GEORGE MASON UNIVERSITY

Network Security - ISA 656

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Course Overview

What is this Course about?

- Network & Computer (in)security
- Network security — protect the network infrastructure, and secure the end-to-end communications
- Not entirely true — we also focus on security of networked applications

Why Network Security?

- Touches every aspect of network and system design and implementation
- Different mentality from other disciplines
  - "Does it work?" vs "Can it be broken?"
  - "Is the fix going to break something else?"
- Learn to think differently :-)

Importance of network security

- Increasingly large deployments of networked computers
- Sensitive information/resources are coming online
- Personal information
- Financial services
- Military operations
- Critical Infrastructure
- Enormous number of users, vast amount of money
- Cyber-attacks can cause significant economic damage

How to Think About Insecurity

- The bad guys don't follow the rules
- To understand how to secure a system, you have to understand what sort of attacks are possible
- Note that that is *not* the same as actually launching them...

Course Objectives

- Learn how to design secure networked systems
- Quantify the cost and tradeoffs of security
- Determine where to apply/use cryptography (Cryptography not a prerequisite!)
- Appreciate the role of correct software
- Prevent?/Mitigate/Limit the security threats that step bad software
- Get hands-on knowledge practicing on real systems in the lab!

Administrivia

Course Location and Time

- Always check the page website for new material:
  `http://ise.gmu.edu/~astavrou/isa656_F07.html`
- Time: Tuesday 7:20 pm - 10:00pm
- Room: Robinson Hall A, room A247
- Lab: Science and Technology I 128
- Lab Meeting: Scheduled the same time as the class, usually every third lecture (you will be notified in advance)
- We will always meet at Robinson Hall A, room A247 and then proceed to labs

Course Structure

- Lectures and Laboratory Sessions
- Approximately five homework assignments, all with programming and non-programming components
- Group Project or Midterm and a Final

Prerequisites

- CS 555, or General Networking:
  - Network layers
  - Basics of TCP/IP
  - Difference between IP, ICMP, TCP, and UDP
  - Port numbers and sequences numbers
  - Some understanding of the TCP flags
- ISA 562 or understanding of network protocols
- Understand how to use "make", the compiler, etc.
- Programming in either C or Java

Readings

- Kaufman, Perlman, and Speciner. *Network Security: Private Communication in a Public World, Second Edition*, Prentice Hall PTR, 2002, ISBN 0130460192. **Required**.
- Cheswick, Bellovin, and Rubin. *Firewalls and Internet Security: Repelling the Wily Hacker, Second Edition*, Addison-Wesley Professional, 2003, ISBN 020163466X. (Recommended)
- Research papers and reference manuals (RFCs etc.) (Provided on the class web site)

Grading

Midterm/Project	20%
Final	25%
Homeworks	50%
Class Participation	5%

In addition: extra credit assignments (why?)

Exams will be open book having part of the exam in the lab.

Office Hours & TAs

Instructor: Angelos Stavrou <astavrou@gmu.edu>
Office: 441 Science & Technology II
Hours: Monday 7 - 9pm & by appointment

TA: Ahmed K Alazzawe <aalazza1@gmu.edu>
Office: Adjunct office, Science & Technology II
Hours: Friday 7 - 9pm & by appointment

Grading Logistics

- For grading issues, approach the TA within two weeks; if you don't receive a satisfactory answer, contact me.
- For issues relating to *this class*, email astavrou@ise.gmu.edu. . .
- The TA should be your first contact point but you can also contact me with any questions or problems related to the class (or security in general) .

Contacting Me

- You don't need to be in trouble to talk with me...
- You can always arrange an appointment with me via email
- We will also have Q&A sessions outside the class hours
- But — I also travel to conferences...

Class & Lab Lectures

- I will prepare slides for each class, and upload them on the web site ahead of time (usually 2-3 weeks)
- Well, occasionally they're uploaded shortly before class...
- For the Laboratory Sessions, you need to come prepared (read the material posted on the web) before the lab starts
- If you miss a class make sure that you read the lecture notes and come see us at our office hours

Homeworks

- A lot of it. . .
- As noted, approximately five homework assignments
- Homeworks are designed for practice, teaching, and evaluation
- Homeworks must be submitted electronically by the start of class
- Homeworks received later that day lose 5%, the next day 10%, two days late 20%, three days late 30%; after that, zero credit
- Exceptions granted only for *unforeseeable* events. Workload, day job, etc., are quite foreseeable.

Programming Assignments

- All programming assignments *must* be done in C or Java
- Assignments will involve socket programming and use of cryptographic libraries — see HW0
- *All* inputs must be checked for validity and proper values and lengths — bugs are *the* major source of security problems

Homework 0

- Simple socket exercise (will be posted online)
- Not collected, not graded, completely optional
- But — it will be a useful base for another assignment
- It's also a refresher exercise for you on socket programming

Co-operation versus Dishonesty

- Discussing homework with others is encouraged
- All programs and written material *must* be individual work unless otherwise instructed
- Looking or Copying other people's work is not allowed
- Zero tolerance for cheating or "outsourced homework"
- See the University academic honesty policy: `http://www.gmu.edu/catalog/apolicies/#Anchor12`. You are responsible for following it
- ALWAYS reference your source of information

The Ethics of Security

- Taking a computer security class is *not* an excuse for hacking
- "Hacking" is any form of unauthorized access, including exceeding authorized permissions
- The fact that a file or computer is not properly protected is no excuse for unauthorized access
- *If* the owner of a resource invites you to attack it, such use is authorized
- No, I'm not joking

Responsibility

- You're all adults
- You're all responsible for your own actions
- Ask the TA or me if you are in doubt!

Practical Focus

- This is not a pure academic-style OS course
- You'll be experimenting with real security holes
- A lot of (in)security is about doing the unexpected
- The ability to "think sideways" is a big advantage

The Security Lab

- We would like you to bring with you a USB key of at least 512MB
- As an alternative, you can bring your own laptop
- If we are more than 30, we will split into two groups
- No food or drink in the Security lab

Network Security

Goals

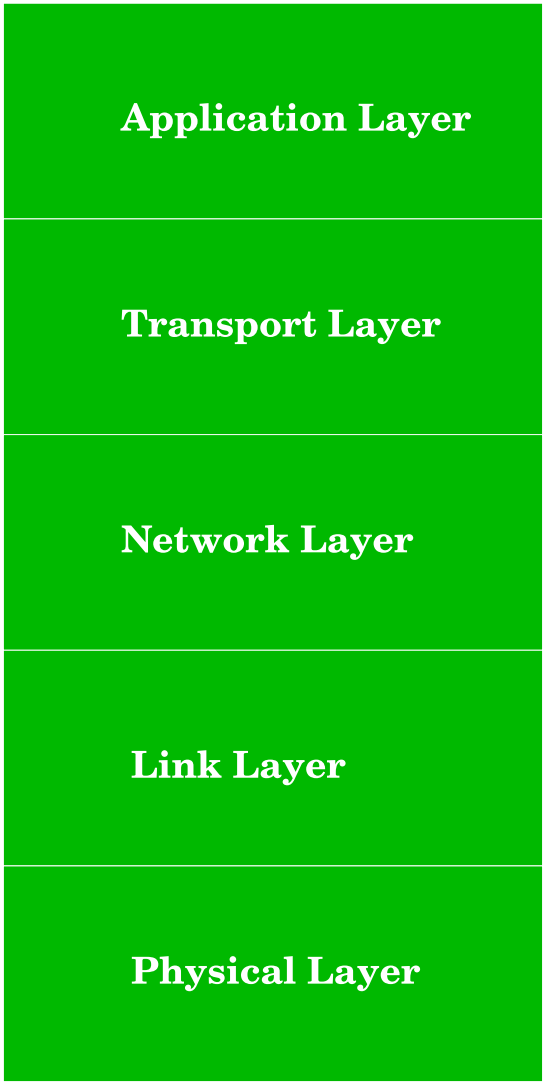
- Usual security trinity: confidentiality, integrity, availability
- Must ensure these in two domains: over-the-wire *and* on the host (for network-connected applications)
- Strategies are very different!

Differences from systems security

- Attacks can come form anywhere, at any time
- Highly automated (scripts)
- Physical security measures are inadequate
- Wide variety of applications, services, protocols Complexity
- Different constraints, assumptions, goals
- No single "authority"/administrator
- Somehow at odds with concept of networking

Network Security:A layered approach

Network Stack



SSH, passwords

SSL

IPsec

Link encryptors

Pressurized cables, guards

Security-aware System Design

- Cost/benefit tradeoffs
- Threat model
- Trust model
- Available mechanims
- Security is not only cryptography
- Security often conflicts with other goals: Fault tolerance, debugging & monitoring, sharing, etc.

Type of security mechanisms

- Pro-active try to keep the bad guys out
  - Passwords
  - Smartcards
  - Encrypted login protocols
  - Armed Marines
  - Reactive mechanisms try to detect and contain an attack
  - Intrusion detection
  - DoS push-back
  - Flood the enemy
  - Attack using physical forces

Reactive mechanisms - problems

- No "strike-back" mechanisms widely in use
- Air Force Caller-ID program
- RIAA anti-P2P work
- It involves legal, moral, and practical issues

Failures of security mechanisms

- Failures of security mechanisms
- Failure to understand the threat model
- Failure to understand what a mechanism protects against
- No (or wrong) mechanism/tool used
- Bad design
- Implementation fault
- Mis-configuration

More failures . . .

- Bad user interface
- Complexity (inherent in "systems")
- Emergent properties vs. bugs
- Theory vs. practical implementation

Network (in)Security

Dichotomy

- The host is (or can be) well-controlled
- There are well-developed authentication and authorization models
- There is a strong notion of "privileged" state, as well as what programs can use it
- None of that is true for the network

Anarchic Networks

- More or less anyone can (and does) connect to the network
- Connectivity can only be controlled in very small, well-regulated environments, and maybe not even then
- Different operating systems have different — or no — notions of userIDs and privileges
- As a consequence, notions of privilege are lacking

Observations about Networks

1. Networks interconnect
2. Networks *always* interconnect
3. Interconnections happen at the edges, not the center

Benign Failures

- On top of all that, most network failures are benign
- You have to program allowing for such failures: data corruption, timeouts, dead hosts, routing problems, etc.
- Rule of thumb: anything that can happen by accident can happen by malice — only more so

Trust Nothing

- A host can trust *nothing* that comes over the wire
- Any desired protections have to be supplied explicitly
- Perhaps there's a middle-ware layer supplying the protection — but such middle-ware is based on the same principles

Unproductive Attitudes

- "Why would anyone ever do *that*?"
- "That attack is too complicated"
- "No one knows how this system works, so they can't attack it"

Better Attitudes

- "Programming Satan's Computer" (Ross Anderson)
- "Assume that serial number 1 of any device is delivered to the enemy
- "You hand your packets to the enemy to deliver; you receive all incoming packets from the enemy

Network Security Tools

- Network-based access control (firewalls and more)
- Monitoring
- Cryptography
- Paranoid design

Protocol Design

- Leave room for crypto and authentication
- Make sure all sensitive fields are protected
- Make authentication bilateral
- Figure out the proper authorization
- Defend against eavesdropping, modification, deletion, replay, and combinations thereof

Buggy Software

- Most network security holes are due to buggy code
- A buggy network-connected program is an insecure one
- Correct coding counts for a lot

Course Outline

Network Availability

- Attacks and threats
- Firewalls & VPNs
- Intrusion Detection
- Network scans
- Worms
- Denial of service
- Network infrastructure Design

Authentication & Secure Protocols

- Cryptography overview
- Network authentication and key management
- Kerberos
- SSL
- IPsec
- Protocol design

Applications

- Web security
- Email security and phishing
- Voice over IP (VoIP) security
- Network storage
- Trust Management