

Lecture 22: Security I



What it's all about

- Risks: Loss of ...
 - Confidentiality/Privacy, Integrity, Availability/Access
 - Risk Analysis: cost/loss * loss freq. vs. cost to protect
 - Engineering trade-offs, not either-or decisions
 - often, Security == 1 / (functionality * convenience)
- Vulnerabilities
 - examples abound, many reasons behind
- Countermeasures
 - carefulness, cryptography, firewalls, detection, recovery

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Some key security goals

- Confidentiality
 - keep information content away from the unauthorized
- Integrity
 - prevent undetected, unauthorized modification of data
- Availability
 - ensure that resources and services are available when needed
- Authentication
 - prove the identity of entities or source of information
- Non-repudiation
 - prevent denial of previous commitments
- Privacy and Anonymity
 - prevent Big Brother from invading your space

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Some key security problems

- 1. Misplaced trust
- 2. Buggy implementations
- 3. Poor configuration choices
- ...
- 12. Unsafe design assumptions
- ...
- 997. Cryptanalysis

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Terminology: Threats

- Threat: A potential vector (means, mechanism) for a system's security to be compromised
 - An attack exercises a threat
 - A successful attacks leads to a security compromise
- Examples of threats:
 - Network traffic arriving from the internet
 - Self-administered systems connected to a corporate (or university) LAN

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Terminology: Vulnerabilities

- A vulnerability is a flaw in a system that has a security implication
- Examples:
 - Unchecked string copy allows buffer overflow
 - Administrator forgets to disable debug mode on a program during configuration, leaving unsafe but convenient features in deployed service
 - Naive home user buys wireless router, but does not alter default password on router
- Compromises occur when attacker matches threats with vulnerabilities

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Scary aspects of "bad guys"

- Patience and time
 - Historically successful crackers have been willing to spend endless hours trying to get into systems
- Automated Tools
 - Crackers don't even have to know anything anymore
 - Copious "cookbooks" and packaged kits
 - One clever person finds a hole, everyone runs her tools
- New profit motive
 - Rent-a-bot-net brokers

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...and if that weren't bad enough

- attackers only need one weakness
 - no need to break thru strongest wall
 - they'll try lots and exploit the weakest

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Example: The Morris Worm

- Released on November 2, 1988
- Written by Robert T. Morris
- Invaded around 6,000 computers within hours (10% of the Internet at the time)
- Disabled many systems and services
- Morris had a friend post instructions for disabling the worm - but it was too late
- Damage estimates between \$10,000 and \$97 million (shows how hard it is to estimate)
- Details in June 1989 Comm. of the ACM
 - "Crisis and Aftermath", Eugene H. Spafford

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How the worm worked

- Copied itself to remote systems via 3 holes
- Exploit hole in finger daemon that caused buffer overflow to create remote shell
 - gets() used to read input
- Exploit hole in Unix sendmail daemon
 - listen()s on TCP port, accept()s connections from mailers
 - Exchanges messages about mail envelope and content
 - when running in debug mode, worm could give it commands to execute
 - sendmail ran the malicious code
- Password cracking with a dictionary of 432 words
 - accounts tested against words in a random order

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"People pick bad passwords, and either forget, write down, or resent good ones."

Steven M. Bellovin

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Effect of worm

- Formation of CERT
- \$10,000 fine, 3 year probation, and 400 hours of community service for Morris
- Heightened awareness of computer system vulnerabilities
- Something for security professionals to quote
 - not so much a problem now ☺

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Example: Melissa virus (1999)

- On all news shows, newspapers, etc.
- Code is in the form of MS Word macro
 - 107 lines of visual basic
- Most impactful mobile code attack since Morris worm
 - millions of \$\$\$ of damage
- Virus didn't "do anything bad" except copy self
 - plus clog and shut down internet mail servers
- If date == time, prints

Twenty-two points, plus triple-word-score, plus fifty points for using all my letters. Game's over. I'm outta here.

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Melissa (cont.)

- First public appearance on alt.sex
- Many copycat viruses immediately appeared
- How Melissa works:
 - word macro virus implanted in MSWord file
 - word file contained a list of pornographic sites
 - MsWord file mailed with subject:
 - Important Message From xxx
 - Body:
 - Here is that document you asked for... don't show anyone else ;-)
 - and an attachment: list1.doc

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How Melissa works (cont.)

- When user opens document
 - warning about document containing macro
 - If user clicks okay, word launches, with the virus
- The virus then:
 - disables future checking for macro viruses (no prompt)
 - check to see if already infected (keyword Kwyjibo)
 - if not infected, then look in outlook address book
 - mail the infected document to the first 50 names
 - infect word template for new documents
 - this is a classic macro virus
 - all future word documents will be infected

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Why Melissa worked

- many, many people using same mailer (outlook)
- many, many people use MsWord in Windows
- many, many people click okay to macro warning
- no separation between applications on Microsoft platforms
- virus protection software only works against known viruses
- lack of domain separation allows access to Outlook data

It could have been A LOT worse!

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Example: W32/Sircam (2001)

- Malicious code that propagates via e-mail
 - "Hi! How are you?<RET>Random<RET>See you later. Thanks"
- Click on the attachment, and virus springs into action
 - Send itself to folks in address book (*.wab)
 - Do various nasty things
 - Search for and e-mail out sensitive files (breach confidentiality)
 - Fill up C: drive (reduce availability)
 - Delete files from C: drive (breach integrity)
- This one isn't as "harmless" as Melissa...

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Recent Examples

- 2006: Nyxem - mass email worm
 - Disables security related software
 - Attempts to destroy certain types of files
- 2005: MySpace virus Samy (fastest spreading to date)
- 2004: MyDoom - mass email worm
- Many, many others

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"Network Security"

- Attacks that use or go after the network
- Many examples we've seen already
 - holes in apps/services can be targeted from a distance
- Network-specific attacks
 - eavesdropping (aka sniffing)
 - impersonation (aka spoofing)
 - protocol disruption/exploitation
 - denial of service
 - Distributed denial of service

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Buggy Code

- 85% of CERT Advisories describe problems that cannot be fixed with cryptography.
- Most of these are bugs in code
- But writing correct code is the oldest -- and probably the most difficult -- problem in computer science. We're not going to solve it any time soon -- and possibly not ever.

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Preventing Bugs

- Structuring code properly can help
 - isolate the security-critical sections
 - use better languages and libraries (and programmers)
- Reducing code complexity
 - when was the last time a vendor deleted features when shipping a new release?
 - when did you ever see an ad bragging that some Web browser doesn't have Javascript?
 - people don't understand how to use what's already there -
- so vendors add even more complexity to help people find the knobs and buttons...

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Buffer Overruns

- 30-40% of newly-reported holes are due to these
 - 9 of 13 CERT advisories in 1998
- C uses character arrays for strings (and for arrays)
 - C compilers do no bounds checking on arrays
 - language design makes such automated checking hard
 - programmers often fail to check all lengths and indices
 - common libc functions (e.g., gets, sprintf) also flawed
 - "Safe" versions also flawed
- Too many programmers say "this array is big enough" -- and it often is, for normal purposes...

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Stack Overruns

- A particularly nasty form of buffer overrun
 - normal buffer overruns allow corruption of data
 - stack overruns can give control of execution
- Happens when buffers allocated on stack
 - e.g., local procedure variables
- Since return address also on stack...
 - attacker can subvert return address
 - ... and insert code to be executed
 - ... and point the return address at the new code
- Example: fingerd bug from Morris Worm

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Format String Bugs

- C library formatted I/O strings can allow almost arbitrary inspection and modification of program if misused
 - First came to light ~2000
 - E.g. "printf(inputstr)" where inputstr is supplied by user
 - inputstr can contain format characters (like %x)
 - printf assumes extra arguments have been pushed on stack, dumps stack contents to output
 - %n format allows write to a memory location

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Incomplete input checks

- Before using an input value, check it
 - such a simple rule, yet it is so often not done
 - Checking can be harder than it seems
- Examples:
 - Format string vulnerabilities
 - MySpace Samy virus
 - passing NULL, -1, 0, 0xdeadbeaf, etc ...
 - Ballista results: 15-35% of bad POSIX parameters cause robustness failures
- Why?
 - Laziness, optimization, forgetsies, reorgs/changes, assumptions, mindsets

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From bug to vulnerability

- So you have a buggy user-level application
 - Why is this so bad?
- In general, compromising a process allows attacker to obtain privileges of that process for arbitrary activities
 - Bad for you, but not necessarily bad for the system
 - Compromising a process with root privilege (on Unix systems) provides a lot of power
 - Read/write any file
 - Read/write kernel memory though /dev/kmem
 - Attach to and trace any running process
 - Install kernel modules / change system configuration

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Insufficient Domain Separation

- Authorization domains should be clearly separated
 - otherwise, less-privileged code can get more-privileged code to do bad things
- Unfortunately, this is often not the case
- Examples:
 - environment inheritance by setuid programs in UNIX
 - e.g., max file length or number of files open

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Security policies are critical

- Most organizations have a stated policy about control of private information and access to resources
- These policies can help guide protocol implementation
 - and can help with political and "clueless user" problems
- If you can't say what's important, how am I supposed to protect it?
 - ...and why should I bother trying?

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Useful "principles" for security

- Principle of Easiest Penetration
 - passwords: crack, sniffing, trojan horses, social engineering
- Principle of Adequate Protection
 - See "risk analysis" and "cost/benefit"...
- Principle of Effectiveness
 - Countermeasures must be used to be useful!!
 - Remember: users are impatient, lazy ...

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Firewalls

- Perimeter defenses for nets with unsafe hosts
 - we seem to be unable to harden hosts
 - firewalls are an admission that hosts may not be secure
 - firewalls provide a barrier between us and them
- Single point of control and expertise
 - access limitation and auditing
 - limits communication to/from the outside world
 - only leave a very few machines exposed to direct attack
 - ... and minimize their functionality
- Sounds great - how come we're not done?

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OS Security Mechanisms

- Access Controls
- FreeBSD Jails
- SELinux

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Access Control

- Common Assumption:
 - System knows identity of user (authentication)
 - Access requests pass through some gatekeeper (authorization)
- Implemented using Access Control Matrix
 - Access control list
 - Capability
- Two main types
 - Discretionary Access Control (DAC)
 - User sets access rights for objects they own
 - Mandatory Access Control (MAC)
 - System sets rights that users can't override

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FreeBSD Jails

- Goal: isolation of processes to contain possible damage without lots of extra security management complexity
- Built on chroot concept
 - Give process (and all its children) separate view of file system tree (chdir /tmp/limited_fs; chroot /tmp/limited_fs)
 - Originally introduced for development
- Added new "jail" command
 - Each jail has own superuser
 - Privileges of superuser restricted to only affect things inside jail
 - Process in jail isolated from ones outside jail

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SELinux

- Security Enhanced Linux
 - Version of Linux created by the NSA and Secure Computing Corporation (SCC)
- Incorporates University of Utah Flask security model
- Supports mandatory access control to all objects
- Supports various policy configurations
 - Role-based access control: rights are assigned to roles which users can take on
 - Multi-level access control
 - Type Enforcement: Each subject and object has a type, policies are represented by relationships between each type

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Ethics and Computer Security

- When technology and legality fail, society must fall back on ethics of right and wrong...
- Ethics are a fuzzy thing
 - everyone must arrive at their own choices
- But, I say again,
 - you should not abuse your extensive knowledge of system design and security weaknesses to break into other people's systems or commit other computer crimes!

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