# CS458: Introduction to Information Security

## Notes 1: Introduction

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Slides: Modified from: “Computer Security: Principles and Practice”, 4th Edition. By: William Stallings and Lawrie Brown, “Cryptography and Network Security”, 6/e, by William Stallings, “Principles of Information Security”, 7th edition 2022, by Michael E. Whitman, Herbert J. Mattord, MIT Computer Systems Security, & Steven Gordon, CQUniversity

# Welcome to CS458

# Who we are. . .

- **Instructor**
  - Yousef Elmehdwi
    - 6th year at IIT, not first time teaching `CS458`☺
    - Email: `yelmehdwi at iit dot edu`
    - Research: data privacy and security
    - Office: Stuart Building, room `237D`
    - Office Hours: `Mondays, 5:35-6:35pm or by appointment`

# Who we are. . .

- **TA**
    - Ryan Timothy Rishab
        - Email: `rtimothyrishab@hawk.iit.edu`
        - Office: TBA
        - Office Hours: TBA

# What is our goal in this course?

- To provide a basic understanding of the problems of information assurance and the solutions that exist to secure information on computers and networks
- To be able to use this ability to design systems that are more protective of security

# Things to cover in CS458

- Introduction to the major topics in computer security
  - human factors in security policy
  - basic applied cryptography, public key cryptography
  - key and identity management, authentication, access control
  - network security, database security, operating system security
  - denial-of-service attacks, malware ...
  - more ...
- Lots of security problems to consider
- But not nearly enough time available?

# What this course is (and is not)

- This is a combination of lecture, discussion and hands-on security exercises class
- For those are interested in more hands-on experience
  - CS 495: Ethical Hacking and Penetration Testing (Spring/Summer)
    - Provide a wide range of topics related to ethical hacking and penetration testing.
  - CSP 544: System and Network Security
    - Present an in-depth examination of topics in data and network security
    - `http://cs.iit.edu/~khale/class/security/s20/`
- Other Security Courses
  - CS 527: Software Security
  - CS 528: Data Privacy and Security
  - CS 549: Cryptography
  - CS 558: Advance Computer Security
- New master of cyber-security degree
  - available for co-terminal students as well
  - `https://www.iit.edu/academics/programs/cybersecurity-mas`

# Course Info

- Time: `M/W 1:50 - 3:05 pm, Perlstein Hall 131`
- Lecture slides in PDF format will be posted before the lectures (Blackboard)
- Lecture slides cover essential material
- Lectures will be recorded and uploaded to course Blackboard right after each class.
- Students can access the recorded lectures whenever they need them.
- Piazza
    - `(piazza.com/iit/fall2022/cs458)` with access code `CS458Fall2022` to sign up.
    - Announcements
    - Participating in discussions
        - Student - Instructor/TA
        - Student - Student
    - *please join piazza to keep up to date*

# Course syllabus

- You are expected to be familiar with the contents of the course syllabus
- Available on the course Blackboard
- If you haven't read it, read it after this lecture

# Workload and Grading

- **Exams**
  - One midterm exam and one final
  - Closed book, closed notes exams
    - Only **ONE** sheet of paper printed on front and back is allowed
  - Midterm Exam: **10/24/2022**
  - Final: During finals week **December 5 -10**
- **Assignments**:
  - 4 hands-on security exercises (at least)
    - Hands-on exercises: SEED Labs
  - Individual work

# Workload and Grading

| | |
|---|---|
| Assignments: Security exercises | 40% |
| Midterm Exam | 25% |
| Final Exam | 35% |

# Letter Grade Distribution

| **Points** | **Grade** |
|---|---|
| 90 - 100 | A |
| 75 - 89 | B |
| 65 - 74 | C |
| 60 - 64 | D |
| 0 - 59 | E |

# Hands-on Exercises

- **Lab 1**: `Lab Environment Setup`
- **Lab 2**: `Secret Key Encryption Lab`
- **Lab 3**: `MD5 Collision Attack Lab`
- **Lab 4**: `SQL Injection Attack`

# Fraud

- All work has to be original!
  - Cheating = 0 points for assignment/exam
  - Possibly **E** in course and further administrative sanctions
  - Every dishonesty will be reported to office of academic honesty

# Recommended textbooks/ other readings

- **Textbooks:**
  - Computer Security: Principles and Practice by William Stallings and Lawrie Brown, any edition (4th)
    - Resource for students from the official textbook website
    - http://williamstallings.com/ComputerSecurity/CompSec4e-Student/
  - Security in Computing, 5th Edition, by Charles P. Pfleeger, Shari Lawrence Pfleeger, Jonathan Margulies
  - Computer Security: A Hands-on Approach, Wenliang Du, 2017
- Additional Readings
  - Additional readings will be assigned throughout the semester, ranging from current news stories to technical articles to research papers.
  - All of the additional readings will either be freely available or copies will be provided for students.

# What is expected from you

- Attend in-person lectures, if you can
- Be active and think critically
- Do hands-on Assignments
  - Start early and be honest
- Study for exams

# A note on security

- In this course, you will be exposed to information about security problems and vulnerabilities with computing systems and networks
- To be clear, you are not to use this or any other similar information to test the security of, break into, compromise, or otherwise attack, any system or network without the express consent of the owner
- In particular, you will comply with all applicable laws

# Outline

- Define Information Security
- History of computer security and how it evolved into information security
- Introduce the CIA Triad
- What is privacy?
- Assets, vulnerabilities, threats, attacks, and defenses
- Architecture for Communication Security
- Computer Security Strategy

# Why Security/Why we Worry about Security

- The word Security which can be inferred as the immunity from any risk or danger that may have undesired outcome.
- Before considering why we care about security, it's important to understand why we would care about security in general.
- We worry about security when we have something of value which is at risk of being harmed.
- Example: individuals store a lot of sensitive data online, such as financial information and medical information. If criminals get their hands on this data, they can monetize it and profit from it.
  - *What is the value in security?*
  - *Where do such threats come from?*
  - *What kind of risk are we talking about?*
  - *Who is the source of the threat?*

# Introduction to Information Security

- Every organization, whether public or private and regardless of size, has information it wants to protect.
    - It could be customer info, product or service info, employee info.
- Organizations have a responsibility to all their stakeholders to protect that information.
- Unfortunately, there aren't enough security professionals to go around.
- As a result, everyone in the organization must have a working knowledge of how to protect the information assigned to them and how to assist in preventing the unauthorized disclosure, damage, or destruction of that information.
- After all, *if you're not part of the solution, you're part of the problem.*

# Why study information security?

- To protect computers, networks, and the information they store, organizations are increasingly turning to information security specialists
- We begin by trying to answer the first question most students starting out in the field ask: *`Why study information security?`*

# The Growing Importance of IT Security and New Career Opportunities

- Increased services to both vendors and employees create worlds of possibilities in satisfying customer needs, but ...
- They also create risks to the confidentiality, integrity, and availability of confidential or sensitive data

# Increasing Demand by Government & Private Industry

- The number of information security specialist is expected to grow 36% from 2012 to 2022.
- Employment of information security analysts is projected to grow 33% from 2020 to 2030, much faster than the average for all occupations[1].
- The median annual wage for information security analysts was $102,600 in May 2021.
- Higher demand for expertly trained individuals
  - U.S. Bureau of Labor Statistics
    - The security of computer networks will continue to increase in importance as more business is conducted over the Internet
    - There will be a high demand of managers proficient in computer security issues
    - Source: `www.collegegrad.com/careers/manage30.shtml`
- Read 10 Reasons Why a Cyber Security Degree is Worth It

[1] *https://www.bls.gov/ooh/computer-and-information-technology/information-security-analysts.htm*

# Becoming an Information Security Specialist

- Getting a degree in information security will involve taking classes in security architecture, laws and ethics, access control, disaster recovery and planning
- Get the right certification
  - Certified Information Systems Security Professional (CISSP)
  - System Security Certified Practitioner (SSCP)
  - Global Information Assurance Certification (GIAC)
- Increase your disaster recovery and risk management skills
- Build a home laboratory
- Consider an internship in IS
- Take a second look at government jobs

# Schools Are Responding to Demands

- Homeland security is a hot topic
- Higher education is also responding to the need with new and robust certificate programs, degrees, and special-interest courses.
- Hundreds of community colleges, 4-year universities, and post-graduate programs are offering degrees and certificates in emergency preparedness, counterterrorism, and security
    - Department of Homeland Security supports the Naval Postgraduate School for Homeland Defense and Security https://www.chds.us.[2]
    - The school educates high-ranking emergency management and public safety officials about policy analysis, advanced strategy, and information technology.

[2] The Center for Homeland Defense and Security (CHDS)

# Achieving Security

- In the ideal world, we would like to achieve perfect security of information.
- It is impossible to protect everything against every attacker under all circumstances while maintaining usability (utility of the system).
- *Given enough time, tools, skills, and inclination, a hacker can break through any security measure*

# Security Mindset

- *What do we mean by the security mindset?*
    - Security mindset is the ability to be able to look for and identify potential or actual compromise.
        - This could be compromise or potential compromise of a process, system, application, operating system, platform, infrastructure and even a person

- You see an advertisement for a new product. What is your reaction?
- Is your first reaction:
    - *"Wow! This is such a cool product. I can't wait to use it!'*

- Or is your reaction:
    - *"Wow! This is a neat product but I wonder what are the potential consequences of using it? Does it work as advertised? Is it safe? Can something go wrong while using it? Can someone else exploit it?"*

- Read: How to think like a security professional

# Example: Nest Learning Thermostat

YouTube: How Nest Learning Thermostat Learns

- Read: Smart Nest Thermostat: A Smart Spy in Your Home

# Security Mindset

- We need to learn to think with a security mindset
- Security mindset
  - It requires you to think like an adversary - to be constantly thinking about how a malicious party might circumvent the goals of a system or product
    - *who is the bad actors, what possibly can exploit, what vulnerability do we have, and if they successful exploiting vulnerability, what the attack going to be.*
  - How could this system be attacked?
  - Who could attack this system?
  - Are they likely to attack the system?
  - What is the weakest point of attack?
  - How could this system be defended?
  - How effective will a given countermeasure be?
  - What is the trade-off between security, cost, and usability?
- Watch: Bruce Schneier: The Security Mindset

# Security Mindset

*"Security requires a particular mindset. Security professionals - at least the good ones - see the world differently. They can't walk into a store without noticing how they might shoplift. They can't use a computer without wondering about the security vulnerabilities. They can't vote without trying to figure out how to vote twice. They just can't help it".*
*Bruce Schneier*

# History of Information Security

- The history of information security begins with computer security.
- Computer security that is, the need to secure physical locations, hardware, and software from threats
- Computer security began immediately after the first mainframes were developed
  - Groups developing code-breaking computations during World War II created the first modern computers.
  - Multiple levels of security were implemented to protect these devices.
- Physical controls limiting access to sensitive military locations to authorized personnel
- During these early years, information security was a straightforward process composed predominantly of physical security and simple document classification schemes.
- The primary threats to security were physical theft of equipment, espionage against products of the systems, and sabotage.

# The 1960s

- During the Cold War, many more mainframe computers were brought online to accomplish more complex and sophisticated tasks.
- It became necessary to enable these mainframes to communicate via a less cumbersome process than mailing magnetic tapes between computer centers.
- In response to this need, the Department of Defense's Advanced Research Project Agency (ARPA) began to examine the feasibility of a redundant, networked communication system to support the military's exchange of information
- Larry Roberts[3] led the development of the ARPANET, which evolved into what we now know as the Internet.

[3] *Larry Roberts, known as the founder of the Internet*

# The 1970s and 80s

- ARPANET grew in popularity, as did its potential for misuse.
- Fundamental problems with ARPANET security were identified
  - Individual remote sites did not have sufficient controls and safeguards to protect data from unauthorized remote users.
  - Other problems included:
    - Vulnerability of password structure and formats
    - Lack of safety procedures for dial-up connections
    - Nonexistent user identification and authorizations
- Because of the range and frequency of computer security violations and the explosion in the numbers of hosts and users on ARPANET, network security was referred to as network insecurity.

# The 1970s and 80s

- Information security began with RAND Report R-609[4]. (paper that started the study of computer security and identified the role of management and policy issues in it).
  - The movement toward security that went beyond protecting physical computing devices and their locations began with a single paper sponsored by the Department of Defense, the Rand Report R-609
- The scope of computer security grew from physical security to include:
  - Securing the data
  - Limiting random and unauthorized access to data
  - Involving personnel from multiple levels of the organization in information security

[4] *The Rand Report R-609, which attempted to define the multiple controls and mechanisms necessary for the protection of a multilevel computer system. The document was classified for almost 10 years and released as Security Controls for Computer Systems: Report of Defense Science Board Task Force on Computer Security- RAND Report R-609-1*

# MULTICS[6]

- Early research on computer security research centered on a system called Multiplexed Information and Computing Service (MULTICS).
- First operating system was created with security integrated into core functions.
- Mainframe, time-sharing OS was developed in the mid-1960s by General Electric (GE), Bell Labs, and Massachusetts Institute of Technology (MIT).
- Several MULTICS key players[5] created a new operating system called UNIX.
  - While the MULTICS system implemented multiple security levels and passwords, the UNIX system did not.
  - The primary purpose of UNIX was text processing.
  - Not until the early 1970s did even the simplest component of security, the password function, became a component of UNIX.
- Late 1970s: The microprocessor expanded computing capabilities and security threats.

[5] *Ken Thompson, Dennis Ritchie, Rudd Canaday, and Doug McIlro*

[6] https://web.mit.edu/multics-history/

# The 1990s

- Networks of computers became more common, as did the need to connect them to each other.
- This gave raise to the Internet, the first global network of networks.
- Initially, network connections were based on de facto standards[7].
  - Because industry standards for interconnection of networks did not exist at that time.
  - These de facto standards did little to ensure the security of information
- In early Internet deployments, security was treated as a low priority.
  - At that time, when all Internet and e-mail users were presumably trustworthy computer scientists, mail server authentication and e-mail encryption did not seem necessary.

[7] *A de facto standard is one that has become accepted in practice but has not undergone any formal process to obtain consensus and may not even have publicly available documentation.*

# The 1990s

- Early computing approaches relied on security that was built into the physical environment of the data center that housed the computers.
- As networked computers became the dominant style of computing, the ability to physically secure a networked computer was lost, and the stored information became more exposed to security threats.
- In 1993, DEFCON conference established for those interested in information security.
- In the late 1990s and into the 2000s, many large corporations began publicly integrating security into their organizations.

*Antivirus products became extremely popular and Information security began to emerge as an independent discipline.*

# 2000 to present

- The Internet brings millions of unsecured computer networks into continuous communication with each other.
- Ability to secure a computer's data influenced by the security of every computer to which it is connected
- Growing threat of cyber attacks has increased the need for improved security
    - Made governments and companies more aware of the need to defend the computerized control systems of utilities and other critical infrastructure.
- The threat environment has grown from the semiprofessional hacker defacing Web sites for amusement to professional cybercriminals maximizing revenue from theft and extortion, as well as government-sponsored cyberwarfare groups striking military, government, and commercial targets.

# What is Security

- A state of being secure - to be free from danger or harm; also, the actions taken to make someone or something secure.
- "The protection of information and its critical elements, including systems and hardware that use, store, and transmit that information" (CNSS)[8].
- The protection of information and information systems from unauthorized access, use, disclosure, disruption, modification, or destruction in order to provide confidentiality, integrity, and availability.
- The Confidentiality, Integrity, and Availability Triad (CIA) is the information security model of most organizations when managing data.
- Necessary tools
    - policy, awareness, training, education, technology

[8] *The Committee on National Security Systems (CNSS)*

# Key Security Objectives: Three Security Goals

- In the context of computers, security generally means three things:
  - Confidentiality: Access to systems or data is limited to authorized parties
    - **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.
  - Integrity: Refer to the trustworthiness of data or resources, and it is usually phrased in terms of preventing improper or unauthorized change.
    - **Data integrity** (the content of the information): Assure information and programs are changed only in a specified and authorized manner.
    - **System integrity**: Assure 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.
    - Keep data and resources available for authorized use especially during emergency or disasters
    - The system or data is there when you want it

# CIA Triad

- The three security goals are confidentiality, integrity, and availability.
- These goals form the CIA Triad, the basic of all security program.
- The CIA Triad is a security model developed to help people think about important aspects of IT security
- CIA = Confidentiality, Integrity, and Availability
  - Was standard for computer security based on confidentiality, integrity, and availability
  - Now expanded into list of critical characteristics of information

# CIA Triad: loss of security

- Definition of a loss of security in each CIA triad:
- Confidentiality:
    - Prevent unauthorized reading of information
    - A loss of confidentiality is the unauthorized disclosure of information.
- Integrity:
    - Prevent unauthorized writing of information
    - A loss of integrity is the unauthorized modification or destruction of information

Availability:

- Ensures data is available in a timely manner when needed
    - Due to denial of service (DoS) threats
- A loss of availability is the disruption of access to or use of information or an information system.

# Security and reliability

- Security has a lot to do with “reliability”
- A secure system is one you can rely on to (for example):
  1. Keep your personal data confidential
  2. Allow only authorized access or modifications to resources
  3. Ensure that any produced results are correct
  4. Give you correct and meaningful results whenever you want them

# What is privacy?

- There are many definitions of privacy
- A useful one: informational self-determination
  - This means that you get to control information about you
  - Control means many things:
    - Who gets to see it
    - Who gets to use it
    - What they can use it for
    - Who they can give it to
    - etc.

# Security of an Information System

- Information System (IS) is the entire set of hardware, software data, people, procedures, and networks that enable a business to use information.
    - set of components necessary to use information as a resource in the organization
- Information security, sometimes shortened to *infosec*, is the practice of protecting information by mitigating information risks.

- We cannot protect information on its own.
- You need to look at the entire system within which the information exists.
- A system is only as strong as its weakest component.

# Security of an Information System

- Understand the system and its components.
- Identify assets.
- Identify vulnerabilities.
- Identify attacks.
- Identify adversaries.

*We worry about security when we have something of value and there is a threat source that poses some kind of risk could be harmed*

# Computer Security Concepts

- Asset
- Vulnerability
- Threat
- Attack
- Countermeasure or control

# Assets (System resource)

- Need to know what you are protecting!
- Asset: Things we might want to protect (Anything of value)
    - Physical Assets: Buildings, computers
    - Logical Assets: Intellectual property, reputation
- You need to know what there is to protect.
- You need to know what is worth protecting

# Assets of Computer Systems to Protect

The assets of a computer system can be categorized as follows:

- Hardware
  - Including computer systems and other data processing, data storage.
- Software
  - Including the operating system, system utilities, and applications.
- Data
  - Including files and databases, as well as security-related data, such as password files.
- Communication facilities and networks
  - Local and wide area network communication links, bridges, routers, and so on.

# Vulnerabilities

- Vulnerabilities: Weaknesses or gaps in the security system that could be exploited[1] to cause loss or harm
  - Its weakness or gabs in your security efforts. In other words, it is a known issue that allows an attack to succeed
- Examples:
  - A file server that doesn't authenticate its users
  - Bad passwords
  - Buggy software
  - Untrained employees
  - Lack of encryption
  - ...
- Categories of vulnerabilities
  - Corrupted (loss of integrity)
  - Leaky (loss of confidentiality)
  - Unavailable or very slow (loss of availability)

[1] *Exploits are the means through which a vulnerability can be leveraged for malicious activity by hackers; these include pieces of software, sequences of commands, or even open-source exploit kits.*

# Vulnerabilities

- General types of vulnerability correspond to the concepts of integrity, confidentiality, and availability:
    - The system can be corrupted, so it does the wrong thing or gives wrong answers (loss of integrity)
        - For example, stored data values may differ from what they should be because they have been improperly modified.
    - The system can become leaky (loss of confidentiality)
        - For example, someone who should not have access to some or all of the information available through the network obtains such access.
    - The system can become Unavailable or very slow (loss of availability)
        - That is, using the system or network becomes impossible or impractical.

# Threats

- Threats are potentials for vulnerabilities to turn into attacks on systems
- Represent potential cause of security harm to an asset
- i.e., a loss or harm that might befall a system
    - e.g., users' personal files may be revealed to the public

# Attacks

- Attacks (threats carried out) an action which exploits a vulnerability to execute a threat
- Attacks lead to compromises or security breaches.
- Examples:
  - Telling the file server you are a different user in an attempt to read or modify their files are ways of exploiting a vulnerability to damage assets
  - Bad passwords: using password crackers.
  - Buggy software: launching an SQL injection attack.
  - Untrained employees: tricking them to share their credentials.
  - Lack of encryption: eavesdropping on communications.
- Threat Action: An attack

# Attacker/Threat Agent/Threat Source

- Entity that attacks/carrying out the attack, or is threat to system (adversary, attacker, malicious user)
    - Cybercriminals: want to profit from your sensitive data for financial gain
    - Nation-states: countries do it for political advantage or for espionage.
    - Hacktivists: Activists who want others to notice their work to inspire action or change.

# Attacks

- Attacks can be classified as:
  - 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
- Attacks can also be classified based on the source/origin of the attacks:
  - Inside Attack
    - initiated by entity with authorized access to system.
  - Outside Attack
    - initiated by unauthorized user of system

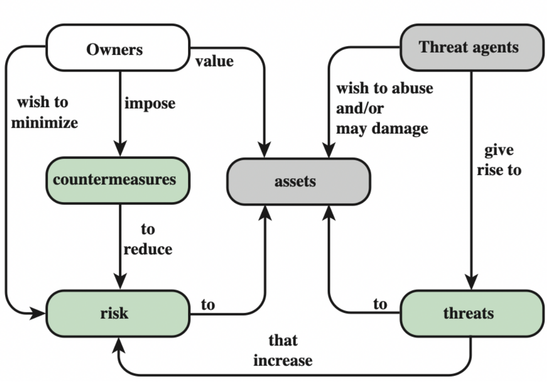
# Risk

- The potential for loss, damage or destruction of an asset as a result of a threat exploiting a vulnerability
- Examples of risk include:
  - Financial losses
  - Loss of privacy
  - Damage to your reputation
  - Legal implications
  - Even loss of life

# Control/Countermeasures

- Q: How can we defend against a threat?
  - A threat is blocked by control of vulnerability
- Means used to deal with security attacks
  - i.e., a mechanism that is designed to detect, prevent, or recover from a security attack.
    - *Ideally, a countermeasure can be devised to prevent a particular type of attack from succeeding. When prevention is not possible, or fails in some instance, the goal is to detect the attack and then recover from the effects of the attack*
  - Prevent, detect, respond, recover
- Even with countermeasures, vulnerabilities may exist, leading to risk to the assets
- Aim to minimize the risks

# Computer Security Concepts and relationships



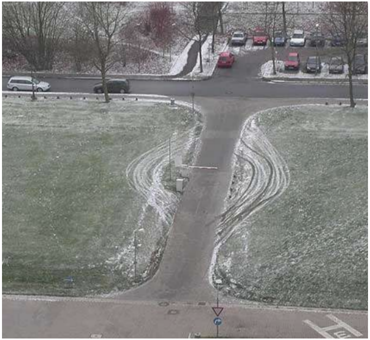
# Example of defense

- Threat: your car may get stolen
- How to defend?
  - Prevent: block the attack: Immobilizer? Is it possible to absolutely prevent?
  - Deter: make the attack harder or more expensive: Store your car in a secure parking facility
  - Deflect: : make yourself less attractive to attacker: Have sticker mentioning car alarm, keep valuables out of sight
  - Detect: notice that attack is occurring (or has occurred)?: Car alarms, OnStar
  - Recover: mitigate the effects of the attack: Insurance

# How secure should we make it?

- Principle of Easiest Penetration
  - “A system is only as strong as its weakest link”
  - The attacker will go after whatever part of the system is easiest for him, not most convenient for you.
  - In order to build secure systems, we need to learn how to think like an attacker!
- Principle of Adequate Protection
  - “Security is economic”
  - Don’t spend $100,000 to protect a system that can only cause $1,000 in damage

# Weakest link



# Balancing Information Security and Access

- Impossible to obtain perfect security
- Security should be considered balance between protection and availability
- Must allow reasonable access, yet protect against threats

# Defense of computer systems

- Remember we may want to protect any of our assets
    - Hardware, software, data
- Many ways to do this
    - Cryptography
    - Software Controls
    - Hardware Controls
    - Physical Controls
    - Policies and Procedures

# Cryptography

- Protecting data by making it unreadable to an attacker
- Authenticating users with digital signatures
- Authenticating transactions with cryptographic protocols
- Ensuring the integrity of stored data
- Aid customers' privacy by having their personal information automatically become unreadable after a certain length of time

# Software controls

- Passwords and other forms of access control
- Operating systems separate users' actions from each other
- Virus scanners watch for some kinds of malware
- Development controls enforce quality measures on the original source code
- Personal firewalls that run on your desktop

# Hardware controls

- Not usually protection of the hardware itself, but rather using separate hardware to protect the system as a whole
- Fingerprint readers
- Smart tokens
- Firewalls
- Intrusion detection systems[1]

[1] *An intrusion detection system is a device or software application that monitors a network or systems for malicious activity or policy violations*

# Physical controls

- Protection of the hardware itself, as well as physical access to the console, storage media, etc.
- Locks
- Guards
- Off-site backups
- Don't put your data center on a fault line in California
- Don't put your nuclear power plant in a tsunami zone

# Security Policy

- Set of the rules and practices that specifies how a system provides security services to protect assets.
- Refers to clear, comprehensive, and well-defined plans, rules, and practices that regulate access to an organization's system and the information included in it.

# Policies and procedures

- Non-technical means can be used to protect against some classes of attack
- If an employee connects his own Wi-Fi access point to the internal company network, that can accidentally open the network to outside attack
    - So don't allow the employee to do that!
- Rules about choosing passwords
- Training in best security practices

# High-level plan for thinking about security

- What is Security: Achieving some goal in the presence of an adversary.
    - *Many systems are connected to the Internet, which has adversaries. Thus, design of many systems might need to address security, i.e., will the system work when there's an adversary?*
- Systematic thought is required for successful defense.
- High-level plan for thinking about security:
    - Policy: Some plan (rules) that will get your system to achieve the goal. The goals you want to achieve.
        - e.g. set permissions on F so its readable only by Alice's processes.
        - e.g. require a password and two-factor authentication.
        - Common goals: confidentiality, integrity, availability.
    - Threat model: Assumptions about what the attacker can do.
        - e.g., can guess passwords, cannot physically steal our server. Better to err on the side of assuming attacker can do something.
    - Mechanism: Software/Hardware that your system uses to enforce policy.
        - e.g., user accounts, passwords, file permissions, encryption.
        - policy might include human components (e.g., do not share passwords) that's outside of the scope of the security mechanisms
    - Resulting goal: As long as the threat model is correct, hopefully, will satisfy the policy. i.e., no way for adversary within threat model to violate policy.
- Building secure systems is hard. *Why?*

# Achieve perfect security?

- *What's the point if we can't achieve perfect security?*
  - Perfect security is rarely required.
  - Make cost of attack greater than the value of the information.
    - So that perfect defenses aren't needed.
  - Make our systems less attractive than other peoples'.
    - Works well if attacker e.g. just wants to generate spam.
  - Find techniques that have big security payoff (i.e. not merely patching holes).
    - We'll look at techniques that cut off whole classes of attacks.
    - Successful: popular attacks from 10 years ago are no longer very fruitful.
  - Sometimes security increases value for defender:
    - VPNs might give employees more flexibility to work at home.
    - Sandboxing (JavaScript, Native Client) might give me more confidence to run software I don't fully understand.

# Architecture for Communications Security

- In order to let different devices (computers, routers, cellular phones) to communicate data in a standardized way, communication protocols had been defined.
- Systematic approach to define requirements for security and approaches to satisfying those requirements.
- ITU-T [9]Recommendation X.800, Security Architecture for OSI
  - OSI Security Architecture
  - Provides abstract view of main issues of security
  - Security aspects: Attacks, mechanisms and services
  - Focuses on security of networks and communications systems
  - Concepts also apply to computer security

[9] The International Telecommunication Union (ITU) Telecommunication Standardization Sector (ITU-T) is a United Nations sponsored agency that develops standards, called Recommendations, relating to telecommunications and to open systems interconnection (OSI). The ITU-T organization published a large set of protocols

# Aspects of Security

The OSI security architecture focuses on security attacks, mechanisms, and services:

- Security Attack
  - Any action that attempts to compromise the security of information owned by an organization.
- Security Mechanism
  - A method that is designed to detect, prevent, or recover from a security attack.
    - mechanism that is built to identify any breach of security or attack on the organization
    - also responsible for providing ways in which an attack can be prevented as soon as it is detected
  - A mechanism might operate by itself, or with others, to provide a particular service.
  - Common security mechanisms are as follows:
    - Cryptography
    - Message digests and digital signatures
    - Digital certificates
    - Public Key Infrastructure (PKI)

# Aspects of Security

- Security Service
  - A service that enhances the security of data processing systems and information transfers.
  - Refer to the different services available for maintaining the security and safety of an organization.
  - Intended to counter security attacks, and they make use of one or more security mechanisms to provide the service.
  - They help in preventing any potential risks to security.
    - Uses security mechanisms to enhance the security of information or facilities in order to stop attacks
    - i.e., security services implement security policies and are implemented by security mechanisms.
- Security services and mechanisms are closely related because a mechanism or combination of mechanisms are used to provide a service

# Security Services

- Authentication
- Access Control
- Data Confidentiality
- Data Integrity
- Non-repudiation
- Availability

# Security Services: Authentication

- Who created or sent the data
- Concerned with assuring that a communication is authentic:
  - In the case of a single message, assures the recipient that the message is from the source that it claims to be from
  - In the case of ongoing interaction, assures the two entities are authentic and that the connection is not interfered with in such a way that a third party can masquerade as one of the two legitimate parties
- Two specific authentication services
  - Peer entity authentication
  - Data origin authentication

# Security Services: Access Control

- Prevent misuse of resources
  - ensure only authorized users have access to the available resources.
- The ability to limit and control the access to host systems and applications via communications links.
- To achieve this, each entity trying to gain access must first be identified, or authenticated, so that access rights can be tailored to the individual

# Security Services: Data Confidentiality

- Responsible for ensuring that the data is kept extremely safe from third-party intruders.
- The protection of transmitted data from passive attacks
  - Broadest service protects all user data transmitted between two users over a period of time
  - Narrower forms of service includes the protection of a single message or even specific fields within a message
- The protection of traffic flow from analysis
  - This requires that an attacker not be able to observe the source and destination, frequency, length, or other characteristics of the traffic on a communications facility

# Security Services: Data Integrity

- Ensure that the transmitted information received by the receiver is well-authenticated and there is no tampering with the information received.
- Can apply to a stream of messages, a single message, or selected fields within a message
- Connection-oriented integrity service, one that deals with a stream of messages, assures that messages are received as sent with no duplication, insertion, modification, reordering, or replays
- A connectionless integrity service, one that deals with individual messages without regard to any larger context, generally provides protection against message modification only

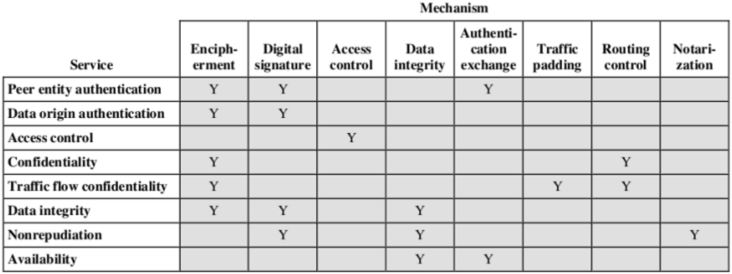
# Security Services: Nonrepudiation

- Prevents either sender or receiver from denying a transmitted message
- When a message is sent, the receiver can prove that the alleged sender in fact sent the message
- When a message is received, the sender can prove that the alleged receiver in fact received the message

# Security Services

- Authentication
  - Assure that the communicating entity is the one that it claims to be. (Peer entity and data origin authentication)
- Access Control
  - Prevent unauthorized use of a resource
- Data Confidentiality
  - Protect data from unauthorized disclosure
- Data Integrity
  - Assure data received are exactly as sent by authorized entity (has not been altered)
- Non-repudiation
  - Protect against denial of one entity involved in communications of having participated in communications
- Availability
  - System is accessible and usable on demand by authorized users according to intended goal

# Security Services and Mechanisms

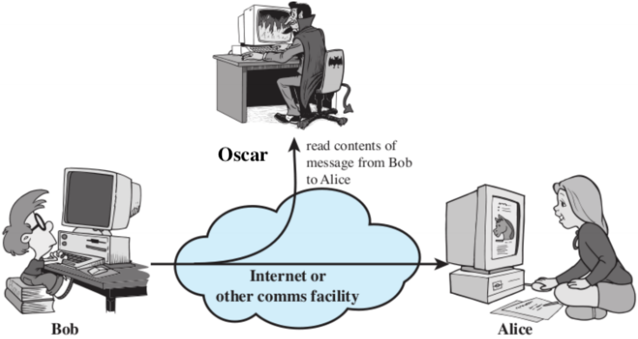


| | Mechanism | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Service | Encipherment | Digital signature | Access control | Data integrity | Authentication exchange | Traffic padding | Routing control | Notarization |
| Peer entity authentication | Y | Y | | | Y | | | |
| Data origin authentication | Y | Y | | | | | | |
| Access control | | | Y | | | | | |
| Confidentiality | Y | | | | | | Y | |
| Traffic flow confidentiality | Y | | | | | Y | Y | |
| Data integrity | Y | Y | | Y | | | | |
| Nonrepudiation | | Y | | Y | | | | Y |
| Availability | | | | Y | Y | | | |

# Attacks on Communication Lines

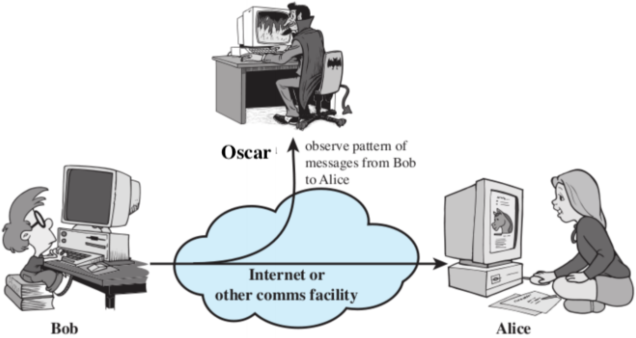
- Passive Attack
  - Attempt to learn or make use of information, but not affect system resources, e.g.,
    1. Release message contents
    2. Traffic analysis
  - Relatively hard to detect, but easier to prevent (usually by encryption)
- Active Attack
  - Attempt to alter system resources or affect their operation.
  - i.e., involve some modification of the data stream or the creation of a false stream,
  - Can be subdivided into four categories:
    1. Masquerade
    2. Replay
    3. Modification of messages
    4. Denial of service
  - Relatively hard to prevent (because it would require physical protection of all communications facilities and paths at all times), but easier to detect

# Release Message Contents


Oscar
read contents of message from Bob to Alice
Internet or other comms facility
Bob
Alice

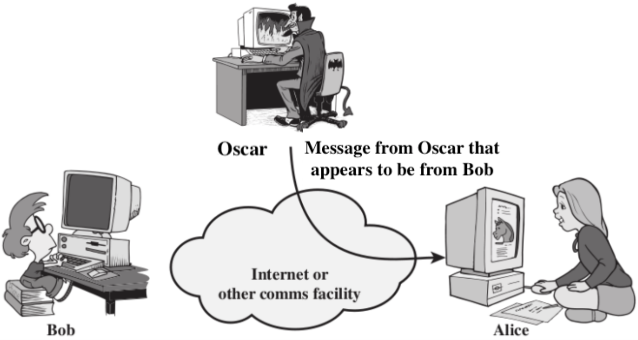
*Message Content is the type of passive Attack that involves the intruder stealing all the message/data transmitted. Here, the information gathered by the intruder is stolen unethically.*

# Traffic Analysis


Oscar
observe pattern of messages from Bob to Alice
Internet or other comms facility
Bob
Alice

*Masked Traffic Analysis: This type of passive Attack involves messages/data being encrypted before transmission. Here, the message being masked/encrypted the intruder can't read the message but only understand the pattern and length of encryption.*

# Masquerade Attack


Oscar
Message from Oscar that appears to be from Bob
Internet or other comms facility
Bob
Alice

*Masquerade is a type of active attack, the attacker tampers the information received by the receiver by claiming itself as the sender.*

- Takes place when one entity pretends to be a different entity
- Usually includes one of the other forms of active attack.
  - For example, authentication sequences can be captured and replayed after a valid authentication sequence has taken place

# “On the Internet, nobody knows you’re a dog”[10]

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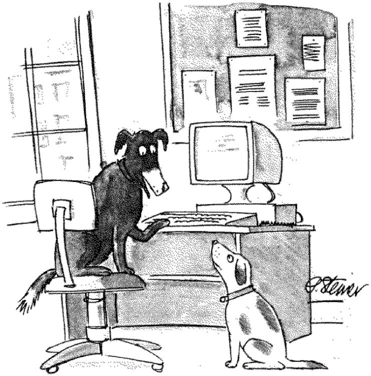
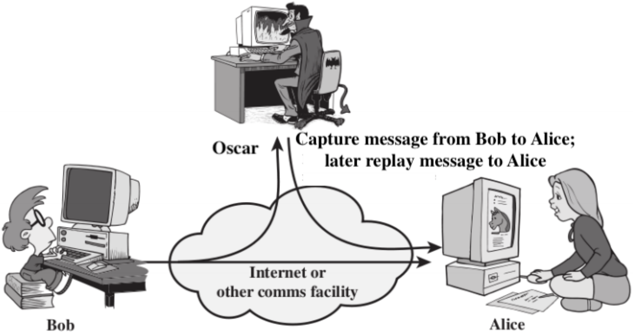


*“On the Internet, nobody knows you’re a dog.”*

[10] Credit: Peter Steiner, The New Yorker magazine

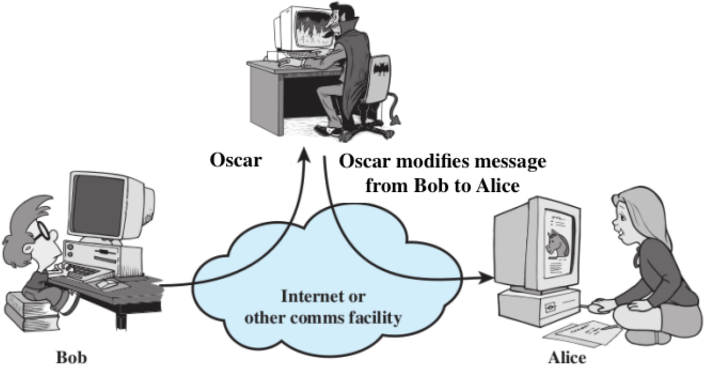
# Replay Attack


Oscar
Capture message from Bob to Alice;
later replay message to Alice
Internet or
other comms facility
Bob
Alice

*Replay is a type of active attack, the attacker attacks the transmitted message through a passive channel and make the final message received by the receiver look like it's not authorized and safe*

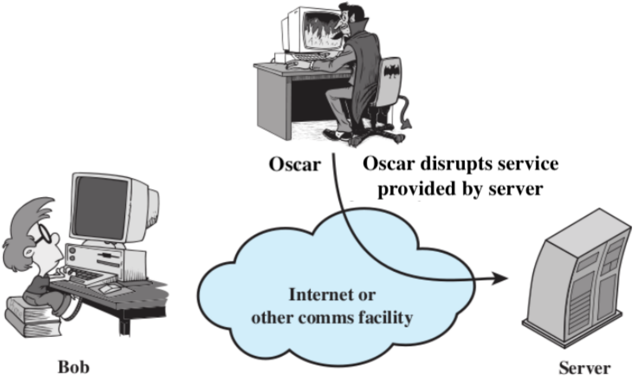
- Involves the passive capture of a data unit and its subsequent retransmission to produce an unauthorized effect

# Modification Attack


Oscar
Oscar modifies message from Bob to Alice
Internet or other comms facility
Bob
Alice

- Some portion of a legitimate message is altered, or messages are delayed or reordered to produce an unauthorized effect

# Denial of Service Attack


Oscar
Oscar disrupts service provided by server
Internet or other comms facility
Bob
Server

*Denial of Services is a type of active attack, the receiver is prevented from receiving the transmitted message as there is an overflow of requests to the receiver, which makes the services hampered from their usual behavior.*

- Prevents/inhibits the normal use or management of communications facilities

# Computer Security Strategy and Principles

The first step in devising security services and mechanisms is to develop a security policy.

- Policy: What is the security scheme supposed to do?
  - Informal description or formal set of rules of desired system behavior
  - Consider: assets value; vulnerabilities; potential threats and probability of attacks
  - Trade-offs: Ease of use vs security; cost of security vs cost of failure and recovery
- Implementation: How does it do it?
  - Security implementation involves four complementary courses of action
    - Prevention, detection, response, recovery
- Assurance: Does it really work?
  - Security consumers want to feel that the security infrastructure of their systems meet security requirements and enforce security policies.
    - Assurance: degree of confidence that security measures work as intended
    - Evaluation: process of evaluating system with respect to certain criteria

# The Cast of Characters

- Alice and Bob are the **good guys**

- Eve/Oscar are the **bad guys**

- Eve is our generic “intruder”

# Think Like Eve/Oscar

- Good guys must think like bad guys!
- A police detective
    - Must study and understand criminals
- In information security
    - We want to understand Eve's/Oscar's methods
    - We might think about Eve's/Oscar's motives
    - We'll often pretend to be Eve/Oscar

# Think Like Eve/Oscar

- Think like the bad guy
- Always look for weaknesses
- Find the weak link before Eve does
- It's OK to break the rules
- But don't do anything illegal!
- But, we cannot act like Eve/Oscar
    - Except in this class
    - and even then, there are limits

# Standardizations

- 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

# Recap

- What is our goal in this course?
  - Identify security and privacy issues
  - Design systems that are more protective of security and privacy
- What is security?
  - Confidentiality, Integrity, Availability
- What is privacy?
  - Informational self-determination

# Recap

- Assets, vulnerabilities, threats, attacks and controls
  - You control a vulnerability to prevent an attack and block a threat
- Methods of defense
  - Cryptography, software controls, hardware controls, physical controls, policies and procedures
- The OSI security architecture
  - Security attacks
  - Passive attacks
  - Active attacks
- Security services
- Authentication, Access control , Data confidentiality , Data integrity , Nonrepudiation , Availability service
- Security mechanisms

# Reading

- Information Security: Principles and Practice, 2nd edition
  - Chapter 1 (Till 1.2.2)
- Computer Security: principles and practice
  - Chapter 1: 1.1, 1.2, 1.7
- Security in Computing
  - Chapter 1: 1.1, 1.2, 1.4