equally trusted and hence is permitted to interact with other content from the site

XSS reflection vulnerability

- Attacker includes the malicious script content in data supplied to a site

Validating Input Syntax



Alternate Encodings

May have multiple means of encoding text

Growing requirement to support users around the globe and to interact with them using their own languages

Unicode used for internationalization

- Uses 16-bit value for characters
- UTF-8 encodes as 1-4 byte sequences
- Many Unicode decoders accept any valid equivalent sequence

Canonicalization

- Transforming input data into a single, standard, minimal representation
- Once this is done the input data can be compared with a single representation of acceptable input values

Validating Numeric Input

- Additional concern when input data represents numeric values
- Internally stored in fixed sized value
  - 8, 16, 32, 64-bit integers
  - Floating point numbers depend on the processor used
  - Values may be signed or unsigned
- Must correctly interpret text form and process consistently
  - Have issues comparing signed to unsigned
  - Could be used to thwart buffer overflow check

Input Fuzzing

Developed by Professor Barton Miller at the University of Wisconsin Madison in 1989

Software testing technique that uses randomly generated data as inputs to a program

- Range of inputs is very large
- Intent is to determine if the program or function correctly handles abnormal inputs
- Simple, free of assumptions, cheap
- Assists with reliability as well as security

Can also use templates to generate classes of known problem inputs

- Disadvantage is that bugs triggered by other forms of input would be missed
- Combination of approaches is needed for reasonably comprehensive coverage of the inputs

Writing Safe Program Code

- Second component is processing of data by some algorithm to solve required problem
- High-level languages are typically compiled and linked into machine code which is then directly executed by the target processor

Security issues:

- Correct algorithm implementation
- Correct machine instructions for algorithm
- Valid manipulation of data

Correct Algorithm Implementation

Issue of good program development technique

- Algorithm may not correctly handle all problem variants
- Consequence of deficiency is a bug in the resulting program that could be exploited

Initial sequence numbers used by many TCP/IP implementations are too predictable

- Combination of the sequence number as an identifier and authenticator of packets and the failure to make them sufficiently unpredictable enables the attack to occur

Another variant is when the programmers deliberately include additional code in a program to help test and debug it

- Often code remains in production release of a program and could inappropriately release information
- May permit a user to bypass security checks and perform actions they would not otherwise be allowed to perform
- This vulnerability was exploited by the Morris Internet Worm

Ensuring Machine Language Corresponds to Algorithm

- Issue is ignored by most programmers
  - Assumption is that the compiler or interpreter generates or executes code that validly implements the language statements
- Requires comparing machine code with original source
  - Slow and difficult
- Development of computer systems with very high assurance level is the one area where this level of checking is required
  - Specifically Common Criteria assurance level of EAL 7

Correct Data Interpretation

- Data stored as bits/bytes in computer
  - Grouped as words or longwords
  - Accessed and manipulated in memory or copied into processor registers before being used
  - Interpretation depends on machine instruction executed
- Different languages provide different capabilities for restricting and validating interpretation of data in variables
  - Strongly typed languages are more limited, safer
  - Other languages allow more liberal interpretation of data and permit program code to explicitly change their interpretation

Correct Use of Memory

- Issue of dynamic memory allocation
  - Unknown amounts of data
  - Allocated when needed, released when done
  - Used to manipulate Memory leak
  - Steady reduction in memory available on the heap to the point where it is completely exhausted
- Many older languages have no explicit support for dynamic memory allocation
  - Use standard library routines to allocate and release memory
- Modern languages handle automatically

Race Conditions

- Without synchronization of accesses it is possible that values may be corrupted or changes lost due to overlapping access, use, and replacement of shared values
- Arise when writing concurrent code whose solution requires the correct selection and use of appropriate synchronization primitives
- Deadlock
  - Processes or threads wait on a resource held by the other
  - One or more programs has to be terminated

Operating System Interaction

Programs execute on systems under the control of an operating system

- Mediates and shares access to resources
- Constructs execution environment
- Includes environment variables and arguments

Systems have a concept of multiple users

- Resources are owned by a user and have permissions granting access with various rights to different categories of users
- Programs need access to various resources, however excessive levels of access are dangerous
- Concerns when multiple programs access shared resources such as a common file

Environment Variables

Collection of string values inherited by each process from its parent	• Can affect the way a running process behaves • Included in memory when it is constructed
Can be modified by the program process at any time	• Modifications will be passed to its children
Another source of untrusted program input	
Most common use is by a local user attempting to gain increased privileges	• Goal is to subvert a program that grants superuser or administrator privileges

Vulnerable Compiled Programs

Programs can be vulnerable to PATH variable manipulation

- Must reset to “safe” values

If dynamically linked may be vulnerable to manipulation of LD_LIBRARY_PATH

- Used to locate suitable dynamic library
- Must either statically link privileged programs or prevent use of this variable

Use of Least Privilege

Privilege escalation

- Exploit of flaws may give attacker greater privileges

Least privilege

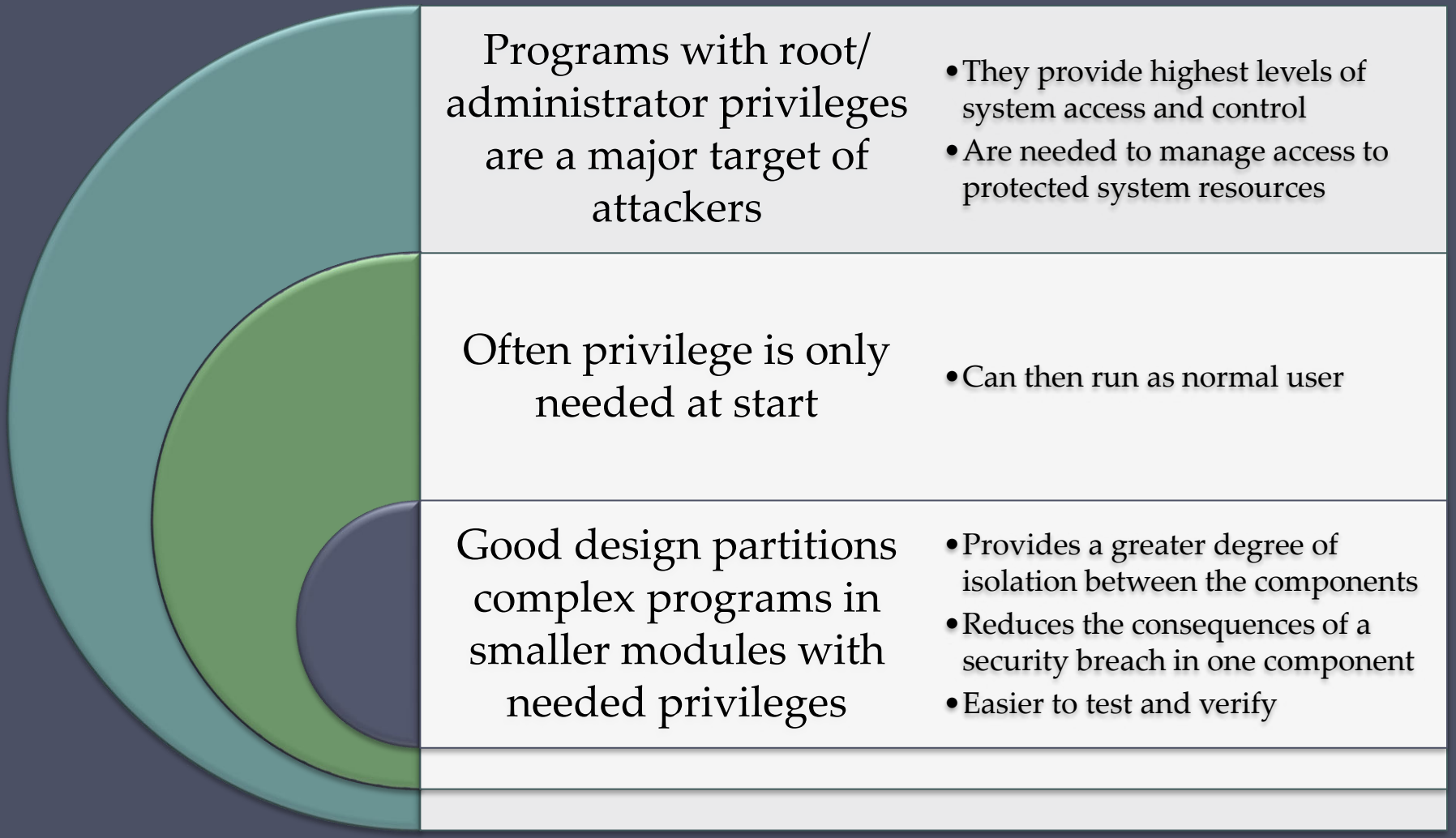
- Run programs with least privilege needed to complete their function

Determine appropriate user and group privileges required

- Decide whether to grant extra user or just group privileges

Ensure that privileged program can modify only those files and directories necessary

Root/Administrator Privileges



System Calls and Standard Library Functions

Programs use system calls and standard library functions for common operations

Programmers make assumptions about their operation

- If incorrect behavior is not what is expected
- May be a result of system optimizing access to shared resources
- Results in requests for services being buffered, resequenced, or otherwise modified to optimize system use
- Optimizations can conflict with program goals

Preventing Race Conditions

- Programs may need to access a common system resource
- Need suitable synchronization mechanisms
  - Most common technique is to acquire a lock on the shared file
- Lockfile
  - Process must create and own the lockfile in order to gain access to the shared resource
  - Concerns
    - If a program chooses to ignore the existence of the lockfile and access the shared resource the system will not prevent this
    - All programs using this form of synchronization must cooperate
    - Implementation

Safe Temporary Files

- Many programs use temporary files
- Often in common, shared system area
- Must be unique, not accessed by others
- Commonly create name using process ID
  - Unique, but predictable
  - Attacker might guess and attempt to create own file between program checking and creating
- Secure temporary file creation and use requires the use of random names

Other Program Interaction

Programs may use functionality and services of other programs

- Security vulnerabilities can result unless care is taken with this interaction
  - Such issues are of particular concern when the program being used did not adequately identify all the security concerns that might arise
  - Occurs with the current trend of providing Web interfaces to programs
  - Burden falls on the newer programs to identify and manage any security issues that may arise

Issue of data confidentiality/integrity

Detection and handling of exceptions and errors generated by interaction is also important from a security perspective

Handling Program Output

- Final component is program output
  - May be stored for future use, sent over net, displayed
  - May be binary or text
- Important from a program security perspective that the output conform to the expected form and interpretation
- Programs must identify what is permissible output content and filter any possibly untrusted data to ensure that only valid output is displayed
- Character set should be specified

Thank You!

Q & A Session