CSE 490K (Spring 2007)

Computer Security and Privacy

Tadayoshi Kohno

http://www.cs.washington.edu/education/courses/490k/07sp

Thanks to Dan Boneh, Dieter Gollmann, John Manferdelli, John Mitchell, Vitaly Shmatikov (slides), Bennet Yee, ...

High-level information

- Instructor: Tadayoshi Kohno (Yoshi)
  - Office: CSE 558
  - Office hours: Mondays, 12:30 - 1:20pm
  - Open door policy – don't hesitate to stop by!
- TA: Nicholas Murphy (Nick)
  - Office/hours: See website (TBD)
- Course website
  - Assignments, reading materials, lecture notes
- Course email list
  - Student discussions, announcements

Prerequisites

- Required: Data Structures
- Required: Working knowledge of C and assembly
  - One of the projects involves writing buffer overflow attacks in C
  - You must have detailed understanding of x86 architecture, stack layout, calling conventions, etc.
- "Required:" Working knowledge of software engineering tools for Unix environments (gdb, etc)

Prerequisites

- Recommended: Computer Networks; Operating Systems
  - Will help provide deeper understanding of security mechanisms and where they fit in the big picture
- Recommended: Complexity Theory; Discrete Math; Algorithms
  - Will help with the more theoretical aspects of this course.

Prerequisites

- Most of all: Eagerness to learn!
  - This is a 400 level course.
  - I expect you to push yourself to learn as much as possible.
  - I expect you to be a strong, independent learner capable of learning new concepts from the lectures, the readings, and on your own.

Course Logistics

- Lectures
  - Tuesday, Thursday 12:00 - 1:20pm
- Projects (35% of the grade)
  - Projects involve a fair bit of programming
  - Can be done in teams of 2-3 students
  - Security is a contact sport!
- Homeworks (20% of grade)
  - Textbook-style questions (10%)
  - Security evaluations (10%)
- Midterm (15% of the grade)
- Final (30% of the grade)

Exceptional work may be rewarded with extra credit

No make-up or substitute exams! If you are not sure you will be able to take the exams in class on the assigned dates, **do not take this course!**

Late Submission Policy

- Assignments should be turned in at the start of class on the due date
- Late assignments will be dropped 20% per day.
  - Late days will be rounded up
  - So an assignment turned in 1.25 days late will be downgraded 40%.

Course Materials

- Textbooks:
  Stamp, "Information Security" (Main textbook)
  Stallings, "Network Security Essentials"
  - Lectures will not follow the textbooks
  - Lectures will focus on "big-picture" principles and ideas of network attack and defense
  - Attend lectures! Lectures will cover some material that is not in the textbook – and you will be tested on it!
- Plus assigned readings from other sources

Other Helpful Books (all online)

- Ross Anderson, "Security Engineering"
  - Focuses on design principles for secure systems
  - Wide range of entertaining examples: banking, nuclear command and control, burglar alarms
- Kaashoek and Saltzer, "Principles of Computer System Design"
- Menezes, van Oorschot, and Vanstone, "Handbook of Applied Cryptography"

Main Themes of the Course

- Thinking about security
  - Threat models, security goals, assets, risks
- Vulnerabilities of computer systems
  - Software problems (buffer overflows); crypto problems; network problems (DoS, worms); people problems (usability, phishing)
- Defensive technologies
  - Protection of information in transit: cryptography, security protocols
  - Protection of networked applications: firewalls and intrusion detection
  - "Defense in depth"

What This Course is Not About

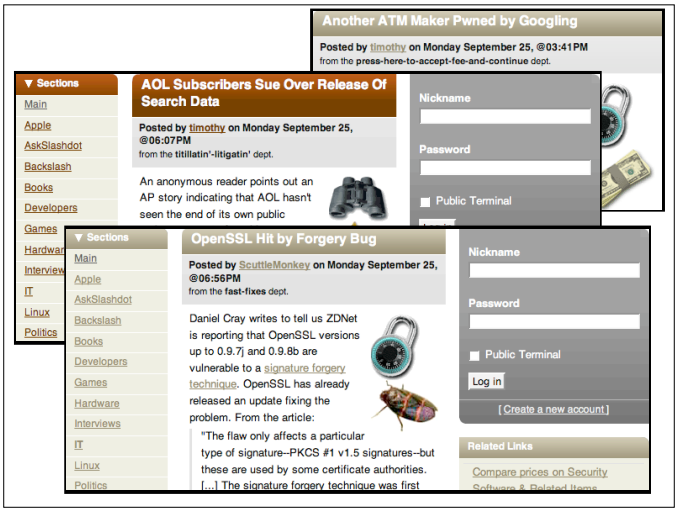
- Not a comprehensive course on computer security
  - Computer security is a broad discipline!
  - Impossible to cover everything in one quarter
    - No language-based security
    - Moderate discussion of crypto (crypto could take a whole course!)
  - So be careful in industry or wherever you go!
- Not about all of the latest and greatest attacks
  - Read bugtraq or other online sources instead
- Not a course on ethical, legal or economic issues
  - We will touch on ethical issues, but not focus on them
- Not a course on how to "hack" or "crack" systems

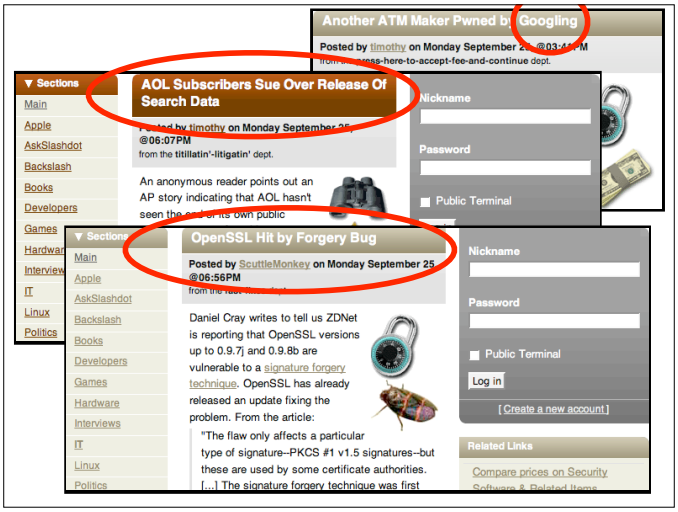
What is Computer Security?

- Systems may fail for many reasons
- Reliability deals with accidental failures
- Usability deals with problems arising from operating mistakes made by users
- Security deals with intentional failures created by intelligent parties
  - Security is about computing in the presence of an adversary

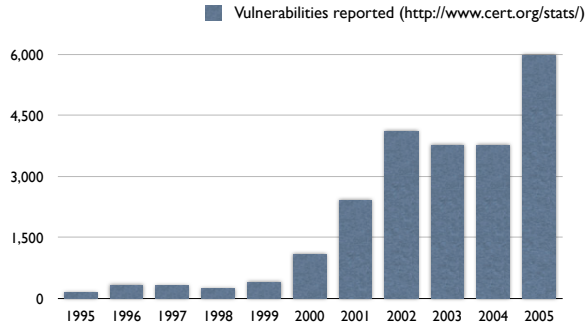
What Drives the Attackers?

- Adversarial motivations:
  - Money, fame, malice, curiosity, politics....
- Fake websites, identity theft, steal money and more
- Control victim's machine, send spam, capture passwords
- Industrial espionage and international politics
- Access copy-protected movies and videos
- Attack on website, extort money
- Wreak havoc, achieve fame and glory





Growing Problem



Challenges: What is "Security?"

- What does security mean?
  - Often the hardest part of building a secure system is figuring out what security means
  - What are the assets to protect?
  - What are the threats to those assets?
  - Who are the adversaries, and what are their resources?
  - What is the security policy?
- Perfect security does not exist!
  - Security is not a binary property
  - Security is about risk management

From Policy to Implementation

- After you've figured out what security means to your application, there are still challenges
  - How is the security policy enforced?
  - Design bugs
    - Poor use of cryptography
    - Poor sources of randomness
    - ...
  - Implementation bugs
    - Buffer overflow attacks
    - ...
  - Is the system usable?

Don't forget the users! They are a critical component!

Many Participants

- Many parties involved
  - System developers
  - Companies deploying the system
  - The end users
  - The adversaries (possibly one of the above)
- Different parties have different goals
  - System developers and companies may wish to optimize cost
  - End users may desire security, privacy, and usability
  - But the relationship between these goals is quite complex (will customers choose not to buy the product if it is not secure?)

Other (Mutually-Related) Issues

- Do consumers actually care about security?
- Security is expensive to implement
- Plenty of legacy software
- Easier to write "insecure" code
- Some languages (like C) are unsafe

Example: Electronic Voting

- Popular replacement to traditional paper ballots

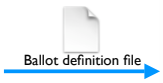
Pre-Election

Poll worker

Pre-election: Poll workers load "ballot definition files" on voting machine.

Pre-Election

Poll worker



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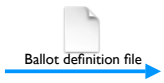
Active Voting

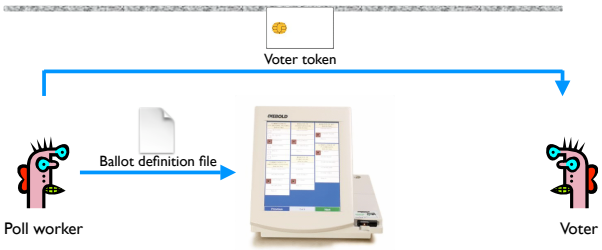
Poll worker



Voter

Active voting: Voters obtain single-use tokens from poll workers. Voters use tokens to active machines and vote.

Active Voting



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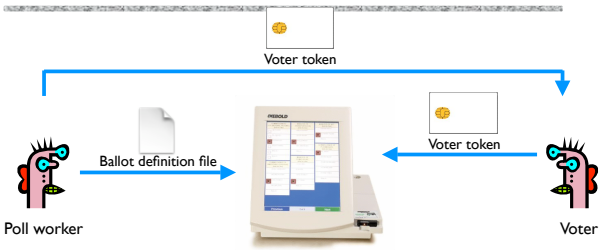

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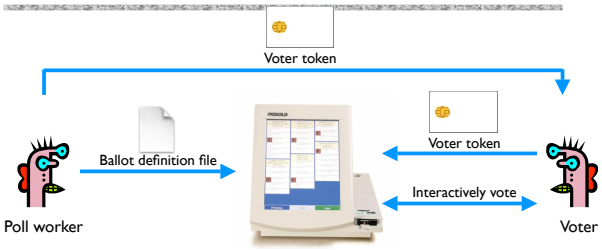

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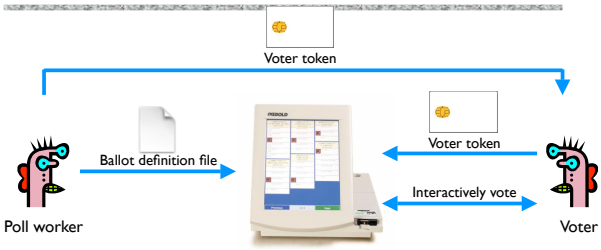
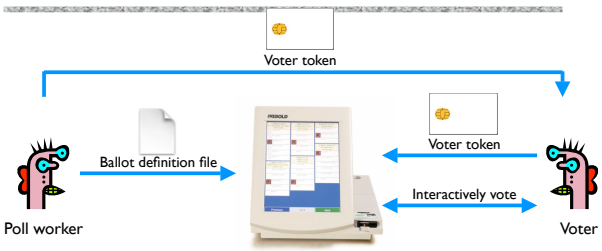


Active voting: Votes encrypted and stored. Voter token canceled.

Active Voting



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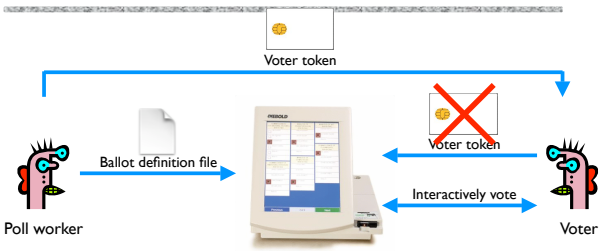

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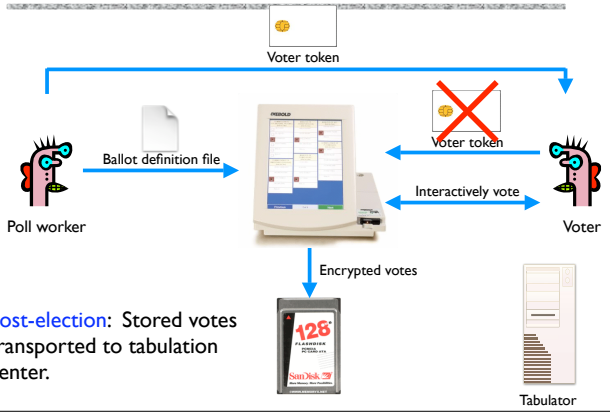
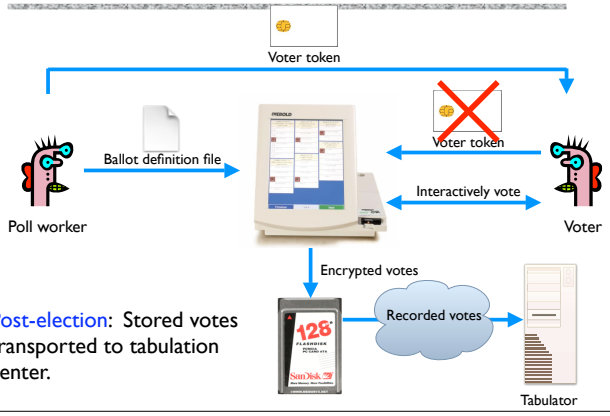
Post-Election



Post-election: Stored votes transported to tabulation center.

Post-Election



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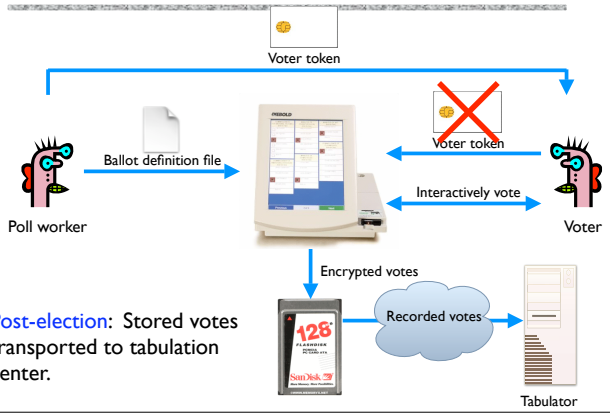
Security and E-Voting (Simplified)

- Functionality goals:
  - Easy to use
  - People should be able to cast votes easily, in their own language or with headphones for accessibility
- Security goals:
  - Adversary should not be able to tamper with the election outcome
    - By changing votes
    - By denying voters the right to vote
  - Is it OK if an adversary can do the above, assuming you can catch him or her or them?
  - Adversary should not be able to figure out how voters vote

Can You Spot Any Potential Issues?



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Potential Adversaries

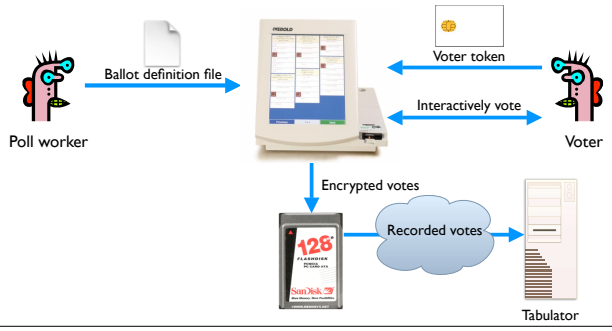
- Voters
- Election officials
- Employees of voting machine manufacturer
  - Software/hardware engineers
  - Maintenance people
- Other engineers
  - Makers of hardware
  - Makers of underlying software or add-on components
  - Makers of compiler
- …
- Or any combination of the above

What Software is Running?

Problem: An adversary (e.g., a poll worker, software developer, or company representative) able to control the software or the underlying hardware could do whatever he or she wanted.

Problem: Ballot definition files are not authenticated.

Example attack: A malicious poll worker could modify ballot definition files so that votes cast for "Mickey Mouse" are recorded for "Donald Duck."



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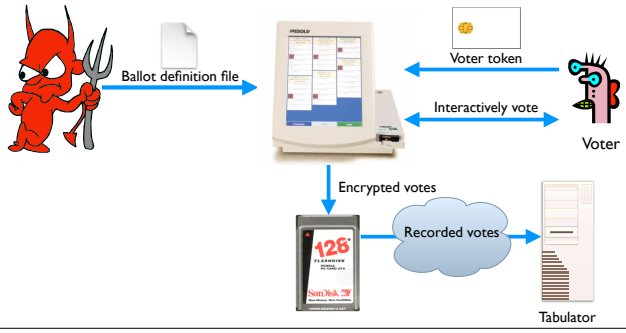

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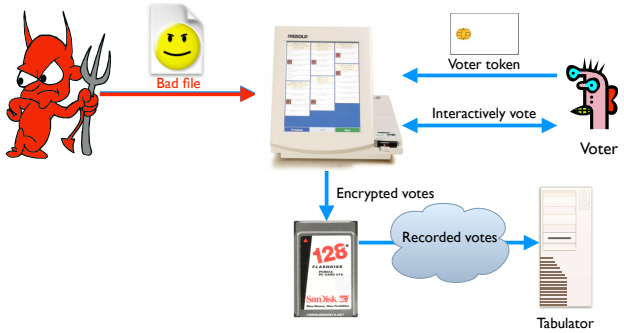

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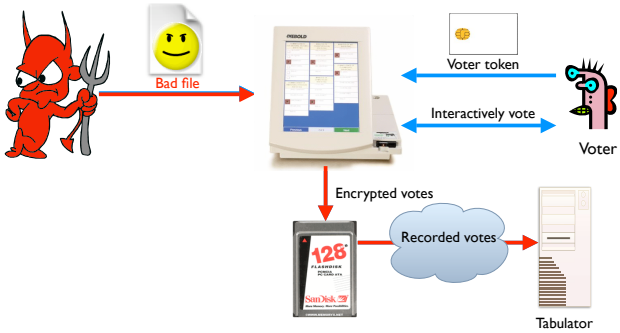

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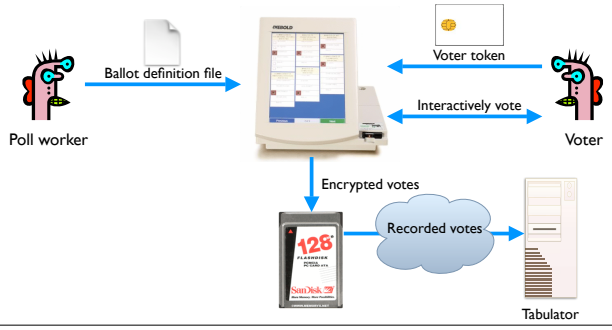
Example attack: A regular voter could make his or her own voter token and vote multiple times.



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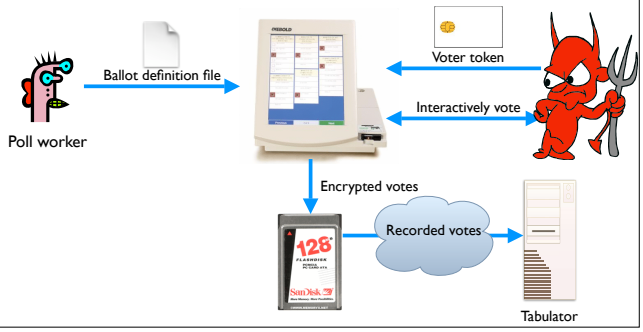

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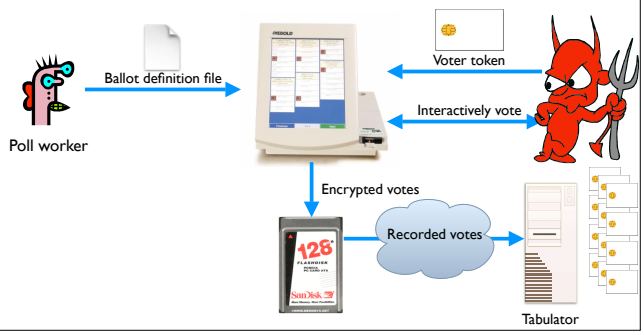

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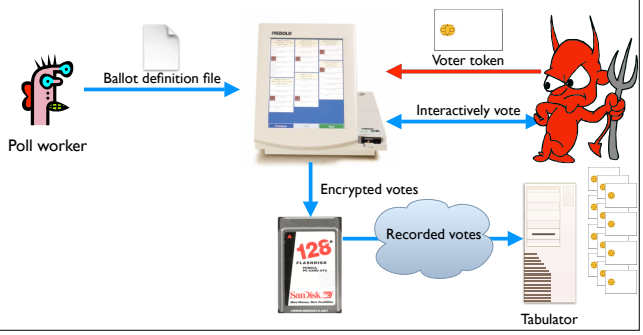

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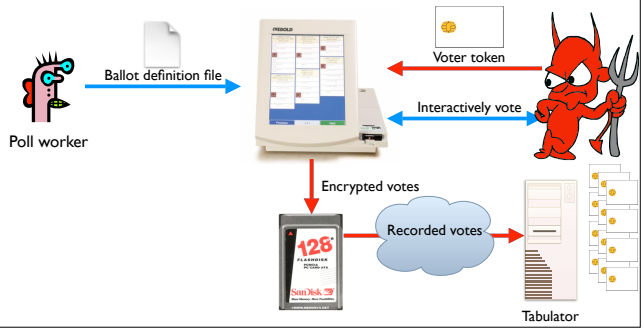

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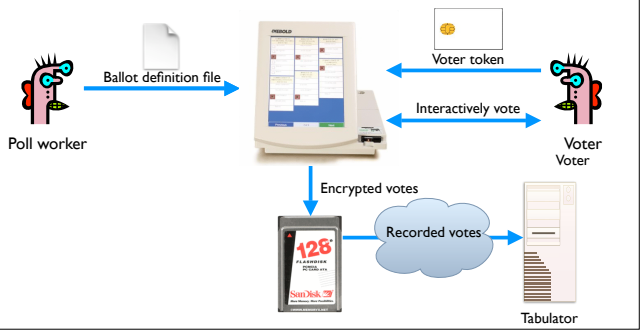
Example attack: A poll worker could determine how voters vote.



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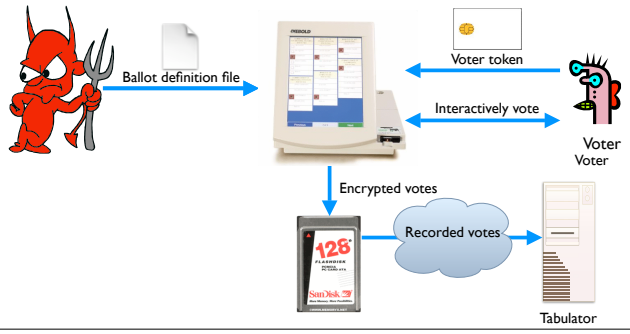

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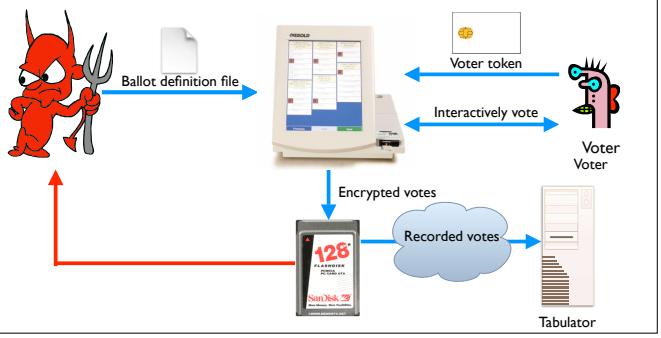

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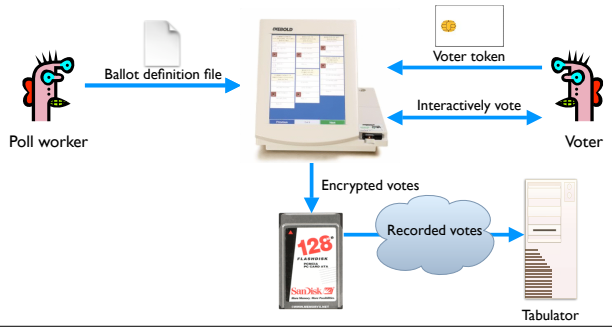

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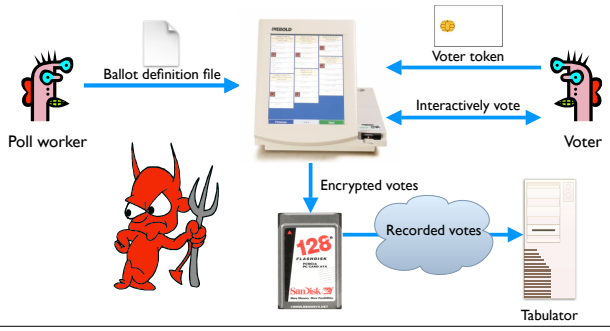

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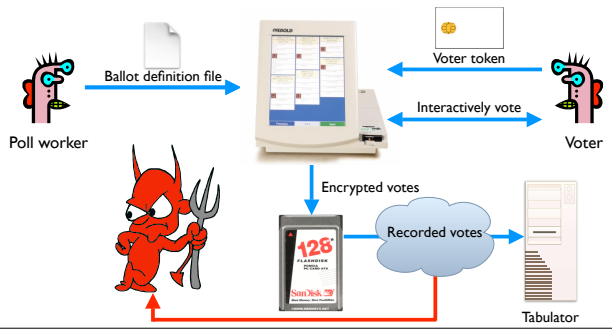


Whole-System is Critical

- Securing a system involves a whole-system view
  - Cryptography
  - Implementation
  - People
  - Physical security
  - Everything in between
- This is because "security is only as strong as the weakest link," and security can fail in many places
  - No reason to attack the strongest part of a system if you can walk right around it.

Analyzing the Security of a System

- First thing: Summarize the system as clearly and concisely as possible
  - Critical step. If you can't summarize the system clearly and concisely, how can you analyze it's security?
- Next steps:
  - Identify the assets: What do you wish to protect?
  - Identify the adversaries and threats: What might an attacker try to do?
  - Identify vulnerabilities: Weaknesses in the system
  - Calculate the risks

Assets

- Need to know what you are protecting!
  - Hardware: Laptops, servers, routers, PDAs, phones, ...
  - Software: Applications, operating systems, database systems, source code, object code, ...
  - Data and information: Data for running and planning your business, design documents, data about your customers, data about your identity
  - Reputation, brand name
  - Responsiveness
- Assets should have an associated value (e.g., cost to replace hardware, cost to reputation, how important to business operation)

Adversaries

- National governments
- Terrorists
- Thieves
- Business competitors
- Your supplier
- Your consumer
- New York Times
- Your family members (parents, children)
- Your friends
- Your ex-friends
- ...

Threats

- Threats are actions by adversaries who try to exploit vulnerabilities to damage assets
  - Spoofing identities: Attacker pretends to be someone else
  - Tampering with data: Change outcome of election
  - Denial of service: Attacker makes voting machines unavailable on election day
  - Elevation of privilege: Regular voter becomes admin
- Specific threats depend on environmental conditions, enforcement mechanisms, etc
  - You must have a clear, simple, accurate understanding of how the system works!

Threats

- Several ways to identify threats
  - By damage done to the assets
  - By the source of attacks
    - (Type of) insider
    - (Type of) outsider
    - Local attacker
    - Remote attacker
    - Attacker resources

Vulnerabilities

- Weaknesses of a system that could be exploited to cause damage
  - Accounts with system privileges where the default password has not been changed (Diebold: 1111)
  - Programs with unnecessary privileges
  - Programs with known flaws
  - Known problems with cryptography
  - Weak firewall configurations that allow access to vulnerable services
  - ...
- Sources for vulnerability updates: CERT, SANS, Bugtraq, the news(?)

Risks

- Quantitative risk management
  - Example: Risk = Asset × Threat × Vulnerability
  - Monetary value to assets
  - Threats and vulnerabilities are probabilities
  - (Yes: Difficult to assign these costs and probabilities)
- Qualitative risk management
  - Assets: Critical, very important, important, not important
  - Vulnerabilities: Has to be fixed soon, should be fixed, fix if convenient
  - Threats: Very likely, likely, unlikely, very unlikely

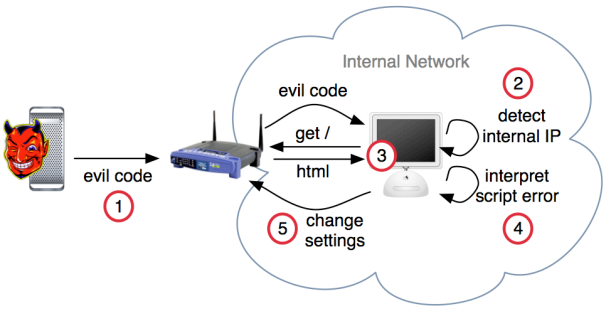
Security is Subtle

- Security attacks can be subtle
- So need to think careful!
  - And keep the whole system in mind
- Phishing one example
  - If attacker can trick user into entering private information, then no protection mechanism will help
  - (So research tries to focus on helping users not be tricked)

Another Example: Drive-By Pharming

- Designed to provide a firewall to external machines (keep the bad guys out)

Another Example: Drive-By Pharming



Reference: http://www.cs.indiana.edu/pub/techreports/TR641.pdf

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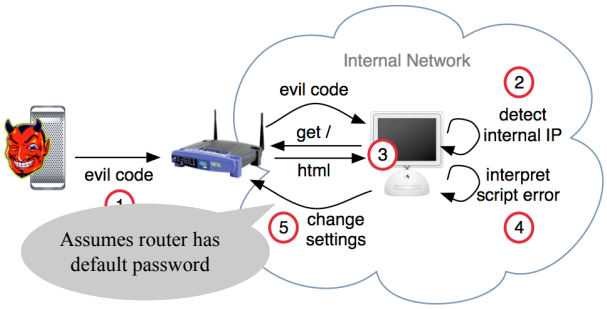

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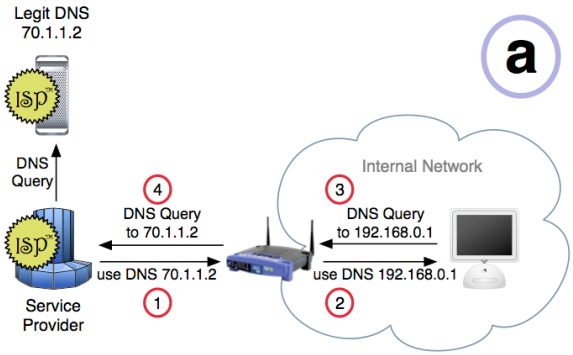
Another Example: Drive-By Pharming



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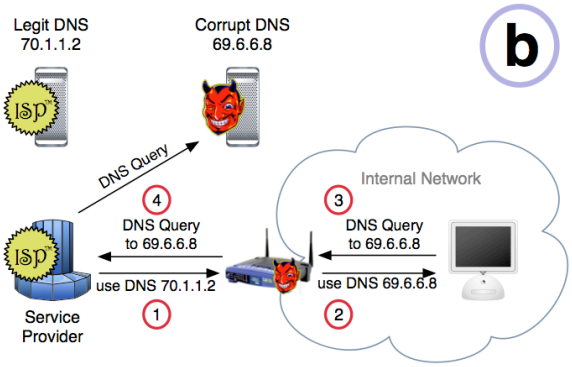
Another Example: Drive-By Pharming



Reference: http://www.cs.indiana.edu/pub/techreports/TR641.pdf

Many Desirable Security Properties

- Authenticity
- Confidentiality
- Integrity
- Availability
- Accountability and non-repudiation
- Freshness
- Access control
- Privacy of collected information
- ...

Syllabus

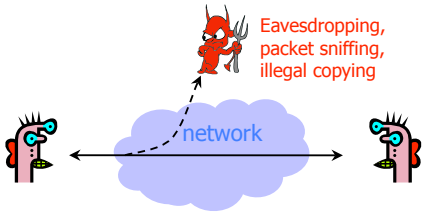
- Thinking about security; the "big picture"
  - The hardest part: Getting the "security mindset"
- Software security, buffer overflow attacks
- Cryptography
  - Block ciphers, stream ciphers, hash functions, MACs, public key encryption, digital signatures, PKI, key exchange, protocols (SSL/TLS, IPsec, Kerberos)
- Authentication, passwords, biometrics
- Trusted computing, secure hardware, tamper resistance

Syllabus

- Wireless security, including RFIDs, 802.11, and the future
- Web security and privacy, cross-site scripting, cookies, spyware
- Anonymous communications: Tor, attacks and defenses
- Information leakage and covert channels
- TCP/IP security, routing security, DNS security
- Firewall and intrusion detection systems
- Botnets and worms

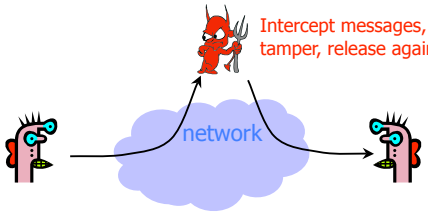
Attack on Confidentiality

- Confidentiality is concealment of information



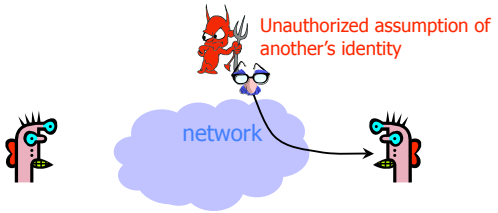
Attack on Integrity

- Integrity is prevention of unauthorized changes



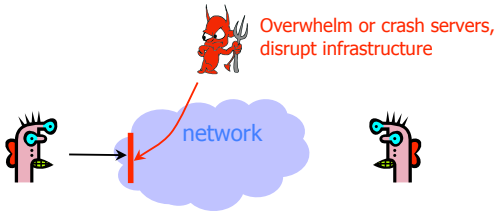
Attack on Authenticity

- Authenticity is identification and assurance of origin of information

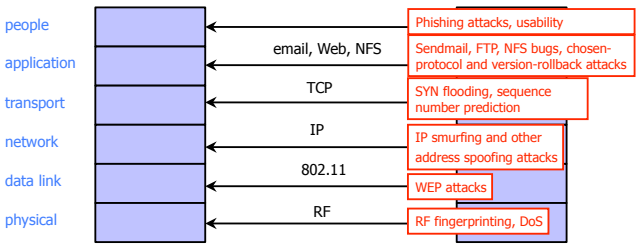


Attack on Availability

- Availability is ability to use information or resources desired

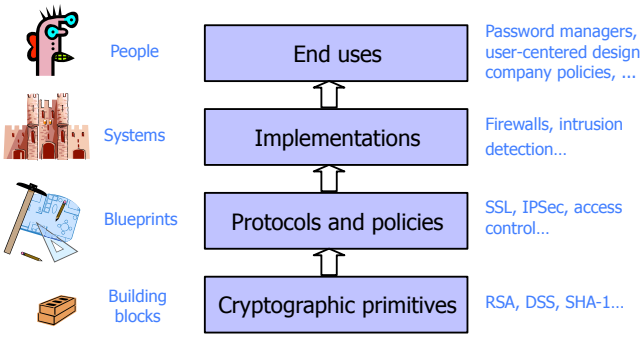


Protocol Stack



Only as secure as the single weakest layer… Or the interconnection between the layers

Defenses



Correctness versus Security

- System correctness: system satisfies specification
  - For reasonable input, get reasonable output
- System security: system properties preserved in face of attack
  - For unreasonable input, output not completely disastrous
- Main difference: active interference from adversary
- Modular design may increase vulnerability
  - Abstraction is difficult to achieve in security: what if the adversary operates below your level of abstraction?
- Modular design may increase security: small TCB
- Complexity may increase vulnerability

Bad News

- Security often not a primary consideration
  - Performance and usability take precedence
- Feature-rich systems may be poorly understood
  - Higher-level protocols make mistaken assumptions
- Implementations are buggy
  - Buffer overflows are the "vulnerability of the decade"
- Networks are more open and accessible than ever
  - Increased exposure, easier to cover tracks
- No matter what technical mechanisms you have, people may circumvent them
  - Phishing, impersonation, write down passwords, ...

Better News

- There are a lot of defense mechanisms
  - We'll study some, but by no means all, in this course
- It's important to understand their limitations
  - "If you think cryptography will solve your problem, then you don't understand cryptography… and you don't understand your problem" -- Bruce Schneier
  - Security is not a binary property
  - Many security holes are based on misunderstanding
- Security awareness and user "buy-in" help
- Other important factors: usability and economics

Approaches to Security

- Prevention
  - Stop an attack
- Detection
  - Detect an ongoing or past attack
- Response
  - Respond to attacks
- The threat of a response may be enough to deter some attackers

Security Evaluations

- Every week (or so) after the first week, you will get the opportunity to briefly evaluate the security of a real product
- Previous courses looked at
  - Nike+iPod Sport Kit
  - Wireless keyboards
  - iPhone
  - Zune
  - SlingBox
  - Nintendo Wii
  - Dodgeball
  - Netflix
  - …

Ethics

- In this class you will learn about how to attack the security and privacy of (computer) systems.
- Knowing how to attack systems is a critical step toward knowing how to protect systems.
- But one must use this knowledge in an ethical manner.

- In order to get a non-zero grade in this course, you must sign the "Security and Privacy Code of Ethics" form by the start of class on April 3 (next Tuesday).

Reading

- Read Stamp chapter 1
- Read Anderson chapter 1
- Start looking at Stamp chapter 11

- No class on Thursday -- called out of town :-(