Introduction to Computer Security

Chapter 1: Overview

Chi-Yu Li (2019 Spring)
Computer Science Department
National Chiao Tung University

Focus: Three Fundamental Questions

- What assets do we need to protect?
- How are those assets threatened?
- What can we do to counter those threats?

Outline

- Computer Security Concept
- Threats, Attacks, and Assets
- Security Functional Requirements
- Fundamental Security Design Principles
- Attack Surfaces and Attack Trees
- Computer Security Strategy

Computer Security Concepts

- Definition of Computer Security

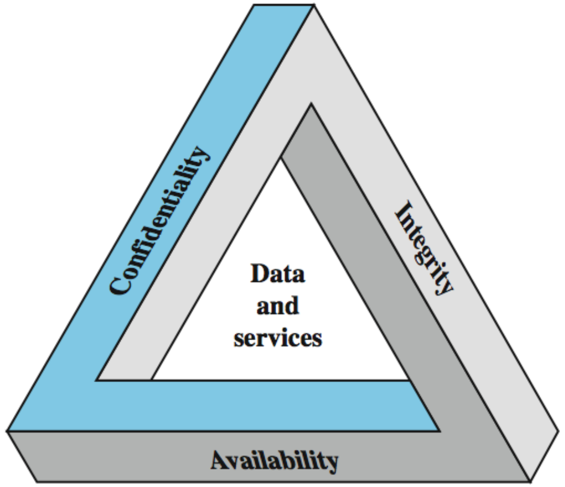
Measures and controls that ensure ***confidentiality***, ***integrity***, and ***availability*** of information system assets including hardware, software, firmware, and information being processed, stored, and communicated.

By the NIST Internal/Interagency Report (NISTIR) 7298
(Glossary of Key Information Security Terms, May 2013)

NIST (National Institute of Standards and Technology): a US federal agency that deals with measurement science, and technology related to US government use.

Three Key Objectives

- Confidentiality
  - □ **Data confidentiality**: Assures that private or confidential info is not disclosed to unauthorized individuals
  - □ **Privacy**: Assures that individuals control or influence what information related to them may be collected and stored
- Integrity
  - □ **Data integrity**: Assures that information and programs are changed only in a specified and authorized manner
  - □ **System integrity**: Assures that a system performs its intended function in an unimpaired manner
- Availability
  - □ Assures that systems work promptly and service is not denied to authorized users



CIA Triad

CIA Triad: Requirements and Definition of Loss

- Confidentiality
  - □ **Requirements**: Preserving authorized restrictions on information access and disclosure, including means for protecting personal privacy and proprietary info
  - □ **Definition of loss**: Unauthorized disclosure of information

- Integrity
  - □ **Requirements**: Guarding against improper info modification or destruction, and includes ensuring info non-repudiation and authenticity
  - □ **Definition of loss**: Unauthorized modification or destruction of information

By the NIST standard FIPS (Federal Information Processing System) 199

(Standards for Security Categorization of Federal Information and Information Systems, February 2004)

CIA Triad: Requirements and Definition of Loss (Cont.)

- Availability
  - □ **Requirements**: Ensuring timely and reliable access to and use of info
  - □ **Definition of loss**: Disruption of access to or use of info or an info system

Other Two Concepts to a Complete Security Picture

- Authenticity
  - Property is genuine and able to be verified and trusted
  - Confident in the validity of a transmission, or a message, or its originator
- Accountability
  - Requirement for actions of an entity to be traced uniquely to that entity
  - Be able to trace a security breach to a responsible party

Three levels of Security Impact

- Defined in FIPS 199
  - □ Low: limited adverse effect (minor)
  - □ Moderate: serious adverse effect (significant)
  - □ High: catastrophic adverse effect (catastrophic)
- Confidentiality
  - □ Low: directory information of departments
  - □ Moderate: student enrollment information (covered by FERPA)
  - □ High: student grade information (covered by FERPA)

FERPA: Family Educational Rights and Privacy Act

Three Levels of Security Impact (Cont.)

- Integrity
  - Low: anonymous online poll
  - Moderate: articles in a discussion forum
  - High: patient allergy information

- Availability
  - Low: online telephone directory lookup application
  - Moderate: a public website for a university
  - High: authentication services for critical systems

Challenges of Computer Security

- Computer security is not simple
    - Requirements seem to be straightforward
    - Mechanisms can be quite complex
- One must consider potential (unexpected) attacks
    - Successful attacks look at the problem in a completely different way
    - Exploiting an unexpected weakness
- Procedures are usually counterintuitive
    - Typically, a security mechanism is complex
    - Make sense only when the various aspects of the threat are considered

Challenges of Computer Security (Cont.)

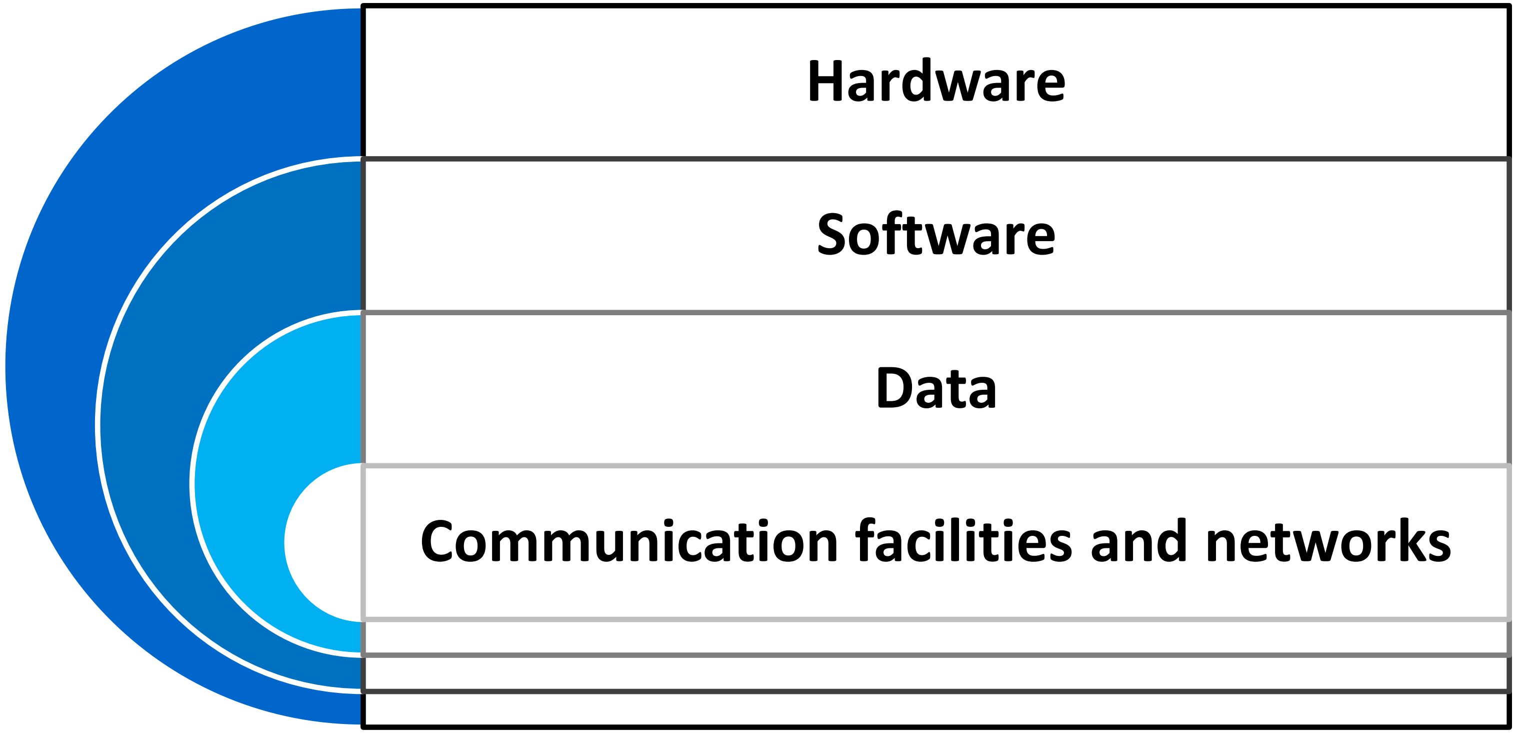
- Must decide where to deploy mechanisms
  - □ At what points in a network
  - □ At what layer of an architecture
- Involve algorithms and secret info (keys)
  - □ How to create, distribute, and protect secret info?
  - □ Relying on underlying protocols may complicate the development
- A battle of wits between attacker and admin
  - □ Attacker: find holes, need only find a single weakness
  - □ Designer: Close holes, eliminate all weaknesses

Challenges of Computer Security (Cont.)

- Users: not perceived on benefits until a security failure
- Requires constant monitoring
  - Difficult in today’s short-term, overloaded environment
- Too often an after-thought (not integral)
  - Not an integral part of the design process
- Strong security is regarded as an impediment to use of system

A Model for Computer Security

- Assets of a computer system (or system resource)



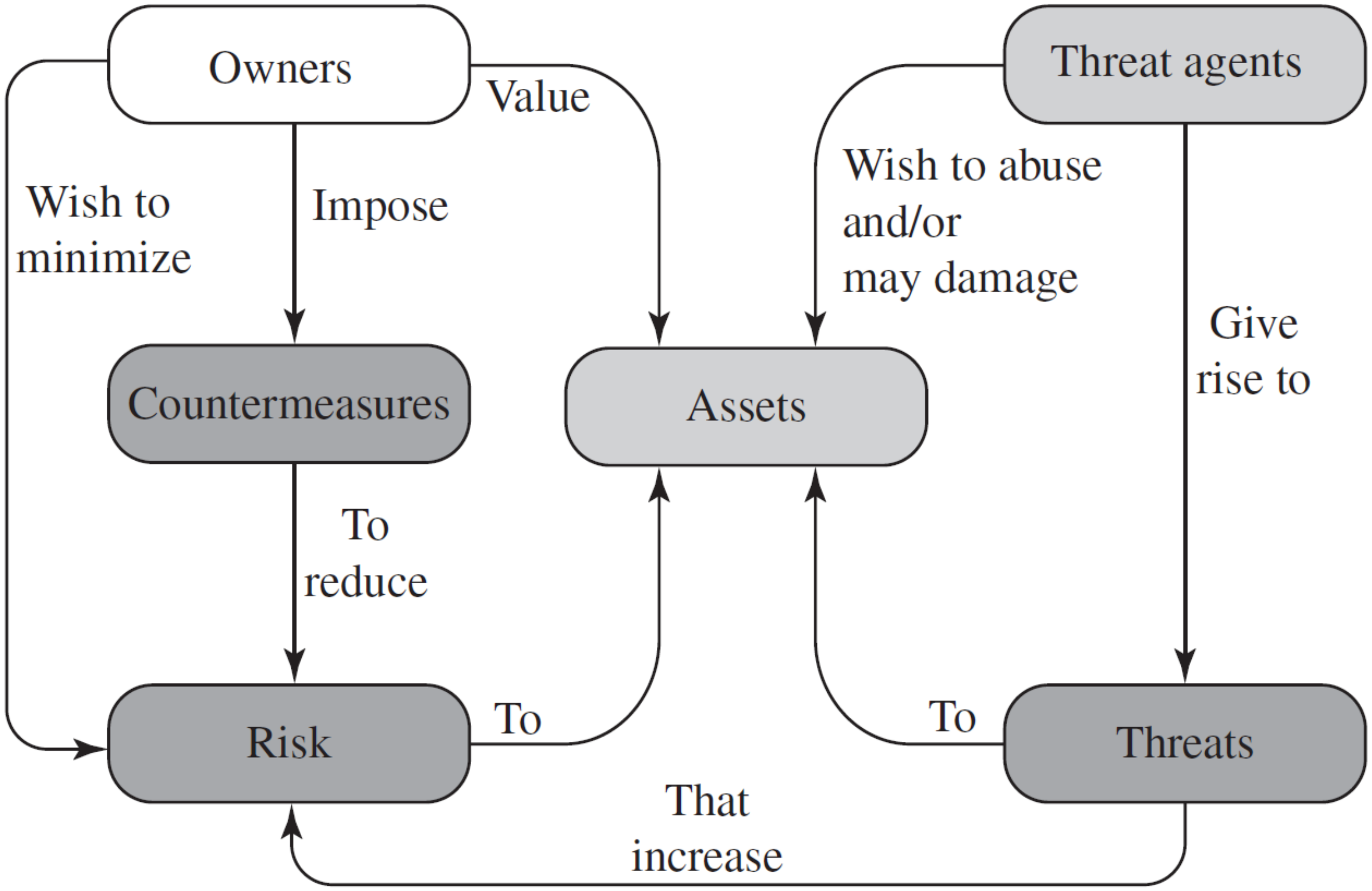
A Model for Computer Security (Cont.)

- Vulnerability: weakness of system resources
  - □ Corrupted: loss of integrity
  - □ Leaky: loss of confidentiality
  - □ Unavailable or very slow: loss of availability
- Threat: capable of exploiting vulnerabilities
  - □ Potential harm to an asset
- Attack: a threat that is carried out (threat action)
  - □ Passive: learn or make use of info, but doesn’t affect system resources
  - □ Active: alter system resources or affect their operation
  - □ Inside: by an authorized user (using authorized resources in a way not approved)
  - □ Outside: by an unauthorized user

A Model for Computer Security (Cont.)

- Countermeasures
  - Means used to deal with security attacks
    - Prevent attacks
    - Or detect them and then recover
  - May itself introduce new vulnerabilities
  - Residual vulnerabilities may remain
  - Goal is to minimize residual level of risk to the assets
    - Residual risk: the amount of risk associated with an action/event remaining, after inherent risks have been reduced by risk controls

Security Concepts and Relationships



See Table 1.1 Computer Security Terminology

Threats and Attacks (RFC 4949)

Threat Consequence	Threat Action (Attack)
Unauthorized Disclosure - Threats to confidentiality	(1) **Exposure**; (2) **Interception**; (3) **Inference**: inferring data/info from traffic patterns or repeated queries; (4) **Intrusion**
Deception - Threats to system/data integrity	**(1) Masquerade**: an unauthorized user who gains access to a system by posing as an authorized user, or a Trojan horse behaves; **(2) Falsification**; **(3) Repudiation**: falsely denying responsibility for an act

See Table 1.2 Threat Consequences, and the Types of Threat Actions

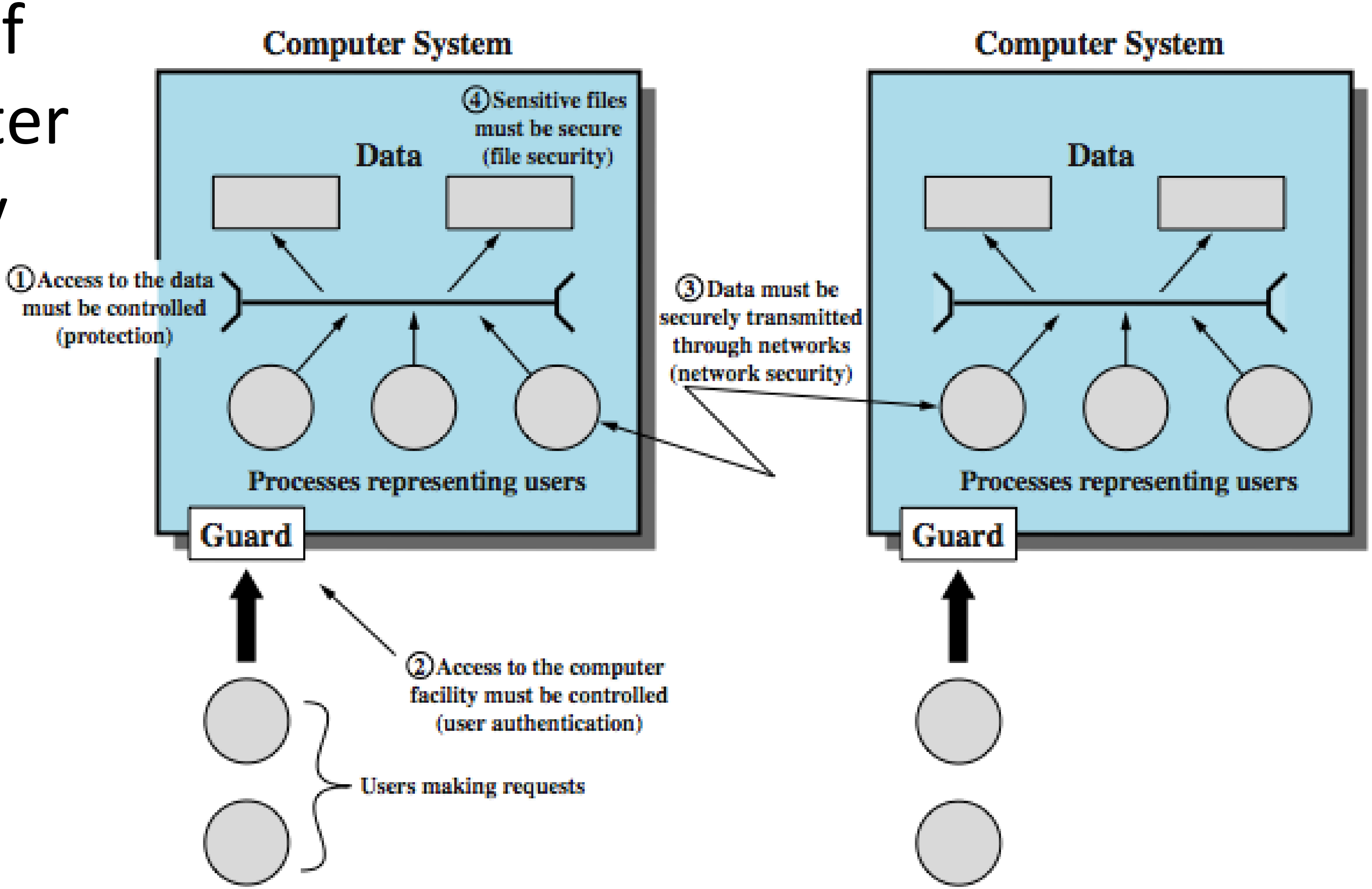
Threats and Attacks (RFC 4949)

Threat Consequence	Threat Action (Attack)
Disruption - Threats to availability or system integrity	**(1) Incapacitation**: prevents or interrupts system operation; **(2) Corruption**: undesirably alters system operation; **(3) Obstruction**: interrupts delivery of system services
Usurpation - Threats to system integrity	**(1) Misappropriation**: unauthorized logical or physical control of a system resource (e.g., DDoS attacks) **(2) Misuse**: gaining unauthorized access to a system

Threats and Assets

- Assets: hardware, software, data, and communication lines and networks
  - Threats: breaches of availability, confidentiality, and integrity
  - see Table 1.3
- Network security attacks
  - Passive attacks
    - Eavesdropping on, or monitoring of, transmissions
    - Goal: to obtain info that is being transmitted
    - Two types: release of message content, and traffic analysis
  - Active attacks
    - Involving some modification of the data stream or the creation of a false stream
    - Four types: replay, masquerade, modification of messages, and DoS

Scope of Computer Security



①Access to the data must be controlled (protection)

②Access to the computer facility must be controlled (user authentication)

③Data must be securely transmitted through networks (network security)

④Sensitive files must be secure (file security)

Security Functional Requirements

- One computer security expert, Bruce Schneier, observed

> If you think technology can solve your security problems, then you don't understand the problems and you don't understand the technology.

- Why?

Security Functional Requirements (FIPS 200)

- Technical measures
  - □ Access control; identification & authentication; system & communication protection; system & information integrity
- Management controls and procedures
  - □ Awareness & training; audit & accountability; certification, accreditation, & security assessments; contingency planning; maintenance; physical & environmental protection; planning; personnel security; risk assessment; systems & services acquisition
- Overlapping technical and management
  - □ Configuration management; incident response; media protection

See Table 1.4 Security Requirements

Fundamental Security Design Principles

- Why do we need principles?
  - □ No security design and implementation techniques that can **systematically** exclude security flaws and prevent all unauthorized actions
  - □ But, good practices for good design have been documented

Fundamental Security Design Principles

- Economy of mechanism
  - □ Design should be as simple and small as possible
- Fail-safe defaults
  - □ Access decisions should be based on permission rather than exclusion
- Complete mediation
  - □ Every access must be checked against the access control mechanism
- Open design
  - □ Design should be open rather than secret
    (e.g., widespread adoption of NIST-approved algorithms)

Fundamental Security Design Principles (Cont.)

- Separation of privilege
    - □ Separate users and processes based on different levels of trust, needs, and privilege requirements
- Least privilege
    - □ Every process and every user of the system should operate using the least set of privileges necessary to perform the task
- Least common mechanism
    - □ Design should minimize the functions shared by different users for mutual security

Fundamental Security Design Principles (Cont.)

- Psychological acceptability
  - □ Should not interfere unduly with the work of users or hinder the usability or accessibility of resources
- Isolation
  - □ Resources at public access systems
  - □ Processes and files of individual users
  - □ Security mechanisms
- Encapsulation
  - □ A specific form of isolation based on object-oriented functionality

Fundamental Security Design Principles (Cont.)

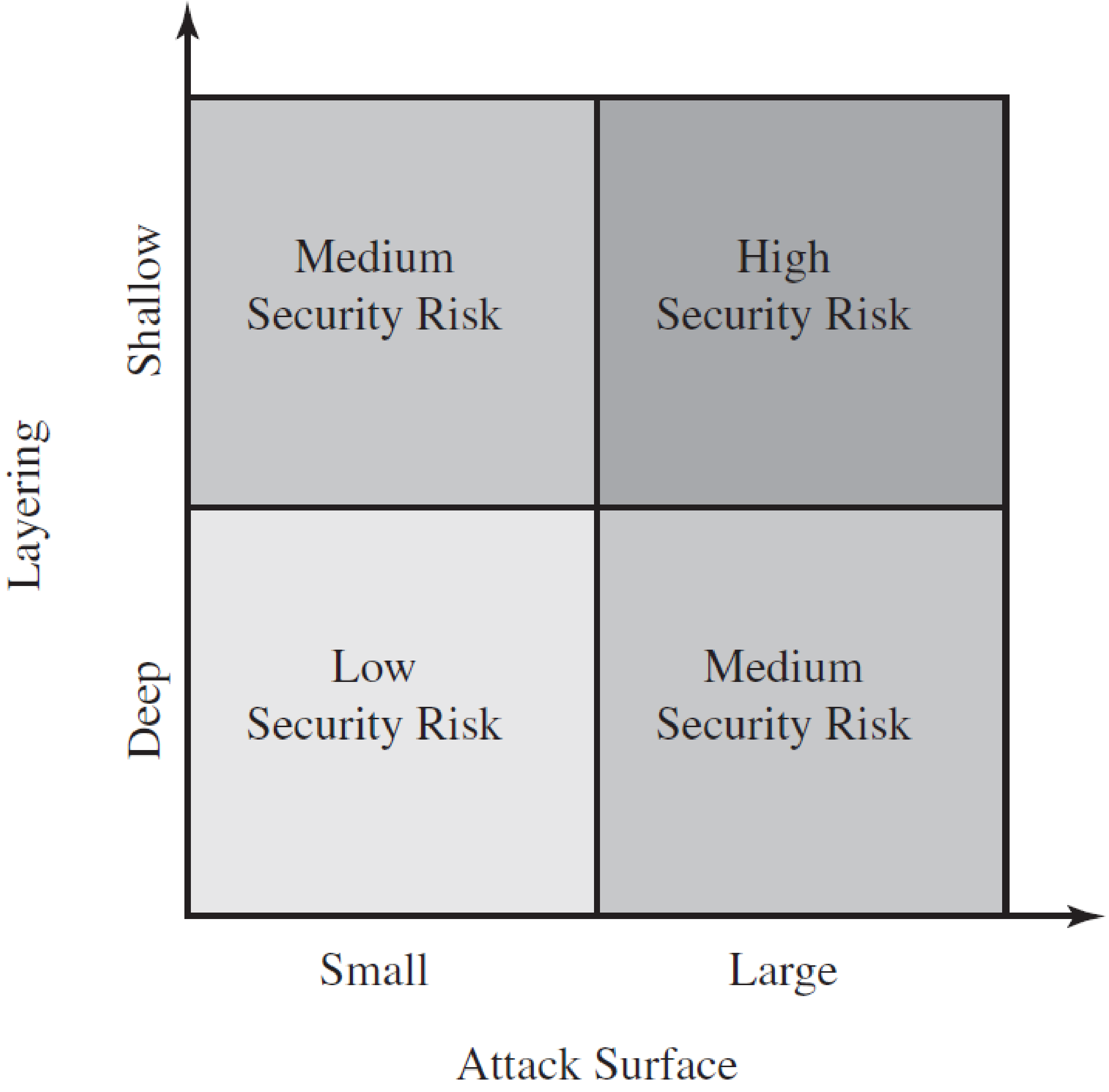
- Modularity
  - Development of security functions as separate, protected modules
  - Use of a modular architecture for mechanism design and implementation
- Layering
  - Use of multiple, overlapping protection approaches
- Least astonishment
  - A program or user interface should always respond in the way that is least likely to astonish the user

Attack Surfaces

- Consist of the reachable and exploitable vulnerabilities in a system
  - Network attack surface
    - Network protocol vulnerabilities
    - e.g., open ports on outward facing Web and other servers
  - Software attack surface
    - Vulnerabilities in application, utility, or operating system code
    - e.g., interfaces, SQL, and web forms
  - Human attack surface
    - Vulnerabilities created by personnel
    - e.g., an employee with access to sensitive info vulnerable to a social engineering attack

Attack Surfaces (Cont.)

- Why is an attack surface analysis useful?
  - □ Assess the scale and severity of threats to a system
  - □ Make developers aware of where security mechanisms are required



Layering

Shallow

Deep

Medium Security Risk

High Security Risk

Low Security Risk

Medium Security Risk

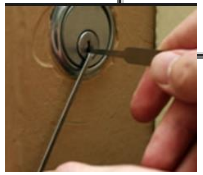
Small

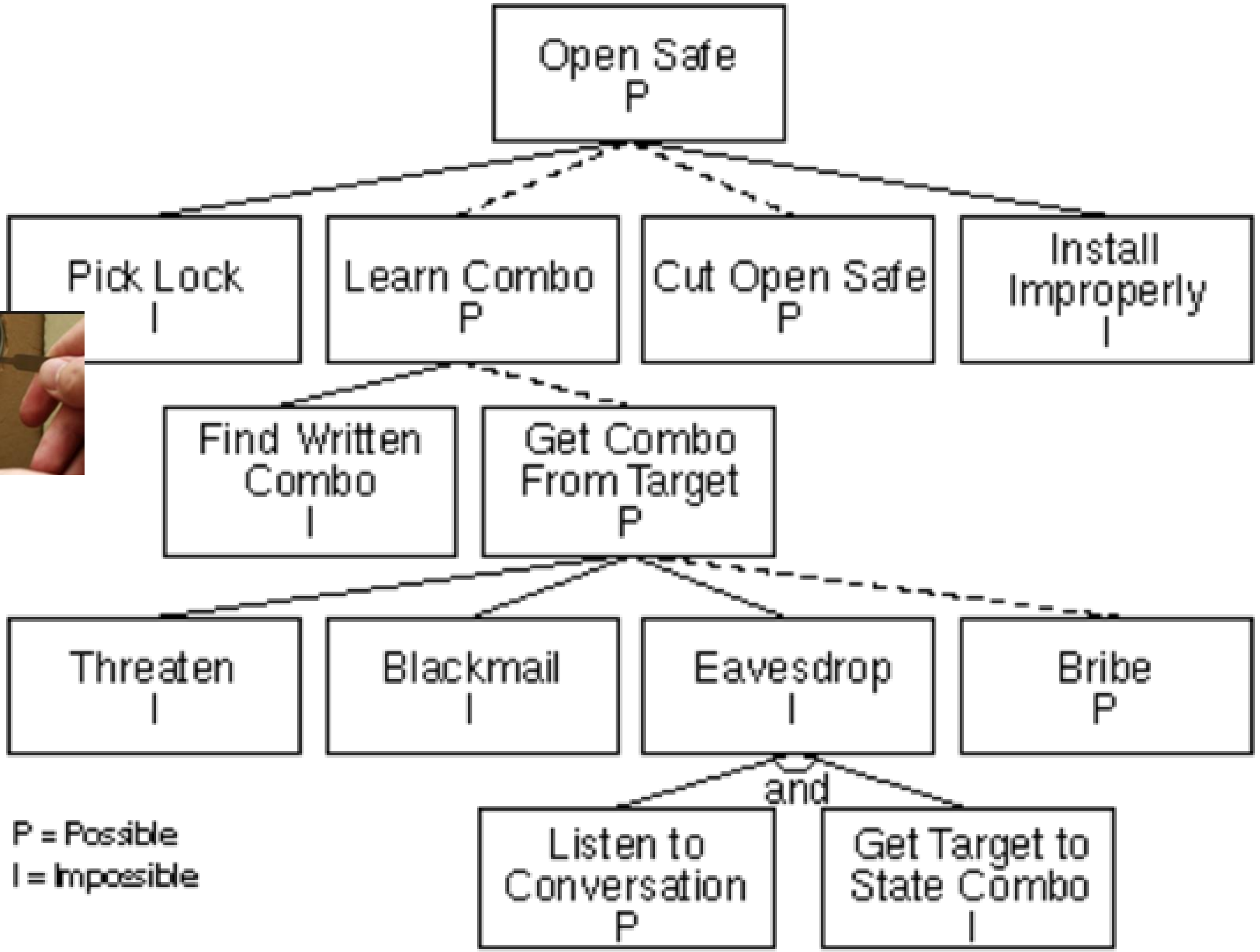
Large

Attack Surface

Attack Trees

- A branching, hierarchical data structure: a set of potential techniques for exploiting security vulnerabilities
  - □ Root: the attack goal
  - □ Leaf: different ways to initiate an attack
  - □ Each node (other than a leaf) is either an AND-node or an OR-node

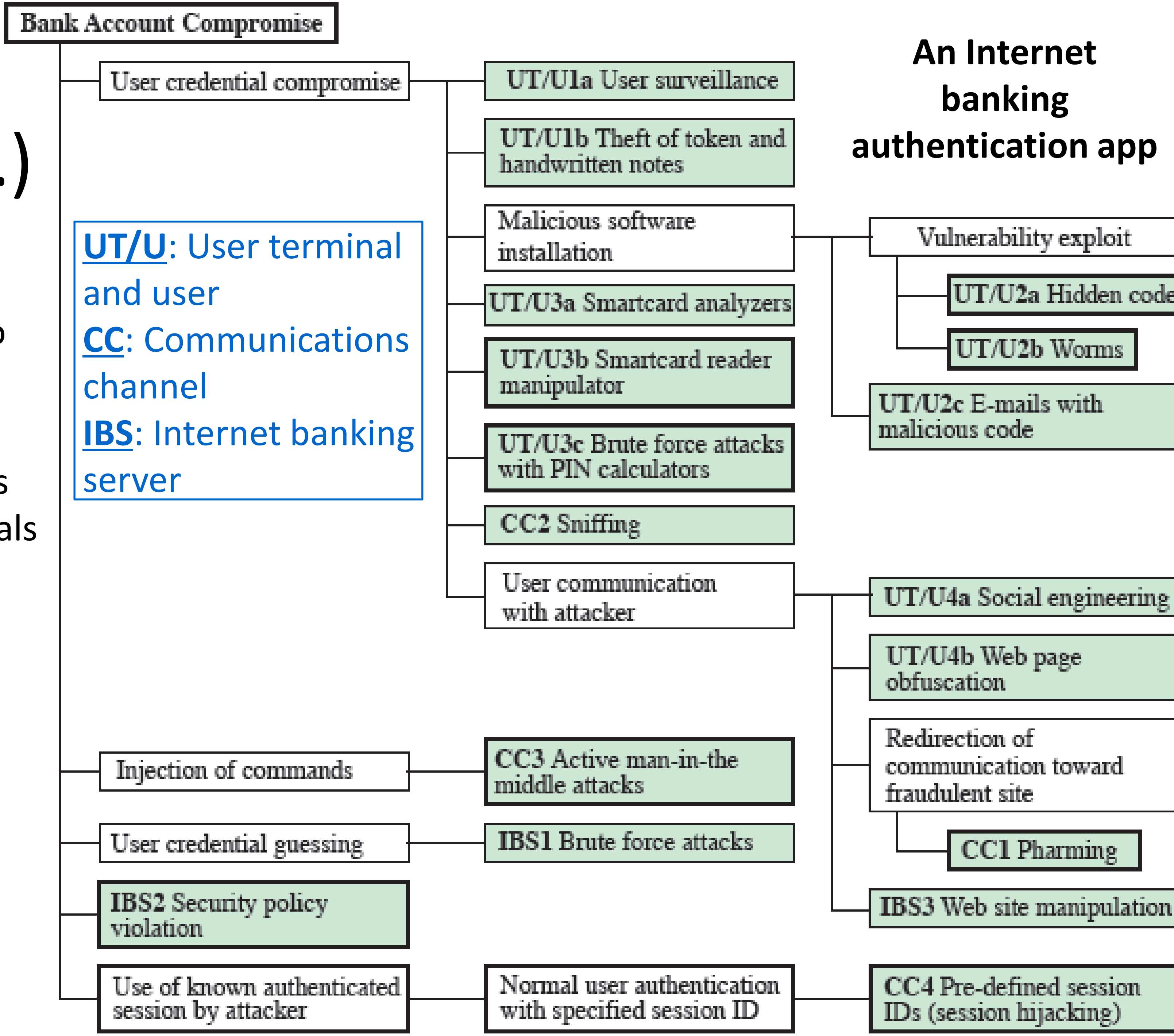




- Why are attack trees needed?

Attack Trees (Cont.)

- The use of attack trees
  - □ To effectively exploit the info available on attack patterns
  - □ To document security attacks in a structured form that reveals key vulnerabilities
  - □ To guide both the design of systems/apps and countermeasures



- Bank Account Compromise
  - User credential compromise
    - UT/U1a User surveillance
    - UT/U1b Theft of token and handwritten notes
    - Malicious software installation
      - Vulnerability exploit
        - UT/U2a Hidden code
        - UT/U2b Worms
      - UT/U2c E-mails with malicious code
    - UT/U3a Smartcard analyzers
    - UT/U3b Smartcard reader manipulator
    - UT/U3c Brute force attacks with PIN calculators
    - CC2 Sniffing
    - User communication with attacker
      - UT/U4a Social engineering
      - UT/U4b Web page obfuscation
      - Redirection of communication toward fraudulent site
        - CC1 Pharming
      - IBS3 Web site manipulation
  - Injection of commands
    - CC3 Active man-in-the middle attacks
  - User credential guessing
    - IBS1 Brute force attacks
  - IBS2 Security policy violation
  - Use of known authenticated session by attacker
    - Normal user authentication with specified session ID
      - CC4 Pre-defined session IDs (session hijacking)

UT/U: User terminal and user
CC: Communications channel
IBS: Internet banking server

An Internet banking authentication app

Computer Security Strategy

- Involves three aspects
  - □ Specification/policy: What is the security scheme supposed to do?
  - □ Implementation/mechanisms: How does it do it?
  - □ Correctness/assurance: Does it really work?

Security Policy

- A formal statement of rules and practices
  - that specify (or regulate) how a system (or organization) provides security services to protect critical system resources (RFC 4949)
- A security manager needs to considers:
  - The value of the assets being protected (e.g., critical files)
  - The vulnerabilities of the system (e.g., the system is open to guests)
  - Potential threats and the likelihood of attacks (e.g., data leakage)
  - Trade-off: ease of use vs. security (e.g., remember and type two passwords?)
  - Trade-off: cost of security vs. cost of failure and recovery

Security policy: a business decision, possibly influenced by legal requirements

Security Implementation and Assurance

- Security implementation
  - Prevention, detection, response, recovery
- Assurance: provides grounds for having confidence that the system operates such that the system's security policy is enforced
  - expressed as a degree of confidence
  - based on formal models
- Evaluation: examines a computer product or system w.r.t. certain criteria

Questions?