

ISA 666

Internet Security Protocols

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Course Description

- Comprehensive Introduction to the Security Problems in the Internet
 - What are the security issues?
 - What techniques are available?
 - The tradeoffs!
- Study Principles, Techniques and Their Applications in Building Secure Internet
 - Basic cryptography
 - Authentication, authorization
 - Digital signature

About the Instructor

- Dr. Duminda Wijesekera, Associate Professor of Information & Software Engineering
 - <http://www.ise.gmu.edu/~duminda/index.html>
 - 703-993-1578
 - Office: Room 351 Science & Technology II
 - Office hours: Monday 3:00PM ~ 4:00PM
Tuesday 3:00PM ~ 4:00PM
or by appointment

Course Description Continued...

- Examine Existing Internet Security Techniques and Protocols
 - IPSEC/VPN
 - Firewall
 - SSL/TLS
- Advanced Internet Security Techniques
 - Intrusion Tracing
 - Steganography/Information Hiding
- Limitations of Existing Security Protocols
- Open Problems in the Internet Security

About the TA

- Min Xu
 - mxu@gmu.edu
- Office hours:
 - Wednesday 3:00PM ~ 4:00PM

Course Objectives

- Gain Understanding of Basic Issues, Concepts, Principles, and Techniques in Internet Security.
 - Basic security concepts
 - Cryptography
 - Authentication, authorization
 - Network security
 - Intrusion response
- Be Able to Determine Appropriate Mechanisms for Particular Security Requirement
 - Only you (or person authorized by you) can change your address record
 - Only I can give your grade in this class

Course Outline

- Network Based Attacks
 - Passive, active attacks
 - Eavesdropping, unauthorized access, modification, deletion, forgery of confidential information
 - Denial-of-service attack
- Basic Security Concepts
 - Confidentiality, integrity, identity, anonymity, availability
 - Security policies, security mechanisms, assurance

Course Outline (Cont'd)

- IPSEC/VPN
 - Security association
 - Authentication header (AH)
 - Encapsulating Security Payload (ESP)
 - Transport, tunnel modes
 - Virtual Private Network (VPN)
- IPSEC Key Management
 - ISAKMP/Oaklay
- PKI

Course Outline (Cont'd)

- Cryptography
 - Basic number theory
 - Secret key cryptosystems
 - Public key cryptosystems
 - Hash function
 - Key management

Course Outline (Cont'd)

- Firewall
 - Packet filtering
 - Stateful inspection
 - Transparent proxy
 - Enclave
 - Firewall limitations
 - Firewalls and Virtual Private Network
- SSL/TSL

Course Outline (Cont'd)

- Identification and Authentication
 - Basic concepts of identification and authentication
 - Password authentication
 - Kerberos
 - Security handshake pitfalls
 - Attack on authentication and identification
 - Identity theft
 - Impersonate somebody else

Course Outline (Cont'd)

- Intrusion Tracing
 - IP Spoofing
 - Stepping Stones
 - Reflector
 - Zombie
- Intrusion Response
 - Blocking?
 - Rate limiting?

Course Outline (Cont'd)

- Advanced Topics
 - Anonymity and privacy
 - Steganography/information hiding
 - Virus, worms, Trojan horse

On-line Resources

- WWW page:
 - <http://www.ise.gmu.edu/~duminda/classes/fall05/ise666.html>
 - For course materials, e.g., lecture slides, homework files, papers, tools, etc.
 - Will be updated frequently. So check frequently.

Prerequisites

- INFS 612 (Data Communication and Distributed Processing) or Equivalent
- INFS 601 (Operating Systems) or Equivalent
- Strong Programming
- Basic Knowledge and Skills in Discrete Mathematics

Grading

- **Assignments 30%, Midterm 40%, Term paper/project 30% (No final exam)**
- The Final Grades Are Computed According to the Following Rules:
 - A+: $\geq 95\%$; A: [90%, 95%]; A-: [85%, 90%];
 - B+: [80%, 85%]; B: [75%, 80%]; B-: [70%, 75%];
 - C+: [66%, 70%]; C: [63%, 66%]; C-: [60%, 63%];
 - D+: [56%, 60%]; D: [53%, 56%]; D-: [50%, 53%];
 - F: $< 50\%$.
- The Boundaries between Grades are Strict
 - Score of 84.999% would be a B+, rather than A-.

Textbook and Handouts

- Required Textbook
 - Charlie Kaufman, Radia Perlman, and Mike Speciner, *Network Security: Private Communication in a Public World, 2nd Edition*, Prentice Hall, ISBN: 0-13-046019-2.
- Reference Book
 - William Stallings, *Network Security Essentials, 2nd Edition*, Prentice Hall.
- Research papers listed on the course website (TBA).

Policies on Late Submissions

- Homework and Term Paper/Project Deadlines Will Be Hard.
- Late Homework Will Be Accepted with a 10% Penalty in Score for Each Day Past Due.
- Once a Homework Assignment is Discussed in Class, No Late Submissions Will Be Accepted.
- Late Submission of Term Paper/Project Will NOT Be Accepted

Policies on Absences

- You may be excused from an exam only with a university approved condition, with proof. For example, if you cannot take an exam because of a sickness, we will need a doctor's note.
- Events such as going on a business trip or attending a brother's wedding are not an acceptable excuse for not taking an exam or present term paper/project at its scheduled time and place.
- You will have one chance to take a makeup exam if your absence is excused. There will be no makeup for homework assignments.

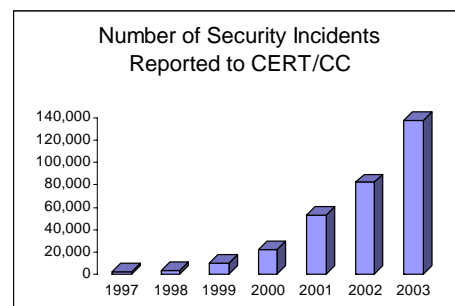
Term Paper/Project (Cont'd)

- To Be Done Individually.
- Proposal
- Presentation
- Final Report
- Suggested Topics (see course website)
- Or Pick Your Own Topic.

Academic Integrity

- All University, School, and Department Policies Against Academic Dishonesty Will Be Strictly Enforced.
- University Academic Policies at
 - <http://www.gmu.edu/catalog/apolicies/#Anchor12>
- ISE Department Honor System and Code
 - <http://www.ise.gmu.edu/Honor.html>

Security Problems on Internet Connected Computers

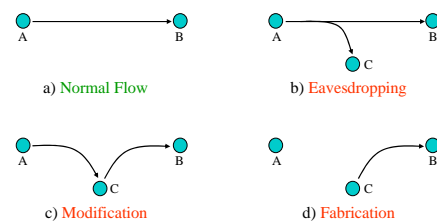


Term Paper/Project

- Can Be:
 - Research Paper
 - Work on original research problem with **original technical contribution**
 - Survey Paper
 - **Comprehensive** summary of a particular topic
 - Design of New Algorithms, Protocols or New Attacks!
 - Should justify the usefulness
 - Analysis/Evaluation of Existing Algorithms, Protocols.
 - Provide **new insights**
 - Implementation and Experimentation.
 - Better implementation of existing algorithm, protocols

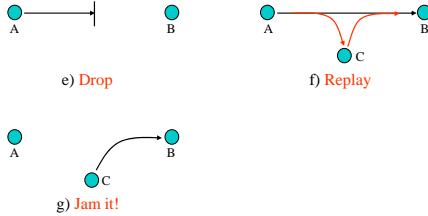
Network Security Problems

- Start From The Basics



Network Security Problems (Cont'd)

Start From The Basics



Real-World Network Based Attacks

- Distributed Denial of Service (DDOS) Attacks
- Worm and Virus Attacks (e.g., worm sasser)
- Monitoring and Capture of Network Traffic
 - User IDs, passwords, and other information are often stolen on Internet
- Exploitation of Software Vulnerability (MS-Windows)
- Unauthorized Access to Resources
 - Disclosure, modification, and destruction of resources
- Compromised System Used as Stepping Stone
- Masquerade as Authorized User or End System
- Data driven attacks
 - Importation of malicious or infected code
- E-Mail Forgery

Network Security Concepts

- Confidentiality
 - Prevent information from being exposed to unintended party
- Integrity
 - Assure that the information has not been tempered
- Identity
 - Assure that the party of concern is authentic - it is what it claims to be
- Availability
 - Assure that unused service or resource is available to legitimate users
- Anonymity
 - Assure that the identity of some party is remain anonymous
- Non-Repudiation
 - Assure that authenticated party has indeed done something and it can not deny it

Contributing Factors

- Lack of Awareness of Threats and Risks of From the Network
 - Security measures are often not considered until an Enterprise has been penetrated by malicious users
- Wide-Open Network Policies
 - Many Internet sites allow wide-open Internet access
- Vast Majority of Network Traffic is Unencrypted
 - Network traffic can be monitored and captured

Commercial Example

- Confidentiality
 - An employee should not come to know the salary of his manager
- Integrity
 - An employee should not be able to modify the employee's own salary
- Identity
 - An employee should be able to uniquely identify and authenticate himself/herself
- Availability
 - Paychecks should be printed on time as stipulated by law
- Anonymity
 - The manager should not know who had a critical review for him
- Non-repudiation
 - Once the employee has cashed out the paycheck, he/she can't deny it

Contributing Factors (Cont'd)

- Lack of Security in TCP/IP Protocol Suite
 - Most TCP/IP protocols were not built with security in mind
 - Work is actively progressing within the Internet Engineering Task Force (IETF)
- Complexity of Management of Network Security
- Exploitation of Software (e.g., Protocol Implementation) Bugs
 - Example: Sendmail bugs
- Attacker' Skills Keep Improving

Existing Internet Security Mechanisms

- Prevention
 - Firewall
 - Authentication, authorization
 - IPSEC/VPN
 - Access control
 - Encryption
- Detection
 - Auditing
 - Misuse detection
 - Anomaly detection
- Survivability
- Response

Security by Legislation

- Security by legislation says that if we instruct our users on how to behave we can secure our systems
- **It is a bad idea**
- For example
 - Users should not share passwords
 - Users should not write down passwords
 - Users should not type in their password when someone is looking over their shoulder
- User awareness and cooperation is important, but cannot be the principal focus for achieving security

Existing Internet Security Mechanisms

- Security mechanisms implement functions that help to *prevent, detect, tolerate, respond* to security attacks
- Prevention is ideal, but...
 - Detection seeks to prevent by threat of punitive action
 - Detection requires that the audit trail be protected from alteration
- If can't completely prevent attack from happening, detection is the only option
- There could be attacks we can't detect, then live with it - survivable system
- Once detect the attack, then what? Active response!!!
- Cryptography underlies (almost) all security mechanisms

Unique Aspects of Security Problem

- **The Whole System is as Strong as Its Weakest Point**
- **The Root Cause of Security Problem is Not Computer, But Human Being**
- **Ever Changing - Moving Target**
 - countermeasures by adversary
- **Conflicting Requirements**
 - Identity/authentication
 - Anonymity

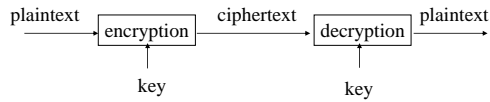
Security by Obscurity

- Security by obscurity says that if we hide the inner workings of a system it will be secure
- **It is a bad idea**
- Less and less applicable in the emerging world of vendor-independent open standards
- Less and less applicable in a world of widespread computer knowledge and expertise

Cryptography

- Cryptography
 - Comes from Greek word
 - Original meaning: The art of secret writing
 - Becoming a science that relies on mathematics (number theory, algebra)
 - Process data into intelligible form, reversible, without data loss
 - Usually one-to-one (not compression)

Encryption/Decryption



- Plaintext: a message in its original form
- Ciphertext: a message in the transformed, unrecognized form
- Encryption: the process that transforms a plaintext into a ciphertext
- Decryption: the process that transforms a ciphertext to the corresponding plaintext
- Key: the value used to control encryption/decryption.

Security of An Encryption Algorithm

- Unconditionally secure
 - It is impossible to decrypt the ciphertext
 - One-time pad (the key is as long as the plaintext)
- Computationally secure
 - The cost of breaking the cipher exceeds the value of the encrypted information
 - The time required to break the cipher exceeds the useful lifetime of the information

Cryptanalysis

- Ciphertext only:
 - Analyze only with the ciphertext
 - Example: Exhaustive search until “recognizable plaintext”
 - Smarter ways available
- Known plaintext:
 - Secret may be revealed (by spy, time), thus <ciphertext, plaintext> pair is obtained
 - Great for mono-alphabetic ciphers

Secret Keys v.s. Secret Algorithms

- Security by obscurity
 - We can achieve better security if we keep the algorithms secret
 - Hard to keep secret if used widely
 - Reverse engineering, social engineering
- Publish the algorithms
 - Security of the algorithms depends on the secrecy of the keys
 - Less unknown vulnerability if all the smart (good) people in the world are examine the algorithms

Cryptanalysis (Cont'd)

- Chosen plaintext:
 - Choose text, get encrypted
 - Useful if limited set of messages
- Chosen ciphertext:
 - Choose ciphertext
 - Get feedback from decryption, etc.

Secret Keys v.s. Secret Algorithms (cont'd)

- Commercial world
 - Published
 - Wide review, trust
- Military
 - Keep algorithms secret
 - Avoid giving enemy good ideas
 - Military has access to the public domain knowledge anyway.
- Security of a secure protocol should be based on the secrecy of the keys, rather than based on obscurity

Some Trivial Codes

- Caesar cipher: substitution cipher:
 - Replace each letter with the one 3 letters later
 - A → D, B → E
- Captain Midnight Secret Decoder rings:
 - shift variable by n : IBM → HAL
 - only 26 possibilities

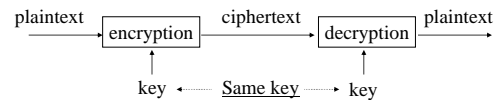
Types of Cryptography

- Number of keys
 - Hash functions: no key
 - Secret key cryptography: one key
 - Public key cryptography: two keys - public, private
- The way in which the plaintext is processed
 - Block cipher: divides input elements into blocks
 - Stream cipher: process one element (e.g., bit) a time

Some Trivial Codes (Cont'd)

- Mono-alphabetic cipher:
 - generalization, arbitrary mapping of one letter to another
 - $26!$, approximately 4×10^{26}
 - statistical analysis of letter frequencies

Secret Key Cryptography



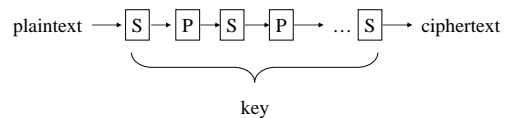
- Same key is used for encryption and decryption
- Also known as
 - Symmetric cryptography
 - Conventional cryptography

Some Trivial Codes (cont'd)

- Poly-alphabetic Ciphers
 - A set of related mono-alphabetic substitution rules is used
 - A key determines which particular rule is chosen for a given transformation

Secret Key Cryptography (cont'd)

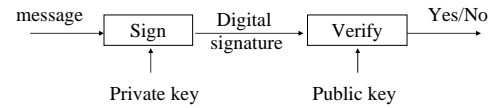
- Basic technique
 - Product cipher:
 - Multiple applications of interleaved substitutions and permutations



Secret Key Cryptography (cont'd)

- Ciphertext approximately the same length as plaintext
- Examples
 - Stream Cipher: RC4
 - Block Cipher: DES, IDEA, AES

Public Key Cryptography (Cont'd)



- Another mode: digital signature
 - Only the party with the private key can create a digital signature.
 - The digital signature is verifiable by anyone who knows the public key.
 - The signer cannot deny that he/she has done so.

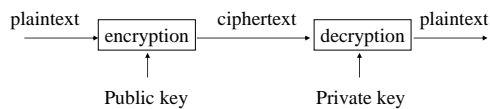
Applications of Secret Key Cryptography

- Transmitting over an insecure channel
 - Challenge: How to share the key?
- Secure Storage on insecure media
- Authentication
 - Challenge-response
 - To prove the other party knows the secret key
 - Must be secure against chosen plaintext attack
- Integrity check
 - Message integrity code (MIC)

Applications of Public Key Cryptography

- Data transmission:
 - Alice encrypts m_a using Bob's public key e_B . Bob decrypts m_a using his private key d_B .
- Storage:
 - Can create a safety copy: using public key of trusted person.
- Authentication:
 - No need to store secrets, only need public keys.
 - Secret key cryptography: need to share secret key for every person to communicate with.

Public Key Cryptography



- Invented/published in 1975
- A public/private key pair is used
 - Public key can be publicly known
 - Private key is kept secret by the owner of the key
- Much slower than secret key cryptography
- Also known as
 - Asymmetric cryptography

Applications of Public Key Cryptography (Cont'd)

- Digital signatures
 - Sign hash $H(m)$ with the private key
 - Authorship
 - Integrity
 - Non-repudiation: can't do with secret key cryptography
- Key exchange
 - Establish a common session key between two parties

Hash Algorithms

Message of arbitrary length → Hash H → A fixed-length short message

- Also known as
 - Message digests
 - One-way transformations
 - One-way functions
 - Hash functions
- Length of $H(m)$ much shorter than length of m
- Usually fixed lengths: 128 or 160 bits

Applications of Hash Functions (Cont'd)

- Password hashing
 - Doesn't need to know password to verify it
 - Store $H(\text{password} + \text{salt})$ and salt, and compare it with the user-entered password
 - Salt makes dictionary attack more difficult
- Message integrity
 - Agree on a secret key k
 - Compute $H(m|k)$ and send with m
 - Doesn't require encryption algorithm, so the technology is exportable

Hash Algorithms (Cont'd)

- Desirable properties of hash functions
 - Performance: Easy to compute $H(m)$
 - One-way property: Given $H(m)$ but not m , it's difficult to find m
 - Weak collision free: Given $H(m)$, it's difficult to find m' such that $H(m') = H(m)$.
 - Strong collision free: Computationally infeasible to find m_1, m_2 such that $H(m_1) = H(m_2)$

Applications of Hash Functions

- Primary application

– Generate/verify digital signature

