Computer Security Overview

Instructor: C. Pu (Ph.D., Assistant Professor)

Lecture 01

puc@marshall.edu

Computer Security Concepts

- **Computer Security**:
  - the *protection* afforded to an *automated information system* in order to attain the applicable objectives of preserving the ***integrity***, ***availability***, and ***confidentiality*** of information system resources (includes hardware, software, firmware, information/data, and telecommunications).
    - definition from the NIST Computer Security Handbook
      - https://www.nist.gov/publications/introduction-computer-security-nist-handbook

Computer Security Concepts

- This definition introduces ***three key objectives*** that are at the heart of computer security:
  - **Confidentiality**:
    - **Data confidentiality**: Assures that private or confidential information is not made available or disclosed to unauthorized individuals.
    - **Privacy**: Assures that individuals control or influence what information related to them may be collected and stored and by whom and to whom that information may be disclosed.

Computer Security Concepts

- This definition introduces ***three key objectives*** that are at the heart of computer security:
  - **Integrity**:
    - **Data integrity**: Assures that information (both stored and in transmitted packets) 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, free from deliberate or inadvertent unauthorized manipulation of the system.
  - **Availability**:
    - Assures that systems work promptly and service is not denied to authorized users.

Computer Security Concepts

- These three concepts form what is often referred to as the ***CIA triad***.

- The three concepts embody the **fundamental security objectives** for both **data** and for **information and computing services**.
  - The NIST standard FIPS 199 (Standards for Security Categorization of Federal Information and Information Systems) lists confidentiality, integrity, and availability as the three security objectives for information and for information systems.
    - https://csrc.nist.gov/publications/detail/fips/199/final

Computer Security Concepts

- FIPS 199 provides a useful characterization of these three objectives in terms of **requirements** and the **definition of a loss of security** in each category:
  - **Confidentiality**:
    - *Requirement*: preserving *authorized* restrictions on information access and disclosure, including means for protecting personal privacy and proprietary information.
    - *Loss of security*: a loss of confidentiality is the *unauthorized* disclosure of information.

Computer Security Concepts

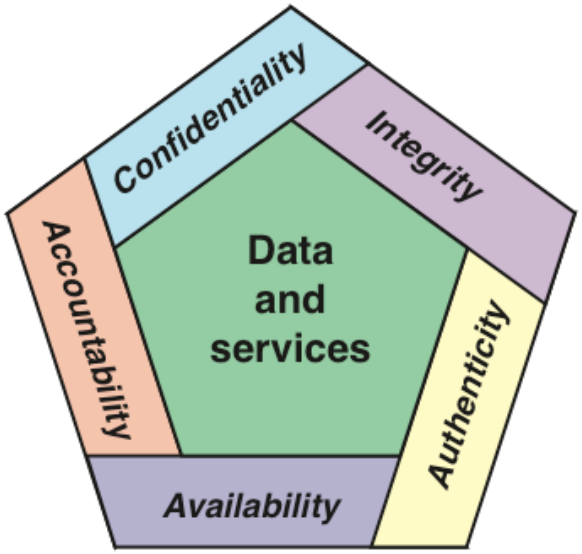
- FIPS 199 provides a useful characterization of these three objectives in terms of **requirements** and the **definition of a loss of security** in each category:
  - **Integrity**:
    - *Requirement*: guarding against improper information modification or destruction, including ensuring information nonrepudiation and authenticity.
    - *Loss of security*: a loss of integrity is the unauthorized modification or destruction of information.

Computer Security Concepts

- FIPS 199 provides a useful characterization of these three objectives in terms of **requirements** and the **definition of a loss of security** in each category:
  - **Availability**:
    - *Requirement*: ensuring timely and reliable access to and use of information.
    - *Loss of security*: a loss of availability is the disruption of access to or use of information or an information system.

Computer Security Concepts

- Although the use of the CIA triad to define security objectives is well established, some in the security field feel that additional concepts are needed to present a complete picture



Essential Network and Computer Security Requirements

Computer Security Concepts

- Two of the most commonly mentioned are as follows:
  - **Authenticity**:
    - The property of being genuine and being able to be verified and trusted; confidence in the validity of a transmission, a message, or message originator.
    - This means verifying that users are who they say they are and that each input arriving at the system came from a trusted source.
  - **Accountability**:
    - The security goal that generates the requirement for actions of an entity to be traced uniquely to that entity.
    - This supports nonrepudiation, deterrence, fault isolation, intrusion detection and prevention, and afteraction recovery and legal action.
    - Because truly secure systems are not yet an achievable goal, we must be able to trace a security breach to a responsible party.
    - Systems must keep records of their activities to permit later forensic analysis to trace security breaches or to aid in transaction disputes.

Computer Security Concepts

- Three levels of **impact** on organizations or individuals are defined in FIPS 199:
  - **Low**: The loss could be expected to have a **limited adverse effect** on organizational operations, organizational assets, or individuals.
    - A **limited adverse effect** means that, for example, the loss of confidentiality, integrity, or availability might
      - (i) cause a degradation in mission capability to an extent and duration that the organization is able to perform its primary functions, but the effectiveness of the functions is **noticeably reduced**;
      - (ii) result in **minor damage** to organizational assets;
      - (iii) result in **minor financial loss**; or
      - (iv) result in **minor harm** to individuals.

Computer Security Concepts

- Three levels of **impact** on organizations or individuals are defined in FIPS 199:
  - **Moderate**: The loss could be expected to have a **serious adverse effect** on organizational operations, organizational assets, or individuals.
    - A **serious adverse effect** means that, for example, the loss might
      - (i) cause a **significant degradation** in mission capability to an extent and duration that the organization is able to perform its primary functions, but the effectiveness of the functions is **significantly reduced**;
      - (ii) result in **significant damage** to organizational assets;
      - (iii) result in **significant financial loss**; or
      - (iv) result in **significant harm** to individuals that does not involve loss of life or serious, life-threatening injuries.

Computer Security Concepts

- Three levels of **impact** on organizations or individuals are defined in FIPS 199:
  - **High**: The loss could be expected to have a **severe or catastrophic adverse effect** on organizational operations, organizational assets, or individuals.
    - A **severe or catastrophic adverse effect** means that, for example, the loss might
      - (i) cause a **severe degradation** in or loss of mission capability to an extent and duration that the organization is **not able to perform** one or more of its primary functions;
      - (ii) result in **major damage** to organizational assets;
      - (iii) result in **major financial loss**; or
      - (iv) result in **severe or catastrophic harm** to individuals involving loss of life or serious, life-threatening injuries.

Computer Security Concepts

- Confidentiality
  - Student grade information is an asset whose confidentiality is considered to be highly important by students. In the United States, the release of such information is regulated by the Family Educational Rights and Privacy Act (FERPA). Grade information should only be available to students, their parents, and employees that require the information to do their job.
  - Student enrollment information may have a moderate confidentiality rating. While still covered by FERPA, this information is seen by more people on a daily basis, is less likely to be targeted than grade information, and results in less damage if disclosed.
  - Directory information, such as lists of students or faculty or departmental lists, may be assigned a low confidentiality rating or indeed no rating. This information is typically freely available to the public and published on a school's Web site.

Computer Security Concepts

- Integrity
  - Several aspects of integrity are illustrated by the example of a hospital patient's allergy information stored in a database.
  - The doctor should be able to trust that the information is correct and current.
  - Now suppose that an employee (e.g., a nurse) who is authorized to view and update this information deliberately falsifies the data to cause harm to the hospital.
    - The database needs to be restored to a trusted basis quickly, and it should be possible to trace the error back to the person responsible.
  - Patient allergy information is an example of an asset with a high requirement for integrity.
    - Inaccurate information could result in serious harm or death to a patient and expose the hospital to massive liability.

Computer Security Concepts

- Availability
  - The more critical a component or service, the higher is the level of availability required.
  - Consider a system that provides authentication services for critical systems, applications, and devices.
  - An interruption of service results in the inability for customers to access computing resources and staff to access the resources they need to perform critical tasks.
  - The loss of the service translates into a large financial loss in lost employee productivity and potential customer loss.

The Challenges of Computer Security

- Computer and network security is both fascinating and complex. Some of the reasons follow:

1. Security is not as simple as it might first appear to the novice.
   - The requirements seem to be straightforward; indeed, most of the major requirements for security services can be given self-explanatory, one-word labels: confidentiality, authentication, nonrepudiation, or integrity.
   - But the mechanisms used to meet those requirements can be quite complex, and understanding them may involve rather subtle reasoning.

The Challenges of Computer Security

- Computer and network security is both fascinating and complex. Some of the reasons follow:
  2. In developing a particular security mechanism or algorithm, one must always consider potential attacks on those security features.
     - In many cases, successful attacks are designed by looking at the problem in a completely different way, therefore exploiting an unexpected weakness in the mechanism.

The Challenges of Computer Security

- Computer and network security is both fascinating and complex. Some of the reasons follow:
  3. Because of previous point, the procedures used to provide particular services are often counterintuitive.
     - Typically, a security mechanism is complex, and it is not obvious from the statement of a particular requirement that such elaborate measures are needed.
     - It is only when the various aspects of the threat are considered that elaborate security mechanisms make sense.

The Challenges of Computer Security

- Computer and network security is both fascinating and complex. Some of the reasons follow:
  4. Having designed various security mechanisms, it is necessary to decide where to use them.
     - This is true both in terms of
       - physical placement (e.g., at what points in a network are certain security mechanisms needed)
       - logical sense (e.g., at what layer or layers of an architecture such as TCP/IP [Transmission Control Protocol/Internet Protocol] should mechanisms be placed).

The Challenges of Computer Security

- Computer and network security is both fascinating and complex. Some of the reasons follow:

5. Security mechanisms typically involve more than a particular algorithm or protocol.
   - They also require that participants be in possession of some secret information (e.g., an encryption key), which raises questions about the creation, distribution, and protection of that secret information.
   - There also may be a reliance on communications protocols whose behavior may complicate the task of developing the security mechanism.

The Challenges of Computer Security

- Computer and network security is both fascinating and complex. Some of the reasons follow:
  6. Computer and network security is essentially a battle of wits between a perpetrator who tries to find holes and the designer or administrator who tries to close them.
     - The great advantage that the attacker has is that he or she need only find a single weakness, while the designer must find and eliminate all weaknesses to achieve perfect security.

The Challenges of Computer Security

- Computer and network security is both fascinating and complex. Some of the reasons follow:

7. 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.

The Challenges of Computer Security

- Computer and network security is both fascinating and complex. Some of the reasons follow:

8. Security requires regular, even constant, monitoring, and this is difficult in today's short-term, overloaded environment.

The Challenges of Computer Security

- Computer and network security is both fascinating and complex. Some of the reasons follow:

9. 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.

The Challenges of Computer Security

- Computer and network security is both fascinating and complex. Some of the reasons follow:

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.

A Model for Computer Security: Computer Security Terminology

Adversary (threat agent)
An entity that attacks, or is a threat to, a system.

Attack
An assault on system security that derives from an intelligent threat; that is, an intelligent act that is a deliberate attempt (especially in the sense of a method or technique) to evade security services and violate the security policy of a system.

Countermeasure
An action, device, procedure, or technique that reduces a threat, a vulnerability, or an attack by eliminating or preventing it, by minimizing the harm it can cause, or by discovering and reporting it so that corrective action can be taken.

Risk
An expectation of loss expressed as the probability that a particular threat will exploit a particular vulnerability with a particular harmful result.

Security Policy
A set of rules and practices that specify or regulate how a system or organization provides security services to protect sensitive and critical system resources.

System Resource (Asset)
Data contained in an information system; or a service provided by a system; or a system capability, such as processing power or communication bandwidth; or an item of system equipment (i.e., a system component—hardware, firmware, software, or documentation); or a facility that houses system operations and equipment.

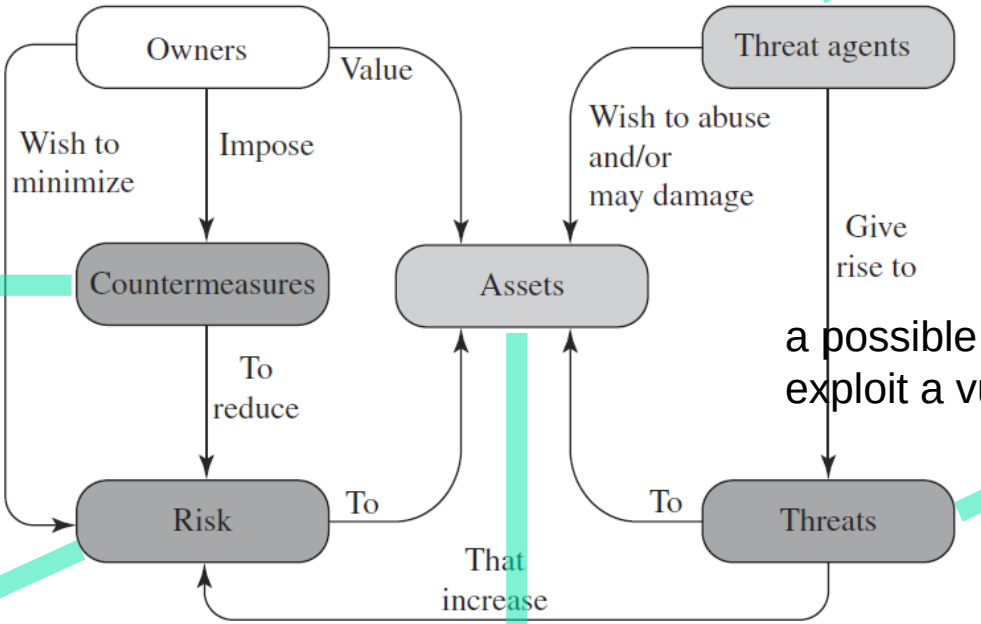
Threat
A potential for violation of security, which exists when there is a circumstance, capability, action, or event, that could breach security and cause harm. That is, a threat is a possible danger that might exploit a vulnerability.

Vulnerability
A flaw or weakness in a system's design, implementation, or operation and management that could be exploited to violate the system's security policy.

A Model for Computer Security

- Security Concepts and Relationships

the agent carrying out the attack



a countermeasure is any means taken to deal with a security attack

a possible danger that might exploit a vulnerability

an expectation of loss expressed as the probability

system resource that users and owners wish to protect

Threats and Attacks

- ***Unauthorized disclosure*** is a threat to confidentiality
  - The following types of attacks can result in this threat consequence:
    - ***Exposure***: Sensitive data are directly released to an unauthorized entity.
      - An insider intentionally releases credit card numbers to an outsider.
      - The result of a human, hardware, or software error.
      - E.g., Universities accidentally posting student confidential information on the Web.

Threats and Attacks

- ***Unauthorized disclosure*** is a threat to confidentiality
  - The following types of attacks can result in this threat consequence:
    - ***Interception***: An unauthorized entity directly accesses sensitive data traveling between authorized sources and destinations.
      - A common attack in communications.
      - In wireless LAN, any device attached to the LAN can receive a copy of packets intended for another device.
      - On the Internet, a determined hacker can gain access to e-mail traffic and other data transfers.

Threats and Attacks

- ***Unauthorized disclosure*** is a threat to confidentiality
  - The following types of attacks can result in this threat consequence:
    - ***Inference***: A threat action whereby an unauthorized entity indirectly accesses sensitive data by reasoning from characteristics or by-products of communications.
      - An example of inference is known as traffic analysis, where adversary is able to gain information from observing the pattern of traffic on a network.
    - ***Intrusion***: An unauthorized entity gains access to sensitive data by circumventing a system's security protections.

Threats and Attacks

- ***Deception*** is a threat to either system integrity or data integrity
  - The following types of attacks can result in this threat consequence:
    - ***Masquerade***: An unauthorized entity gains access to a system or performs a malicious act by posing as an authorized entity.
      - An unauthorized user to gain access to a system by posing as an authorized user with user ID and password.
    - ***Falsification***: This refers to the altering or replacing of valid data or the introduction of false data into a file or database.
      - A student may alter his or her grades on a school database.
    - ***Repudiation***: A user either denies sending data or a user denies receiving or possessing the data.

Threats and Attacks

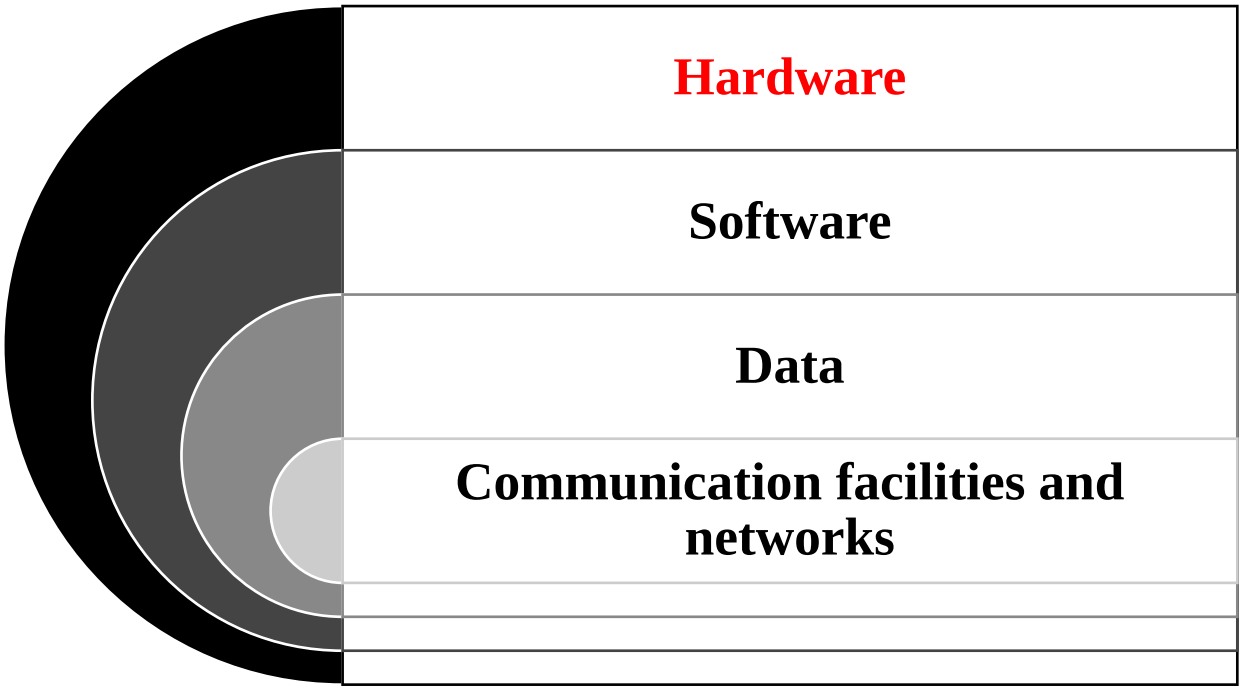
- ***Disruption*** is a threat to availability or system integrity.
  - The following types of attacks can result in this threat consequence:
    - ***Incapacitation***: Prevents or interrupts system operation by disabling a system component.
      - A result of physical destruction of or damage to system hardware.
    - ***Corruption***: Undesirably alters system operation by adversely modifying system functions or data.
      - A user placing backdoor logic in the system to provide subsequent access to a system and its resources by other than the usual procedure.
    - ***Obstruction***: A threat action that interrupts delivery of system services by hindering system operation.
      - Interfere with communications by disabling communication links or altering communication control information.

Threats and Attacks

- ***Usurpation*** is a threat to system integrity.
  - The following types of attacks can result in this threat consequence:
    - ***Misappropriation***: An entity assumes unauthorized logical or physical control of a system resource.
      - Theft of service
      - E.g., a distributed denial of service attack, when malicious software is installed on a number of hosts to be used as platforms to launch traffic at a target host.
    - ***Misuse***: Causes a system component to perform a function or service that is detrimental to system security.
      - Misuse can occur by means of either malicious logic or a hacker that has gained unauthorized access to a system.

Threats and Assets

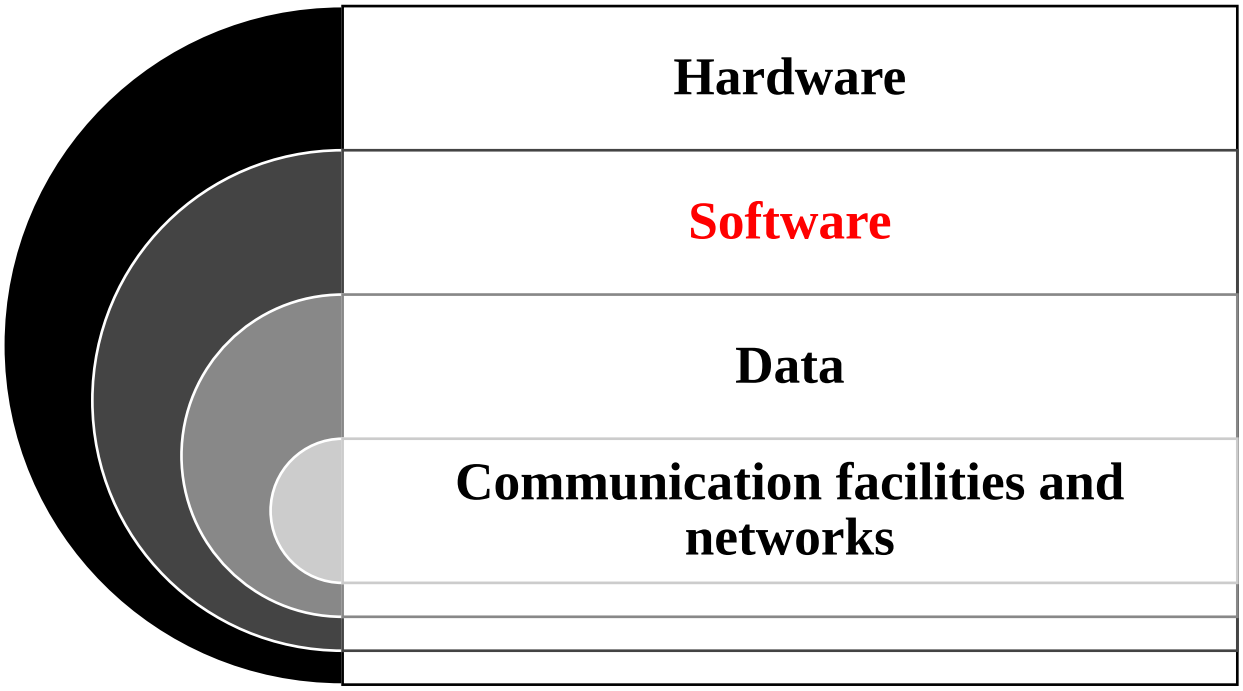
- The assets of a computer system can be categorized as hardware, software, data, and communication lines and networks.



- Major threat: the threat to availability
- Threats include accidental and deliberate damage to equipment as well as theft.
- Physical and administrative security measures are needed to deal with these threats.

Threats and Assets

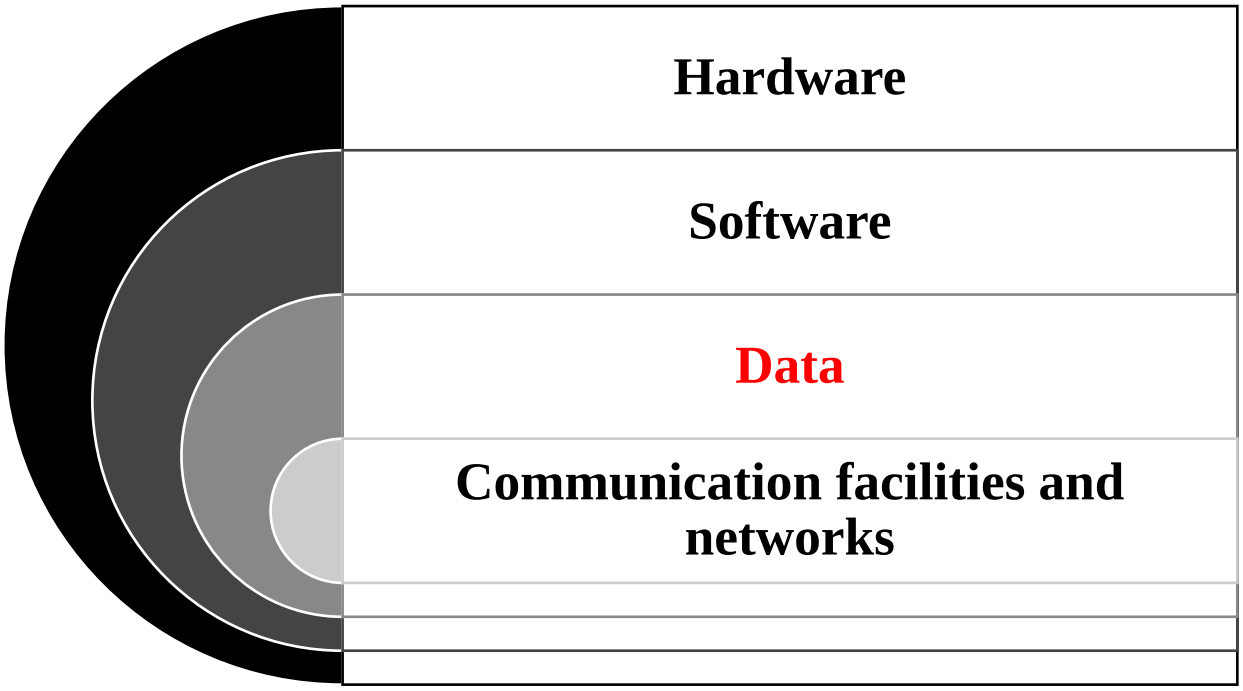
- The assets of a computer system can be categorized as hardware, software, data, and communication lines and networks.



- Software includes the operating system, utilities, and application programs.
- Major threat: the threat to availability.
- Software can be deleted, altered or damaged.

Threats and Assets

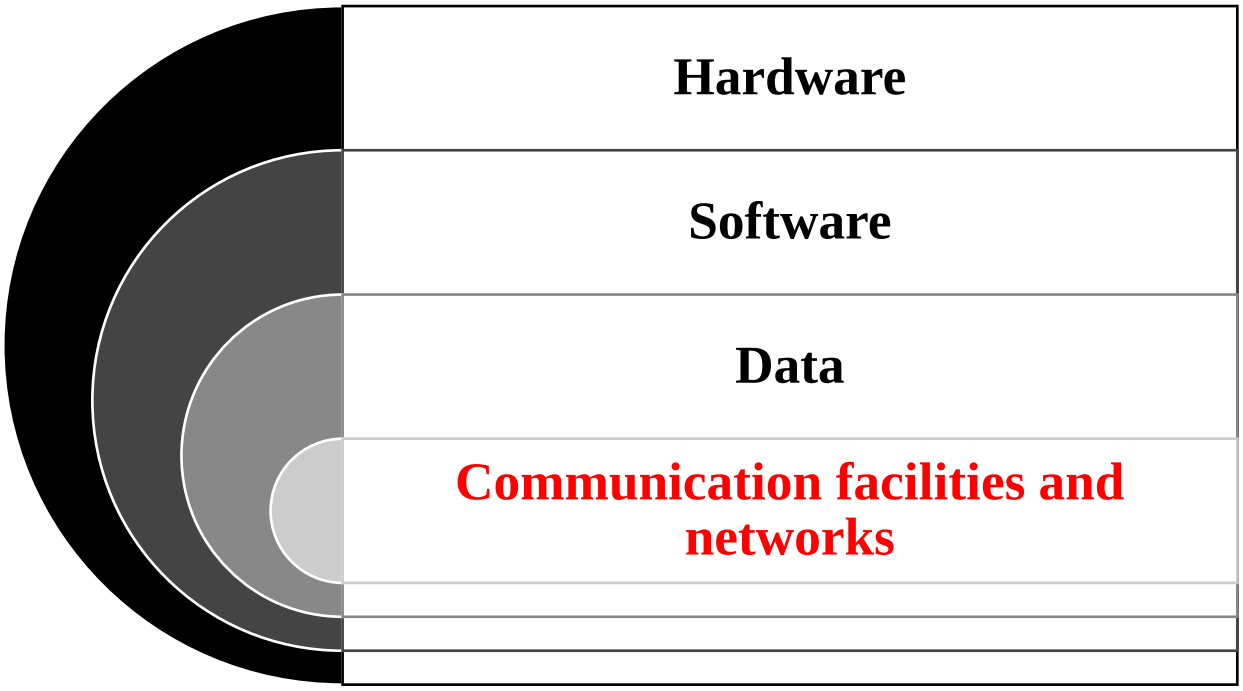
- The assets of a computer system can be categorized as hardware, software, data, and communication lines and networks.



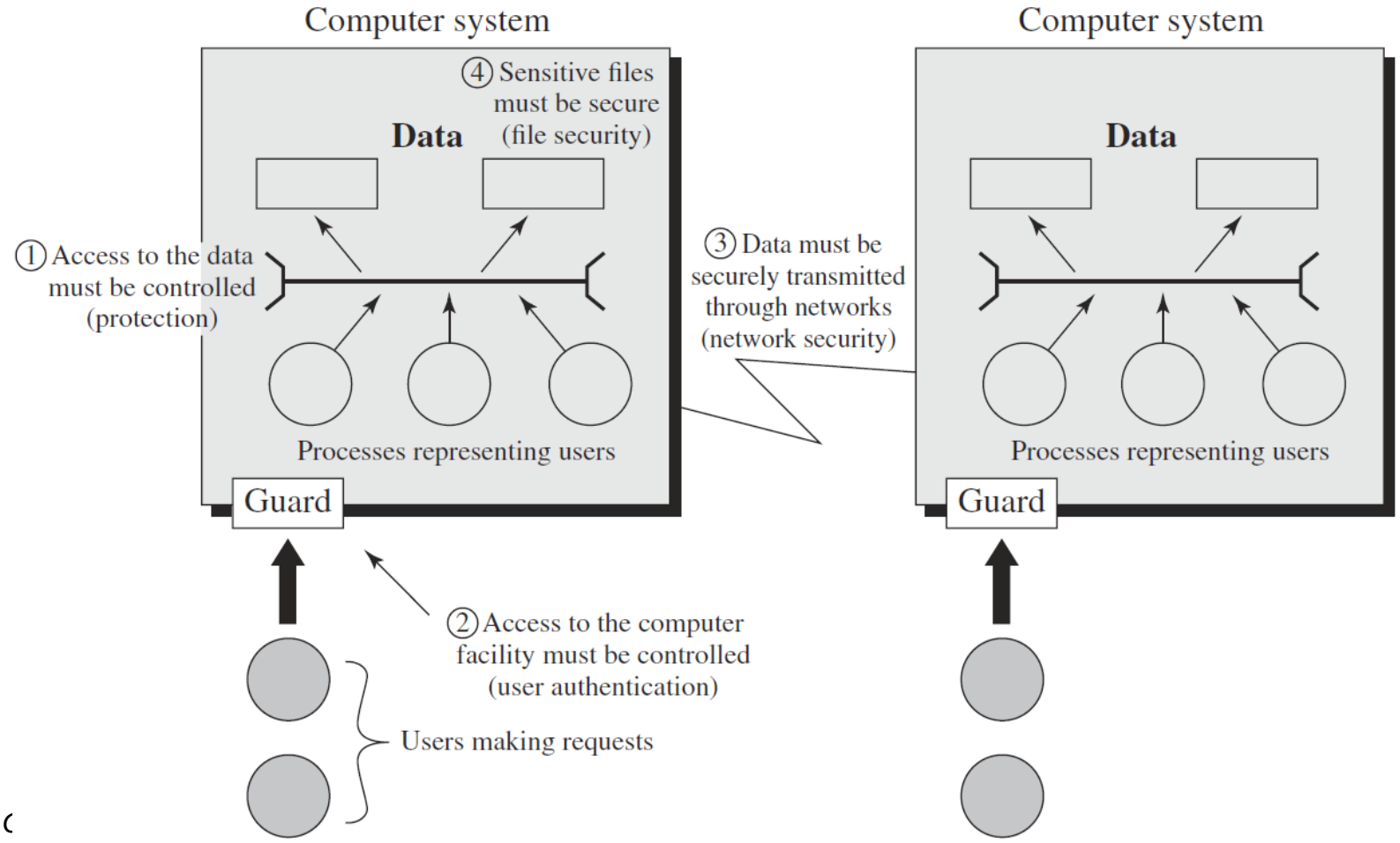
- Security concerns with respect to data are broad, encompassing availability, secrecy, and integrity.
- In the case of availability, the concern is with the destruction of data files.
- The obvious concern with secrecy is the unauthorized reading of data files or databases.

Threats and Assets

- The assets of a computer system can be categorized as hardware, software, data, and communication lines and networks.

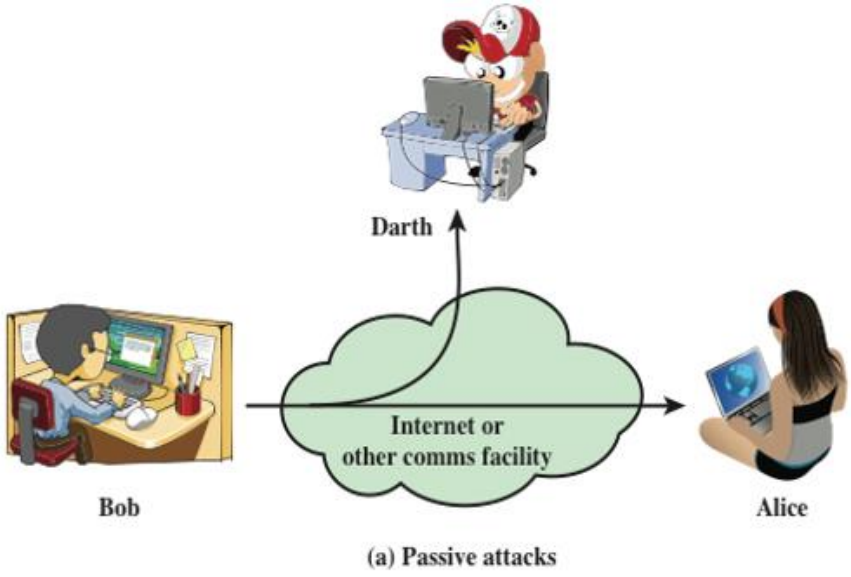


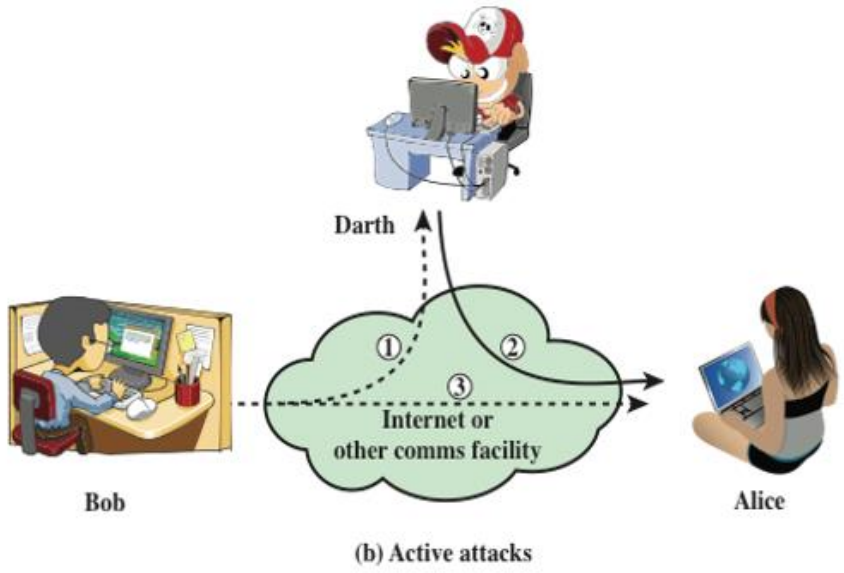
Threats and Assets: Scope of Computer Security



Communication Lines and Networks

- A useful means of classifying security attacks is in terms of ***passive attacks*** and ***active attacks***



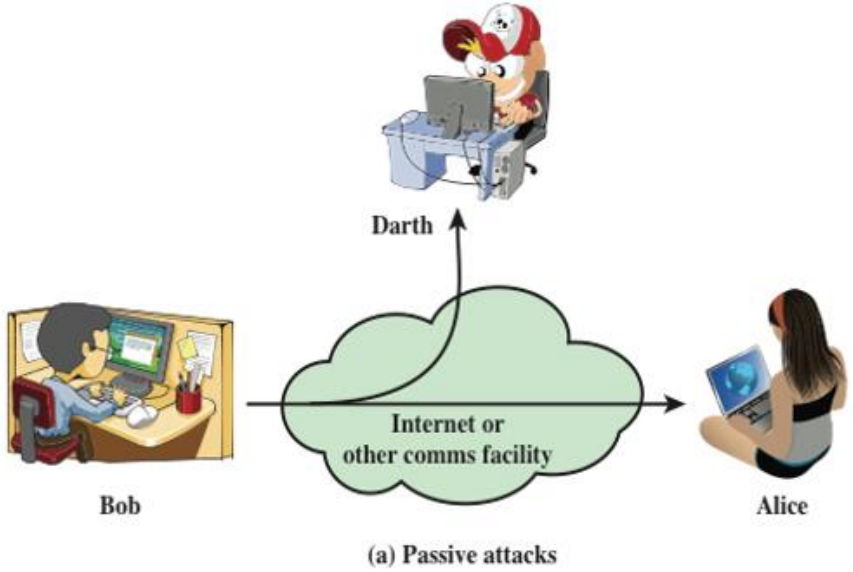


A passive attack attempts to learn or make use of information from the system but does not affect system resources.

An active attack attempts to alter system resources or affect their operation.

Communication Lines and Networks

- Passive attacks are in the nature of eavesdropping on, or monitoring of, transmissions.
- The goal of the opponent is to obtain information that is being transmitted.



(a) Passive attacks

A passive attack attempts to learn or make use of information from the system but does not affect system resources.

Communication Lines and Networks

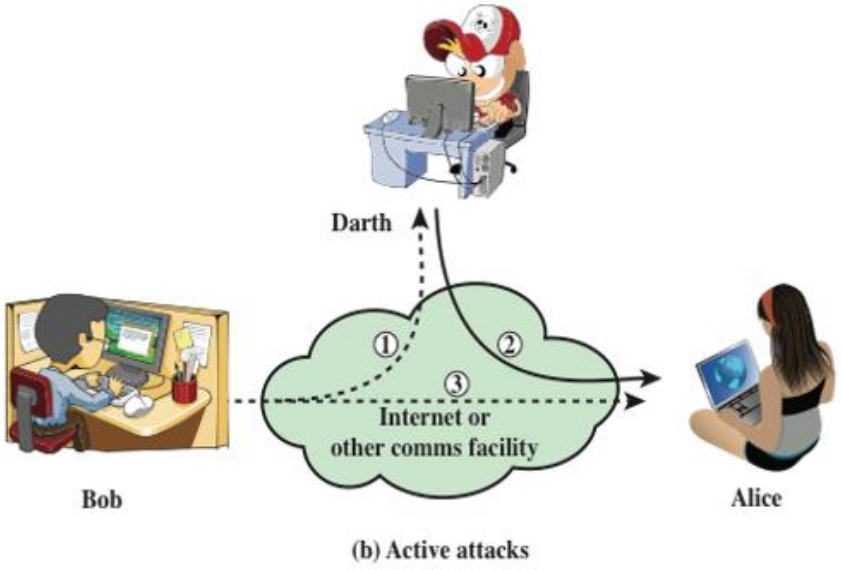
- Two types of passive attacks are the **release of message contents** and **traffic analysis**:
  - **Release of message contents**
    - The release of message contents is easily understood.
    - A telephone conversation, an electronic mail message, and a transferred file may contain sensitive or confidential information.
    - We would like to prevent an opponent from learning the contents of these transmissions.
  - **Traffic analysis**
    - The opponent could determine the location and identity of communicating hosts and could observe the frequency and length of messages being exchanged.
    - This information might be useful in guessing the nature of the communication that was taking place.

Communication Lines and Networks

- Passive attacks are very difficult to detect, because they do not involve any alteration of the data.
  - Typically, the message traffic is sent and received in an apparently normal fashion, and neither the sender nor receiver is aware that a third party has read the messages or observed the traffic pattern.
  - However, it is feasible to prevent the success of these attacks, usually by means of encryption.
  - Thus, the emphasis in dealing with passive attacks is on prevention rather than detection.

Communication Lines and Networks

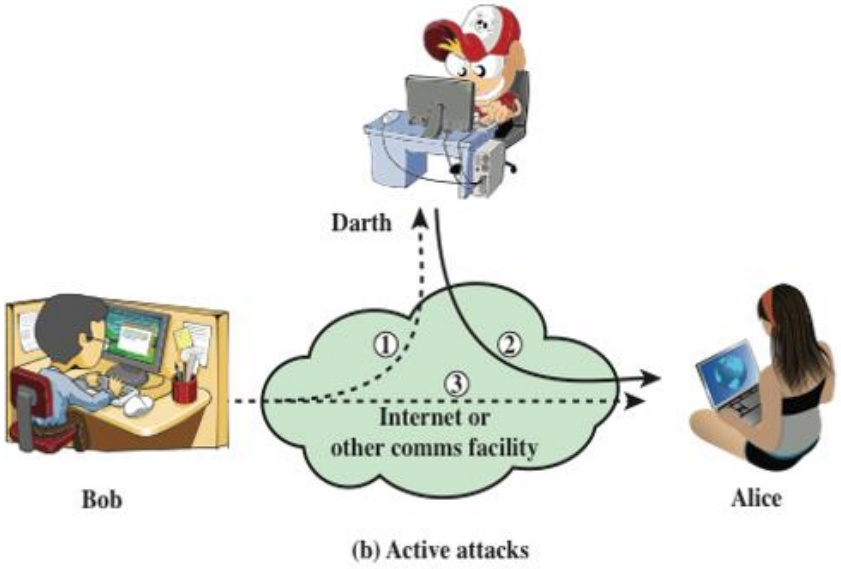
- Active attacks involve some modification of the *data stream* or the creation of a *false stream* and can be subdivided into four categories: **masquerade**, **replay**, **modification of messages**, and **denial of service**.



An active attack attempts to alter system resources or affect their operation.

Communication Lines and Networks

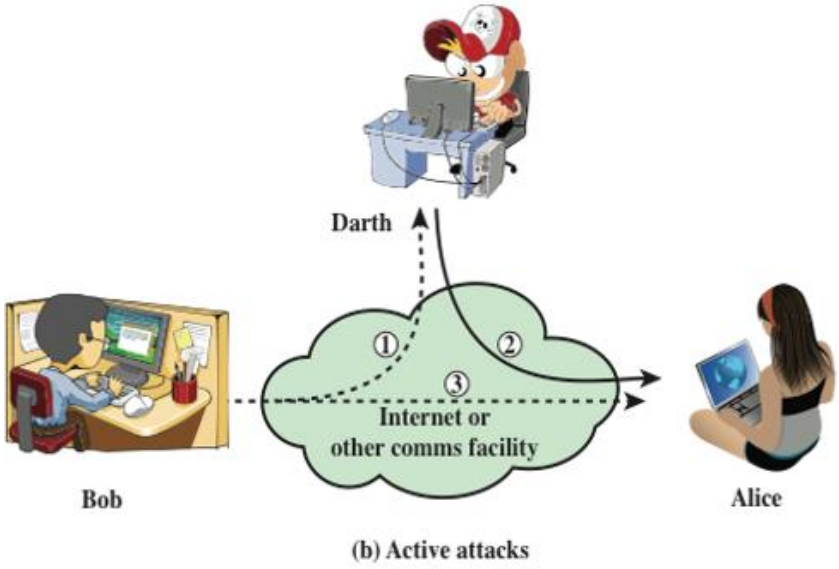
- A **masquerade** takes place when one entity pretends to be a different entity.
- Path 2



An active attack attempts to alter system resources or affect their operation.

Communication Lines and Networks

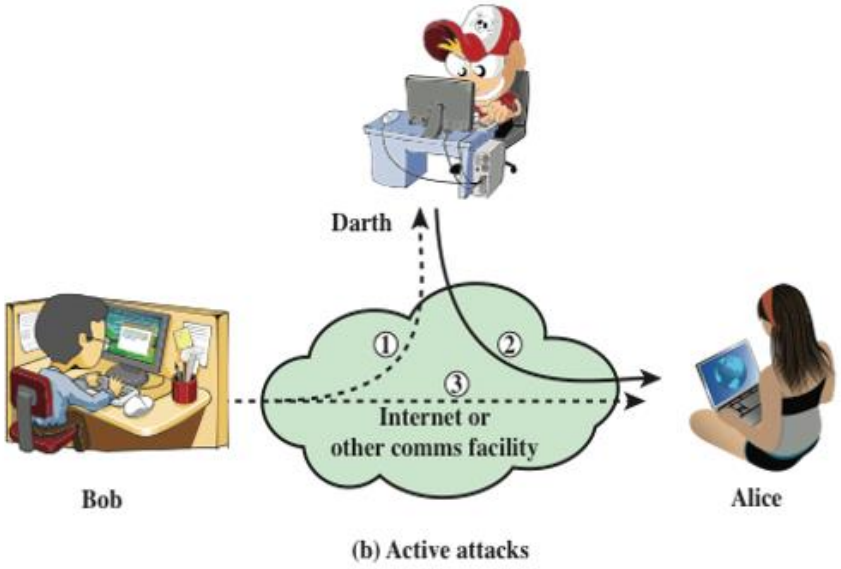
- **Replay** involves the passive capture of a data unit and its subsequent retransmission to produce an unauthorized effect.
- Path 1,2,3



An active attack attempts to alter system resources or affect their operation.

Communication Lines and Networks

- **Modification of messages** simply means that some portion of a legitimate message is altered, or that messages are delayed or reordered, to produce an unauthorized effect.
- Path 1,2



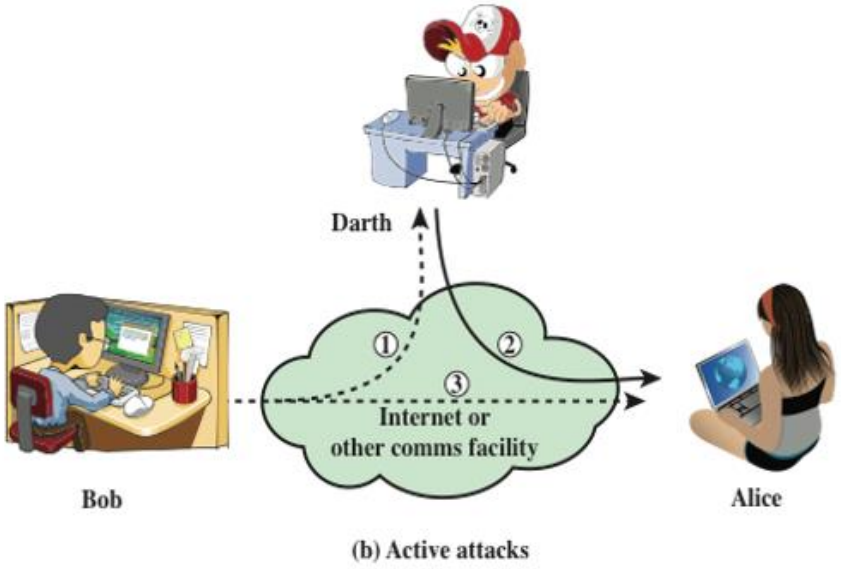
An active attack attempts to alter system resources or affect their operation.

Communication Lines and Networks

- **Modification of messages** simply means that some portion of a legitimate message is altered, or that messages are delayed or reordered, to produce an unauthorized effect.
- For example,
  - A message meaning "Allow John Smith to read confidential file accounts" is modified to mean "Allow Fred Brown to read confidential file accounts."

Communication Lines and Networks

- The **denial of service** prevents or inhibits the normal use or management of communications facilities.
  - This attack may have a specific target;
- Path 3



(b) Active attacks

An active attack attempts to alter system resources or affect their operation.

Communication Lines and Networks

- The **denial of service** prevents or inhibits the normal use or management of communications facilities.
  - This attack may have a specific target;
- For example,
  - An entity may suppress all messages directed to a particular destination (e.g., the security audit service).
  - Another form of service denial is the disruption of an entire network, either by disabling the network or by overloading it with messages so as to degrade performance.

Communication Lines and Networks

- Active attacks present the opposite characteristics of passive attacks.
  - Passive attacks are difficult to detect, measures are available to prevent their success.
  - On the other hand, it is quite difficult to prevent active attacks absolutely because of the wide variety of potential physical, software, and network vulnerabilities.
  - Instead, the goal is to detect active attacks and to recover from any disruption or delays caused by them.
  - If the detection has a deterrent effect, it may also contribute to prevention.

Active Attacks Real Examples

- Phishing
  - On the weekend of January 3, 2009, several users on the social network Web site, Twitter, became victims of a phishing attack. The users were deceived into giving away their passwords when they received an e-mail similar to one that they would receive from Twitter with a link that read, "hey, check out this funny blog about you…". The link redirects to a site masquerading as the real Twitter site. Any personal information entered by the user on the fake site is then captured by the attacker.

Active Attacks Real Examples

- Denial-of-service
  - In the fall and winder of 2012 and 2013, 26 or more U.S. banks were hit with overwhelming storms of internet traffic. While a group calling itself the Izz ad-Din al-Qassam Cyber Fighters claimed responsibility for the attacks. The attacks disrupted, or knocked completely offline, Bank of America, Capital One, Chase, Citibank, PNC Bank, Wells Fargo and others.