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

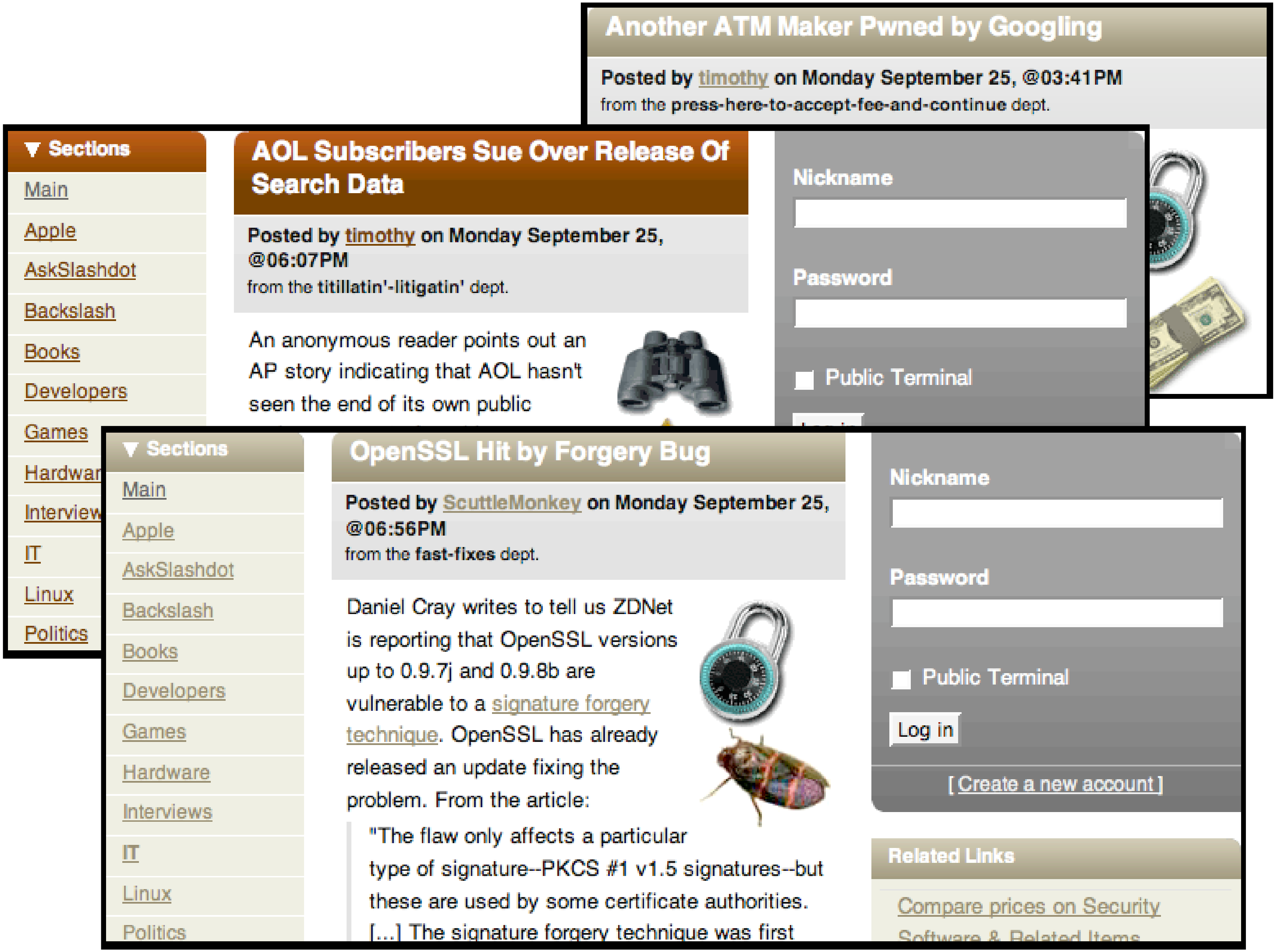
- Not a comprehensive course on computer security
  - Computer security is a broad discipline!
  - Impossible to cover everything in one quarter
    - No language-based security
    - Moderate discussion of crypto (crypto could take a whole course!)
  - So be careful in industry or wherever you go!
- 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



Another ATM Maker Pwned by Googling

Posted by timothy **on Monday September 25, @03:41PM**
from the **press-here-to-accept-fee-and-continue** dept.

AOL Subscribers Sue Over Release Of Search Data

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An anonymous reader points out an AP story indicating that AOL hasn't seen the end of its own public

OpenSSL Hit by Forgery Bug

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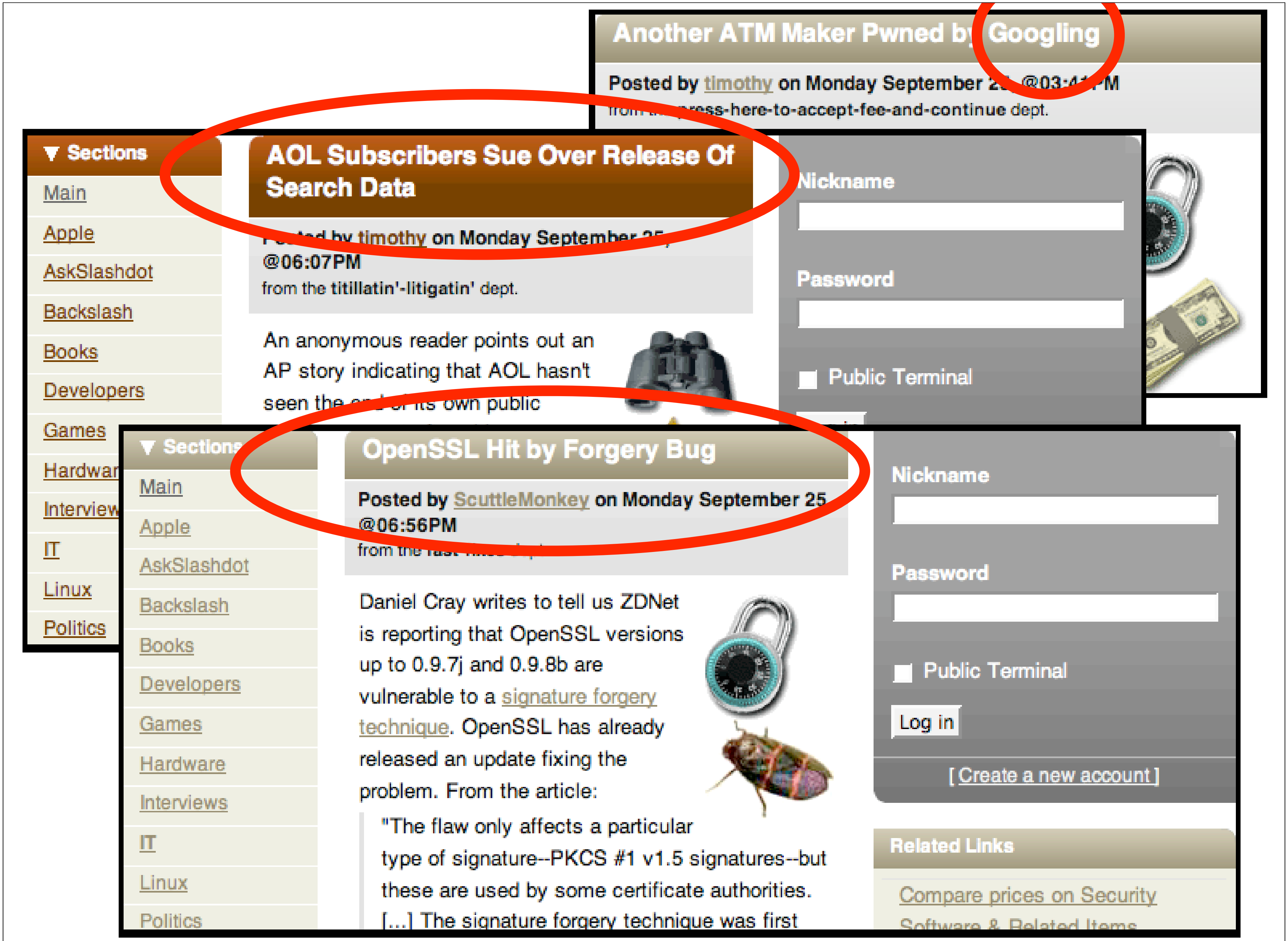
Daniel Cray writes to tell us ZDNet is reporting that OpenSSL versions up to 0.9.7j and 0.9.8b are vulnerable to a signature forgery technique. OpenSSL has already released an update fixing the problem. From the article:

> "The flaw only affects a particular type of signature--PKCS #1 v1.5 signatures--but these are used by some certificate authorities. [...] The signature forgery technique was first



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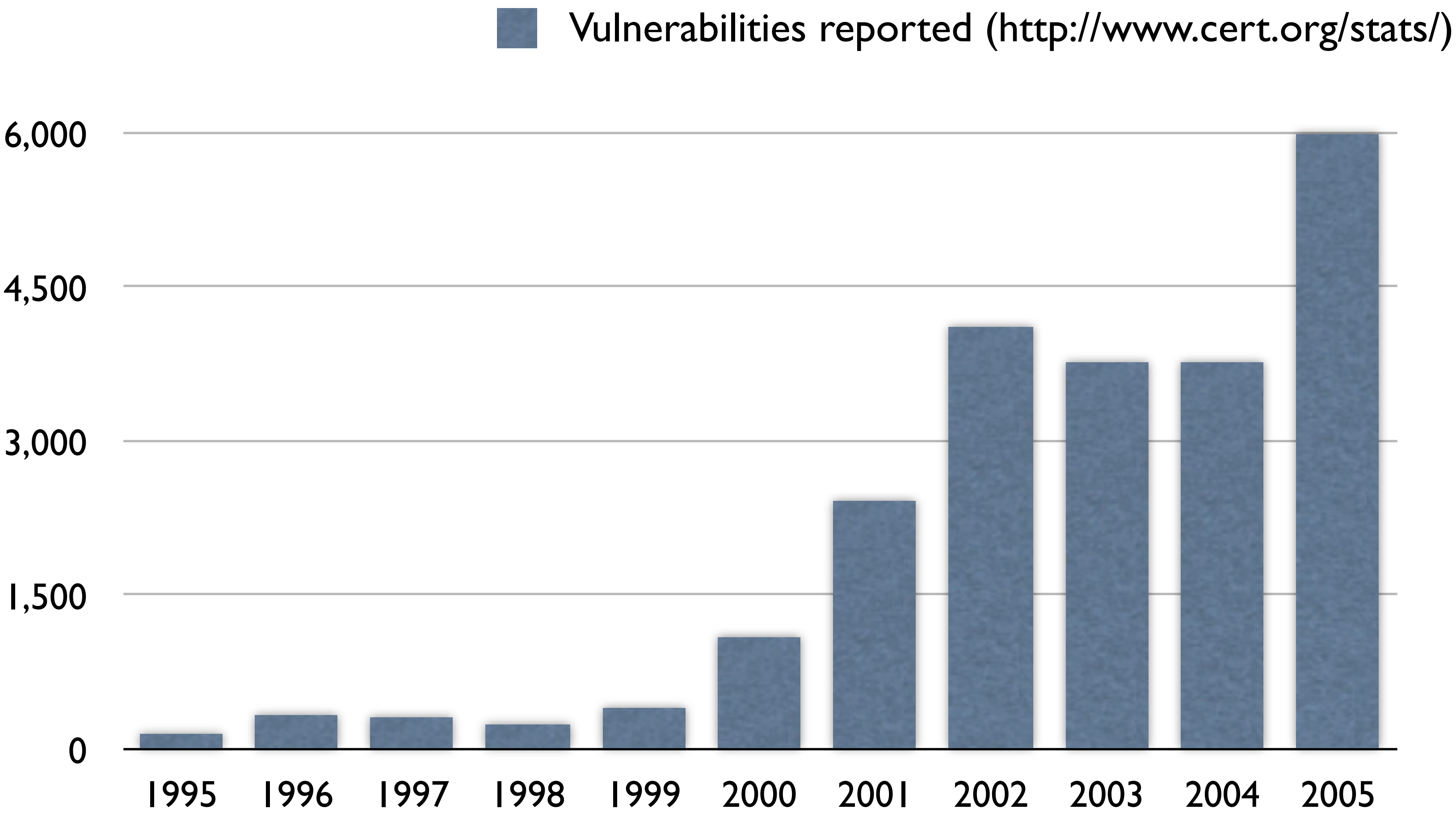
Growing Problem



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 <u>not</u> 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 <u>usable</u>?

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

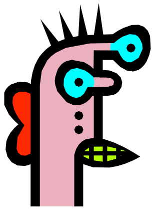
- Do consumers actually care about security?
- Security is expensive to implement
- Plenty of legacy software
- Easier to write “insecure” code
- Some languages (like C) are unsafe

Example: Electronic Voting

- Popular replacement to traditional paper ballots

AP

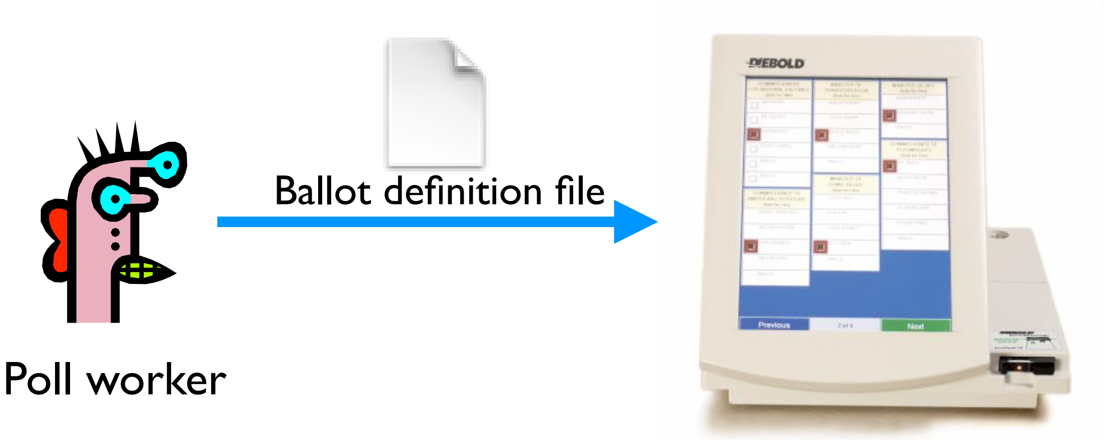
Pre-Election



Poll worker

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

Pre-Election



Ballot definition file

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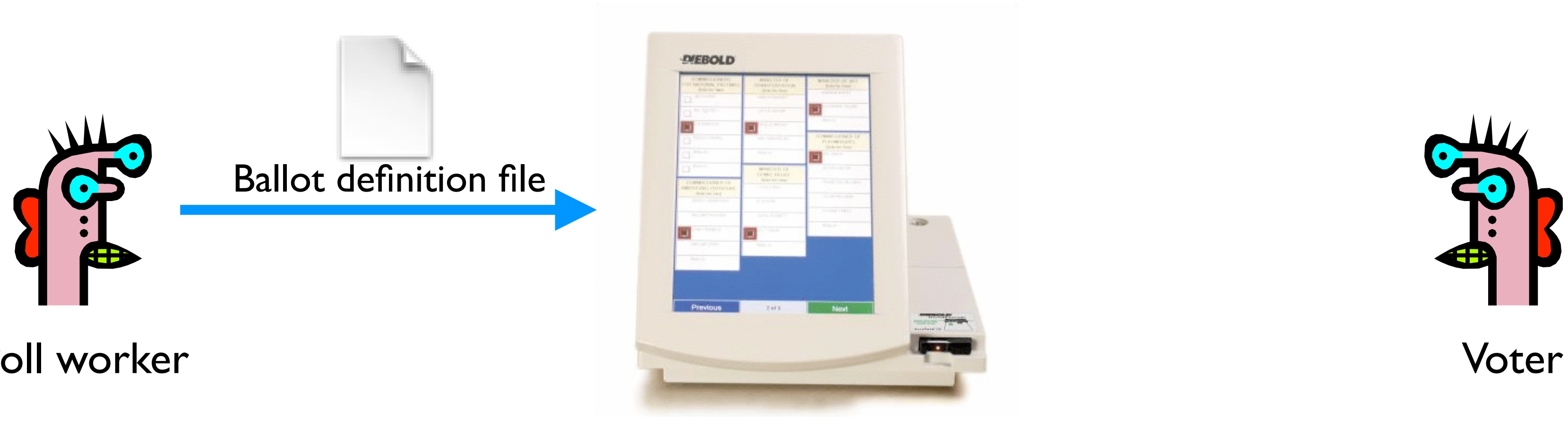
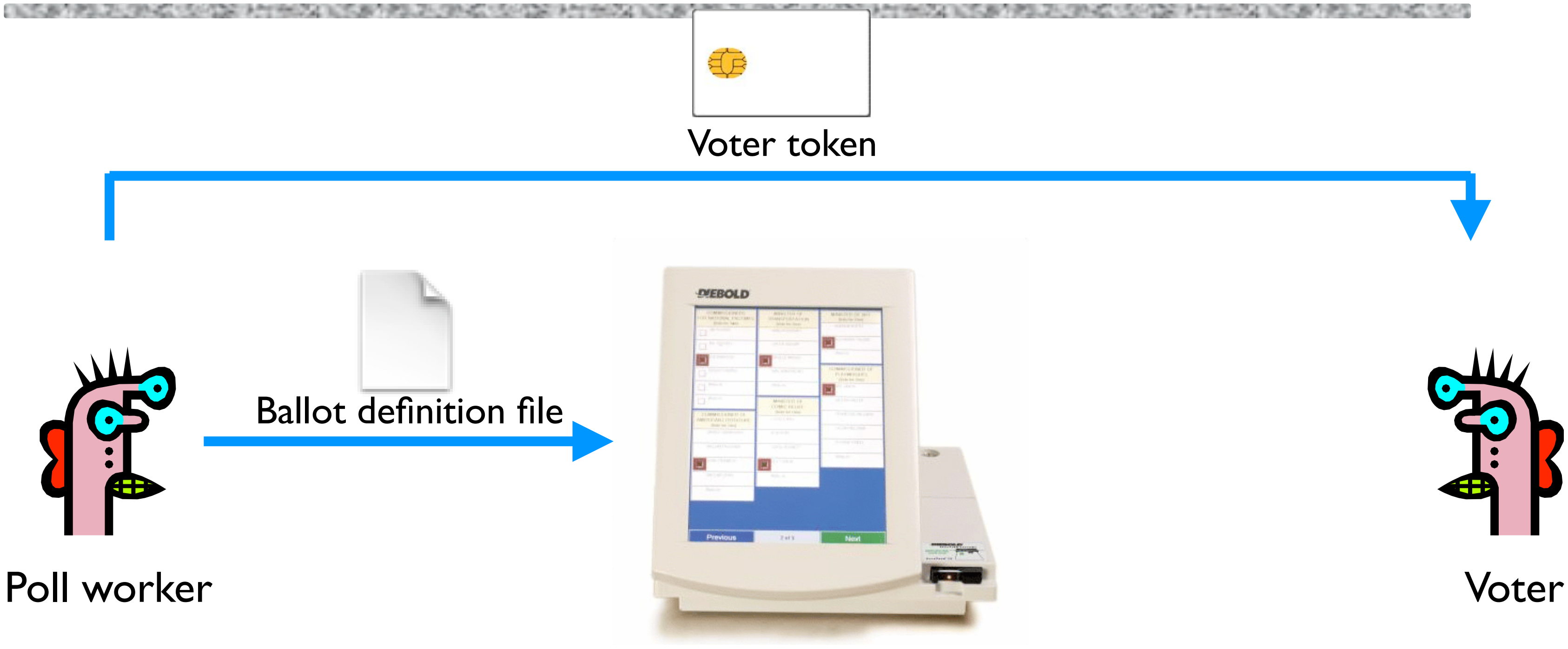
Active Voting



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

Active Voting



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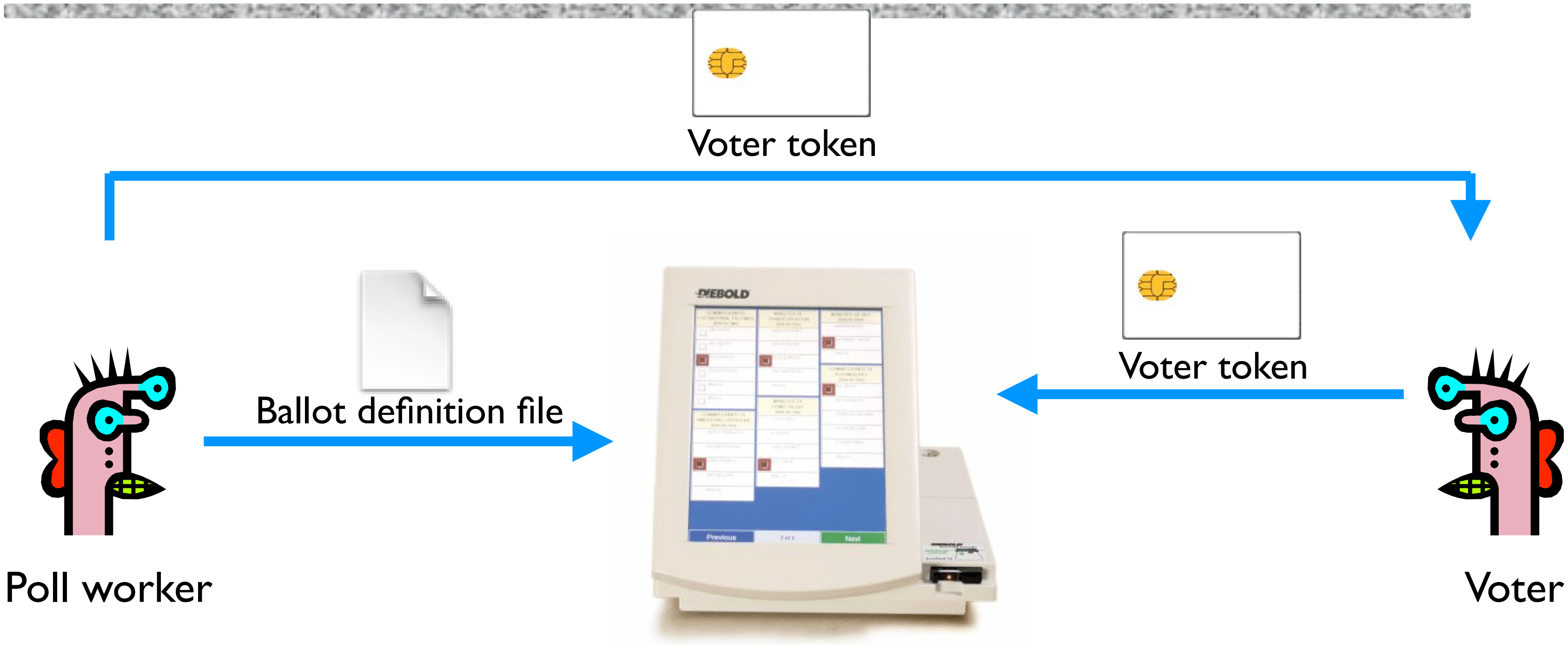

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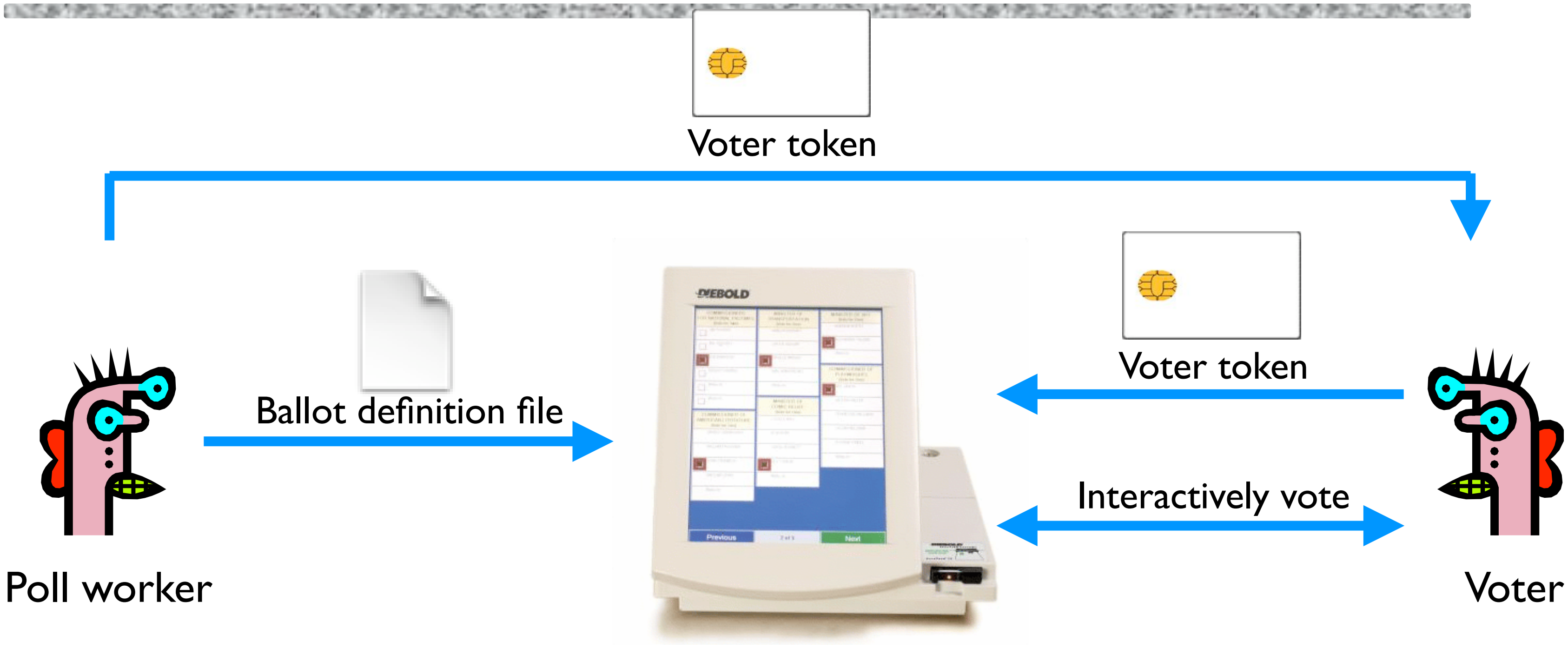

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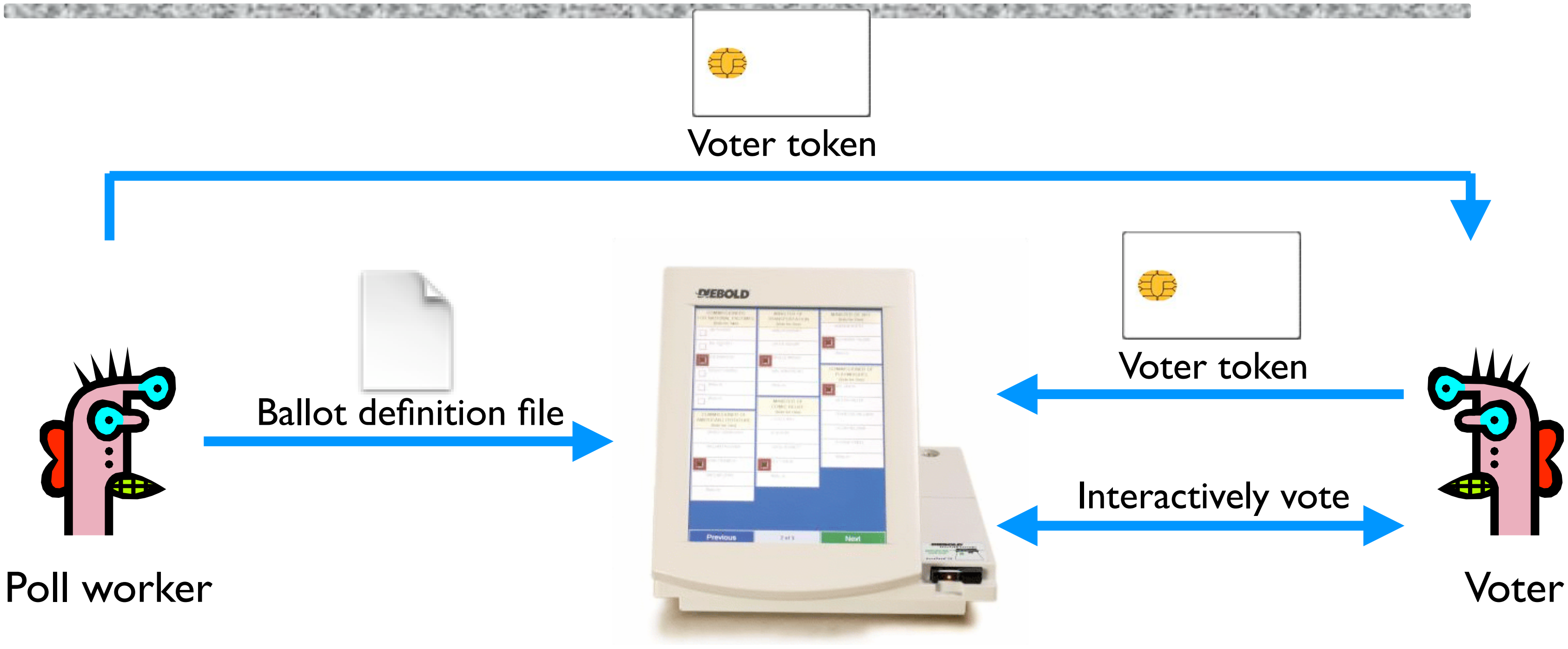

Active voting: Votes encrypted and stored. Voter token canceled.

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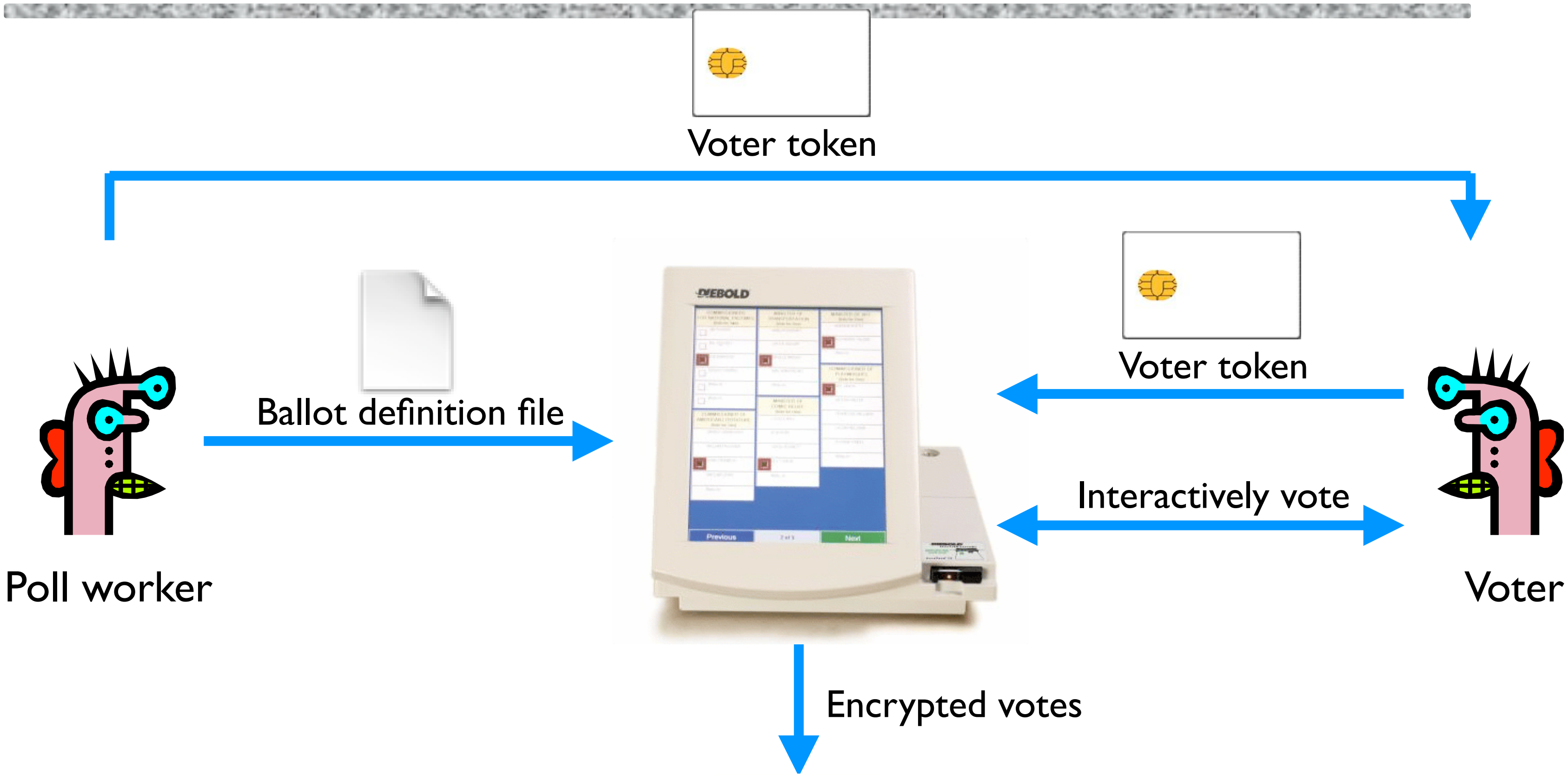

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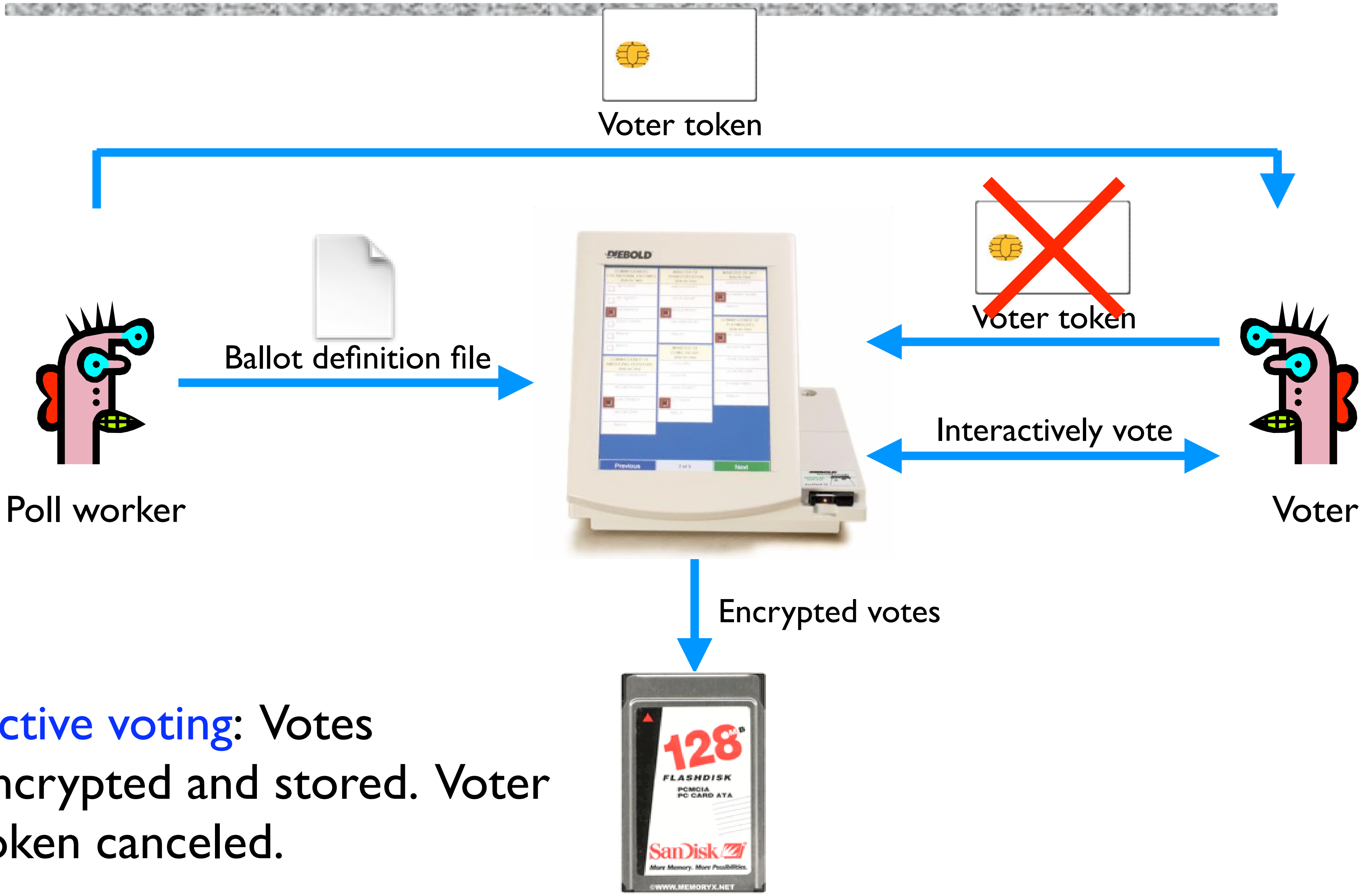

Voter token

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Interactively vote

Poll worker

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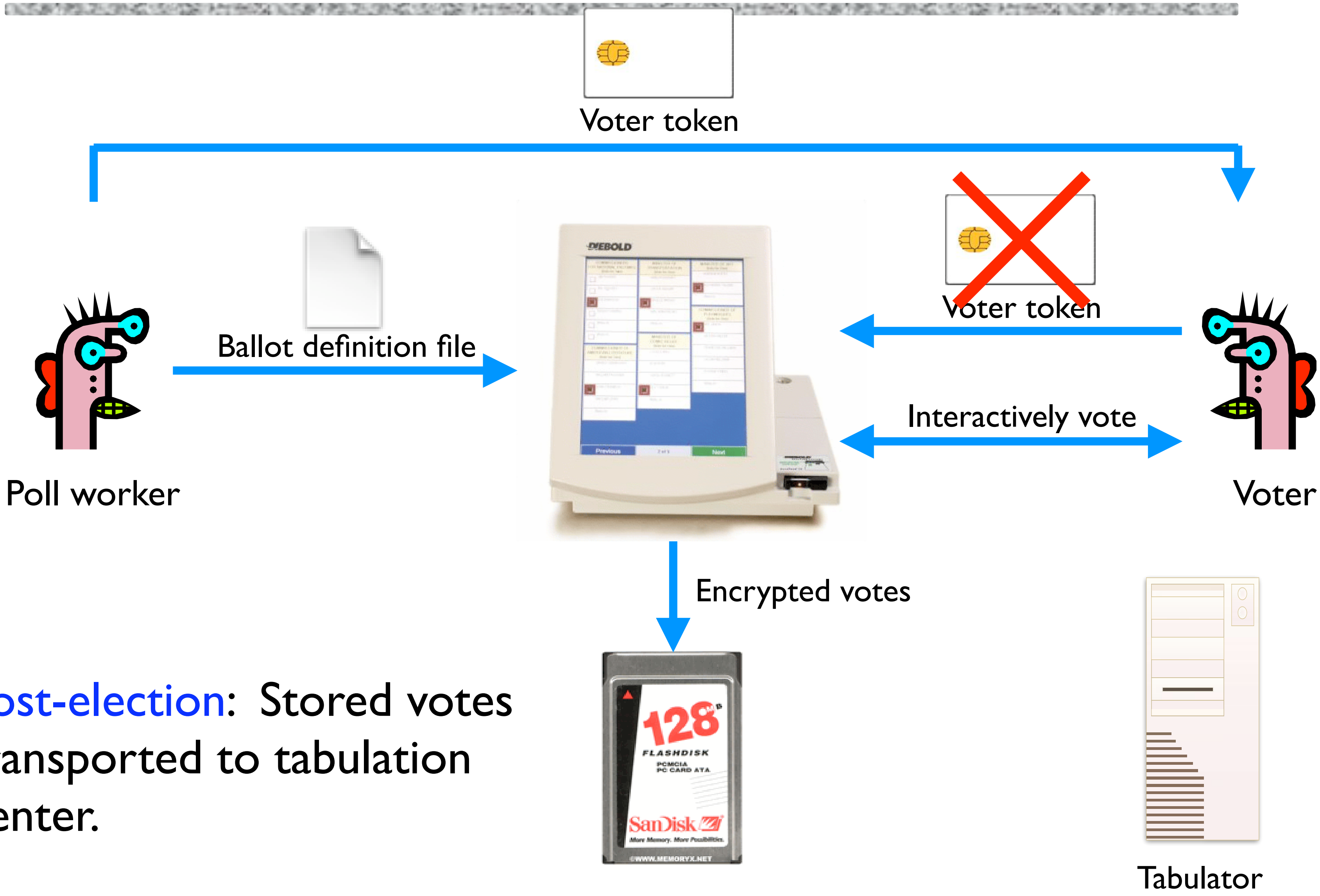

Post-election: Stored votes transported to tabulation center.

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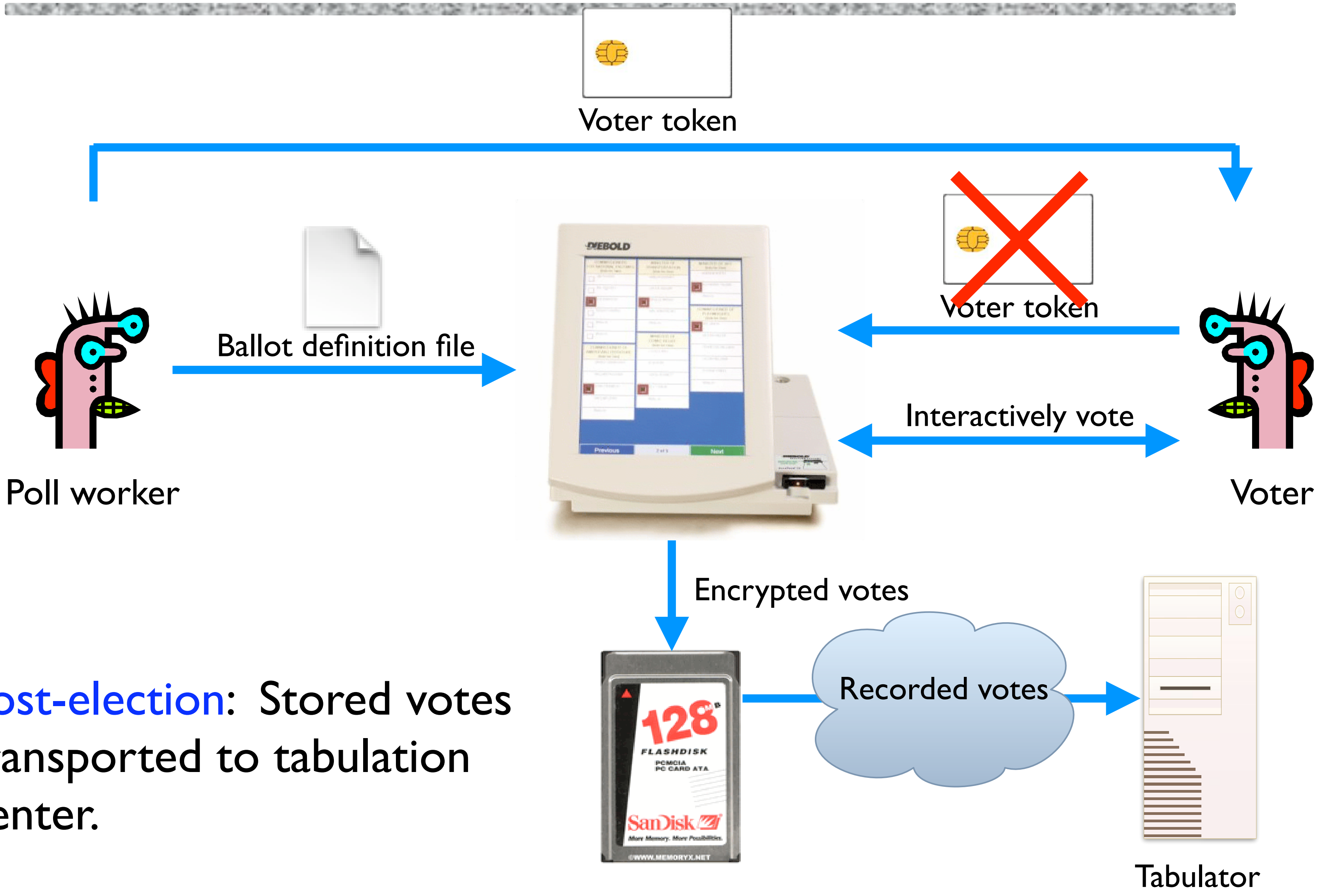

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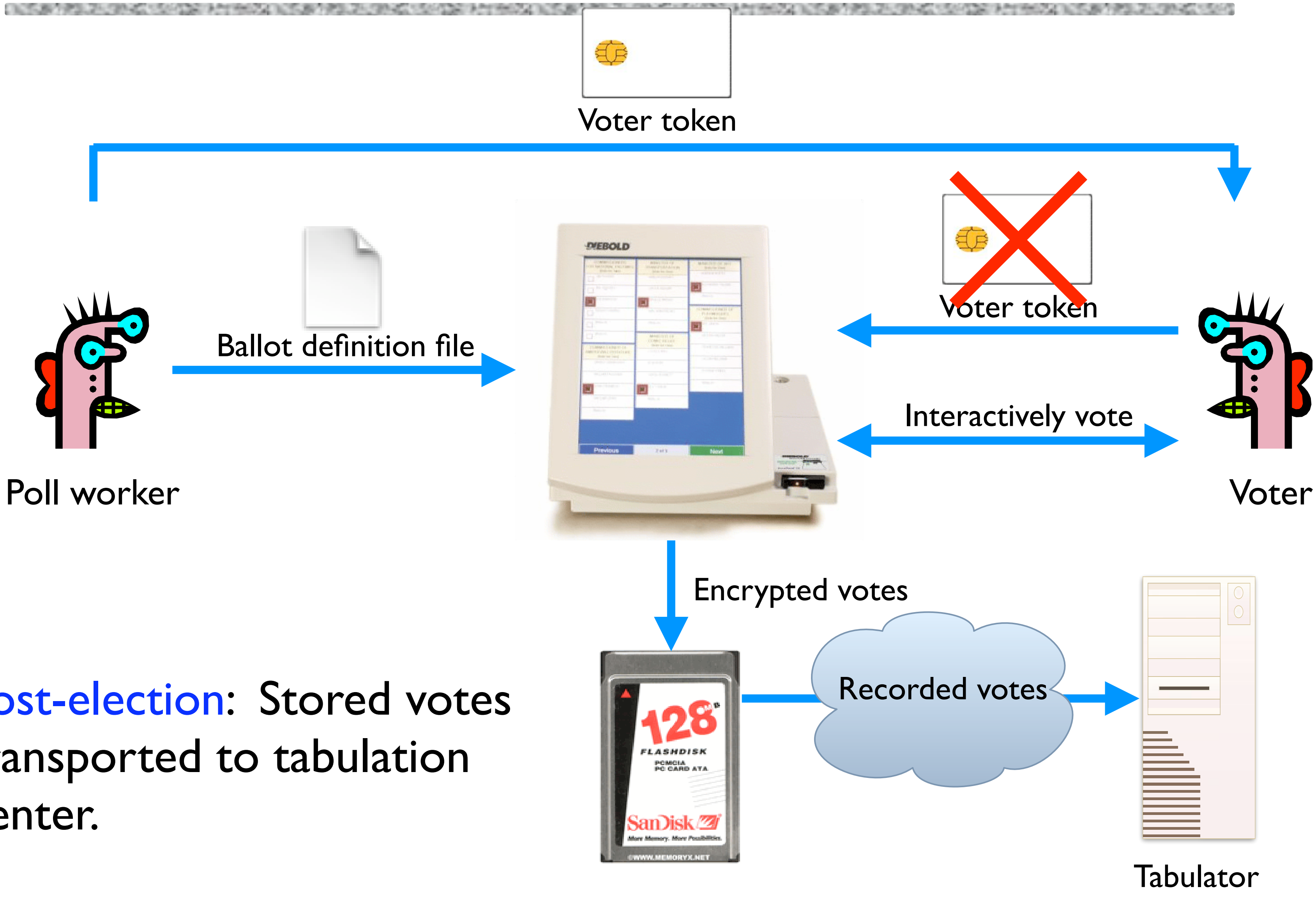
Security and E-Voting (Simplified)

- 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

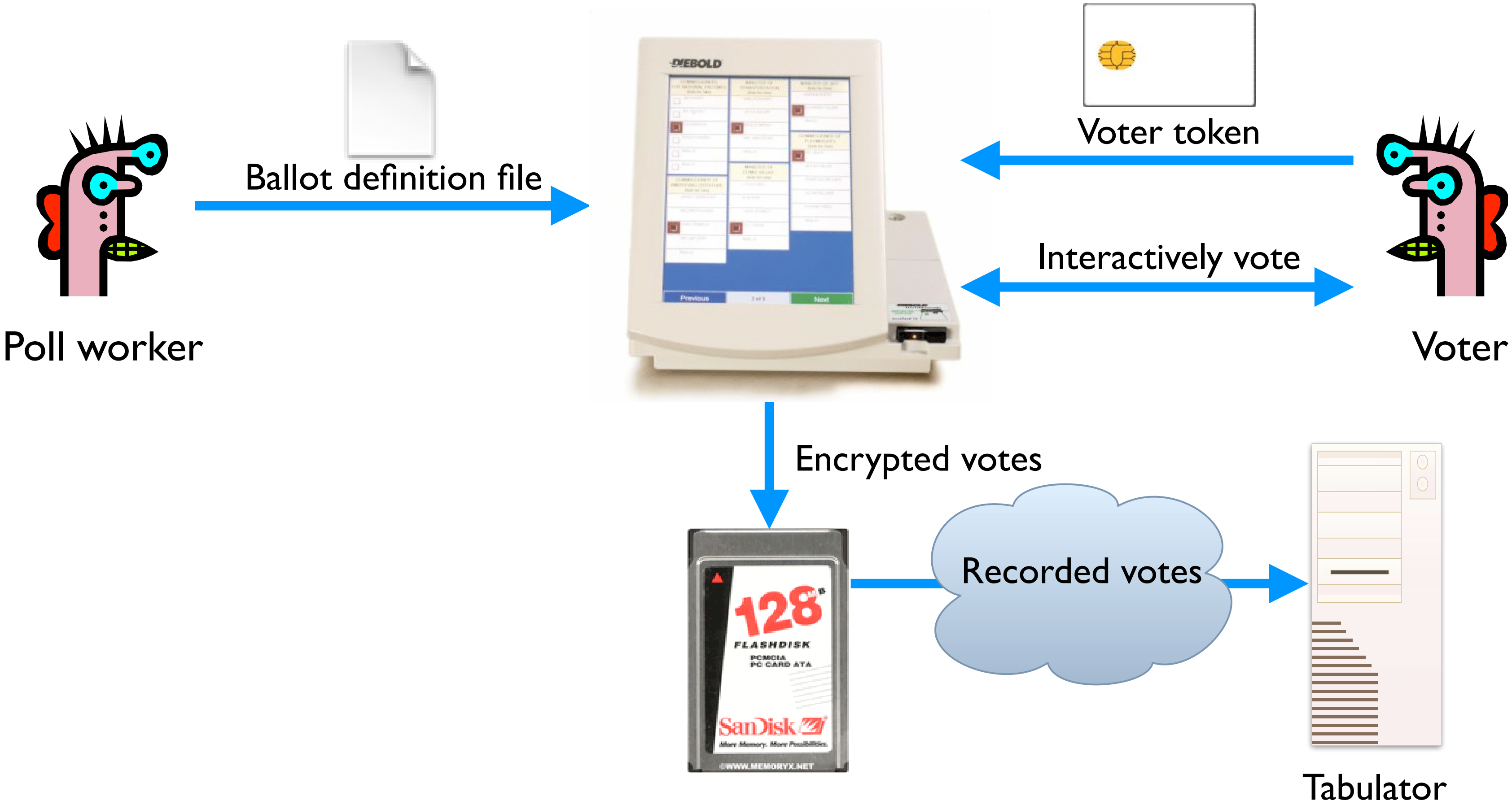
- Voters
- Election officials
- Employees of voting machine manufacturer
  - Software/hardware engineers
  - Maintenance people
- Other engineers
  - Makers of hardware
  - Makers of underlying software or add-on components
  - Makers of compiler
- …
- Or any combination of the above

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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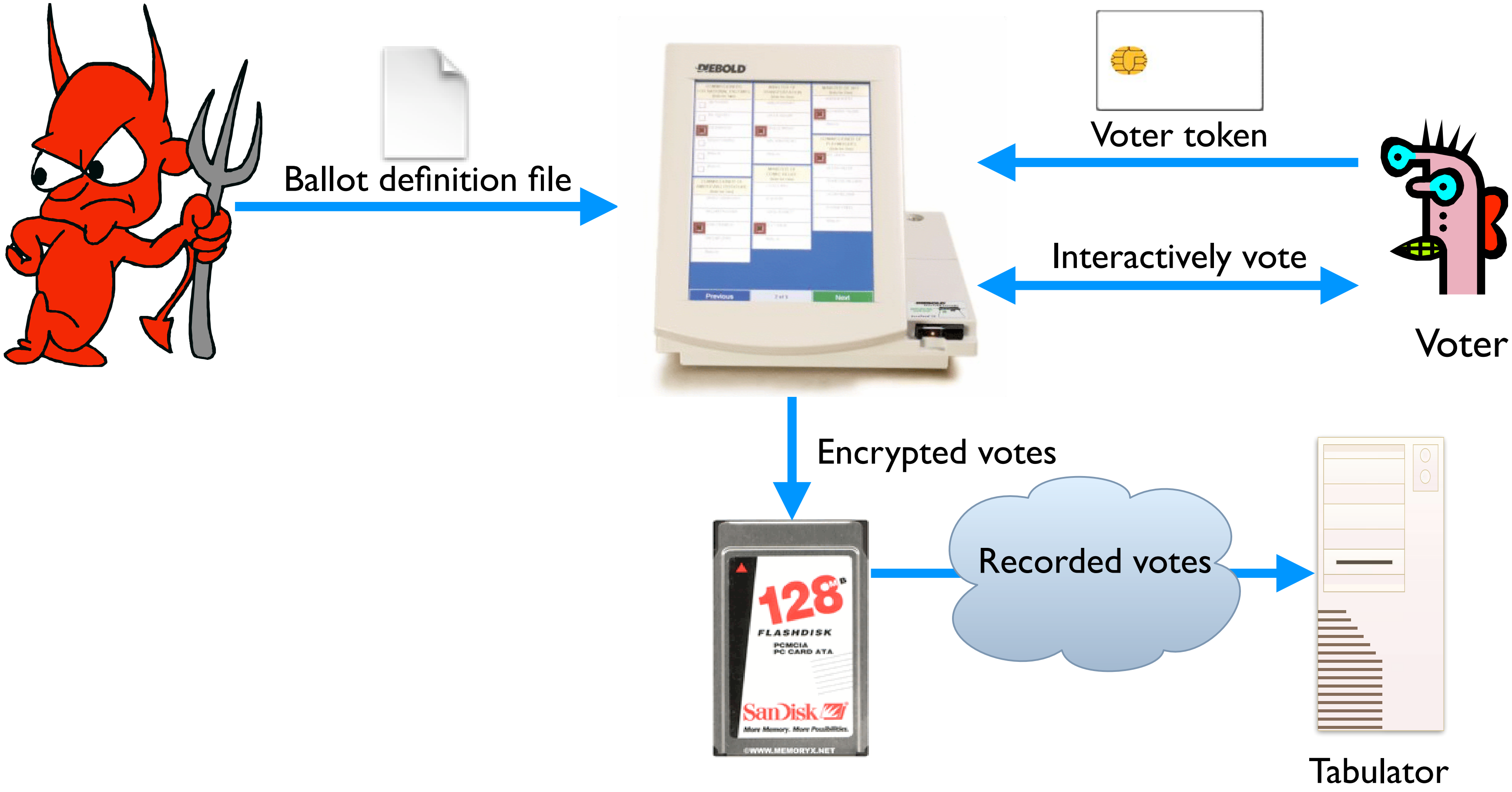

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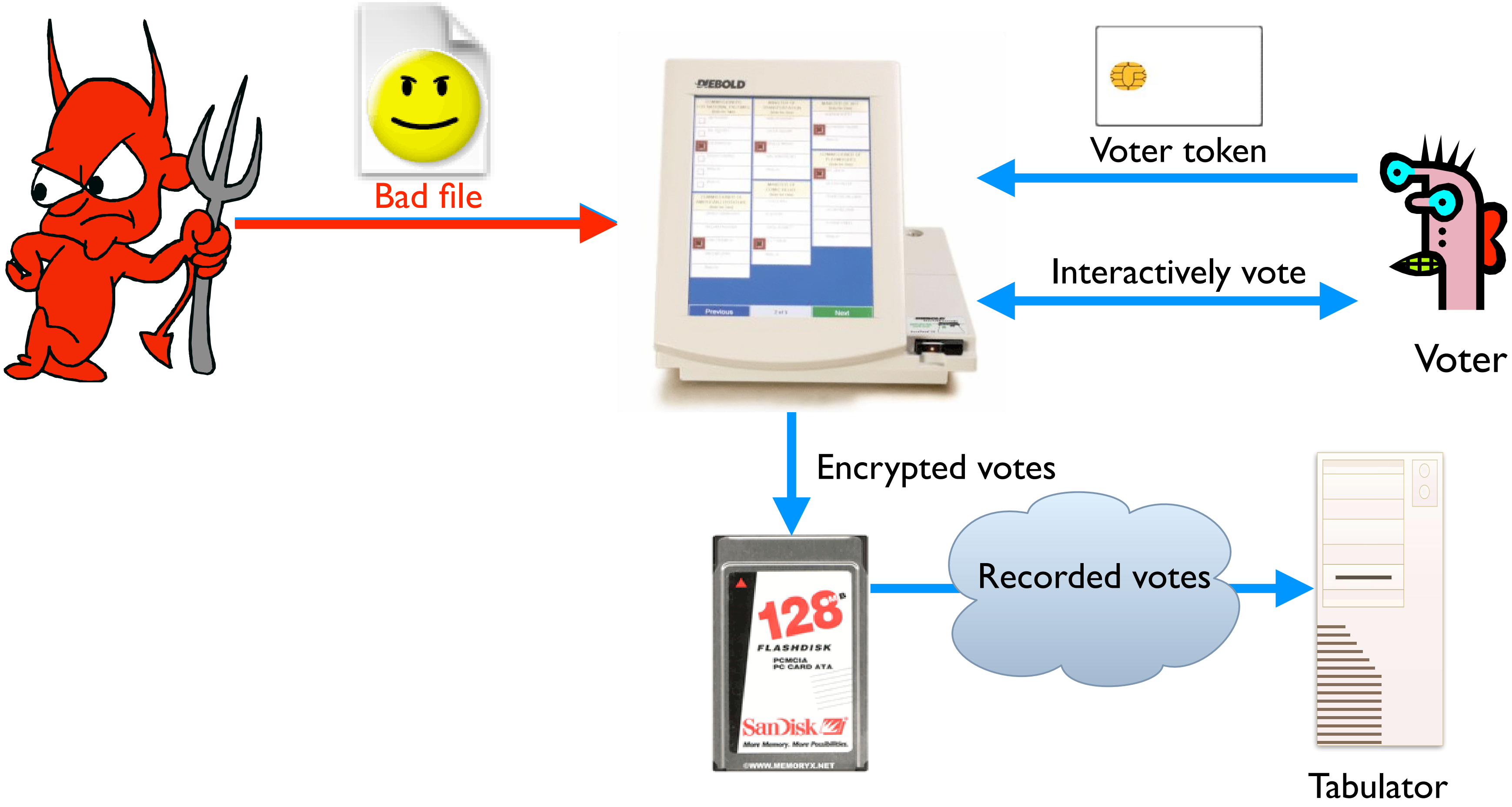

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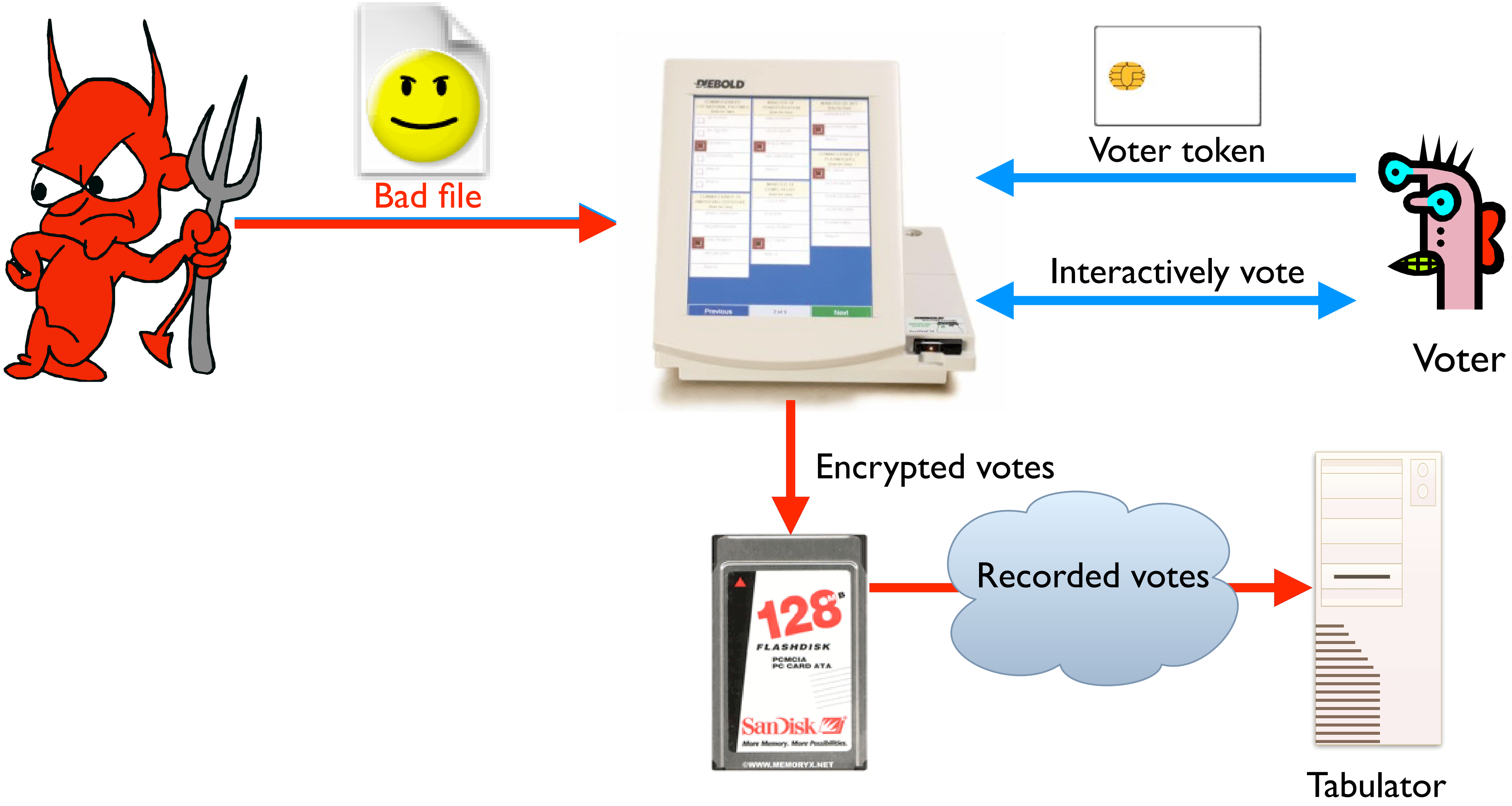

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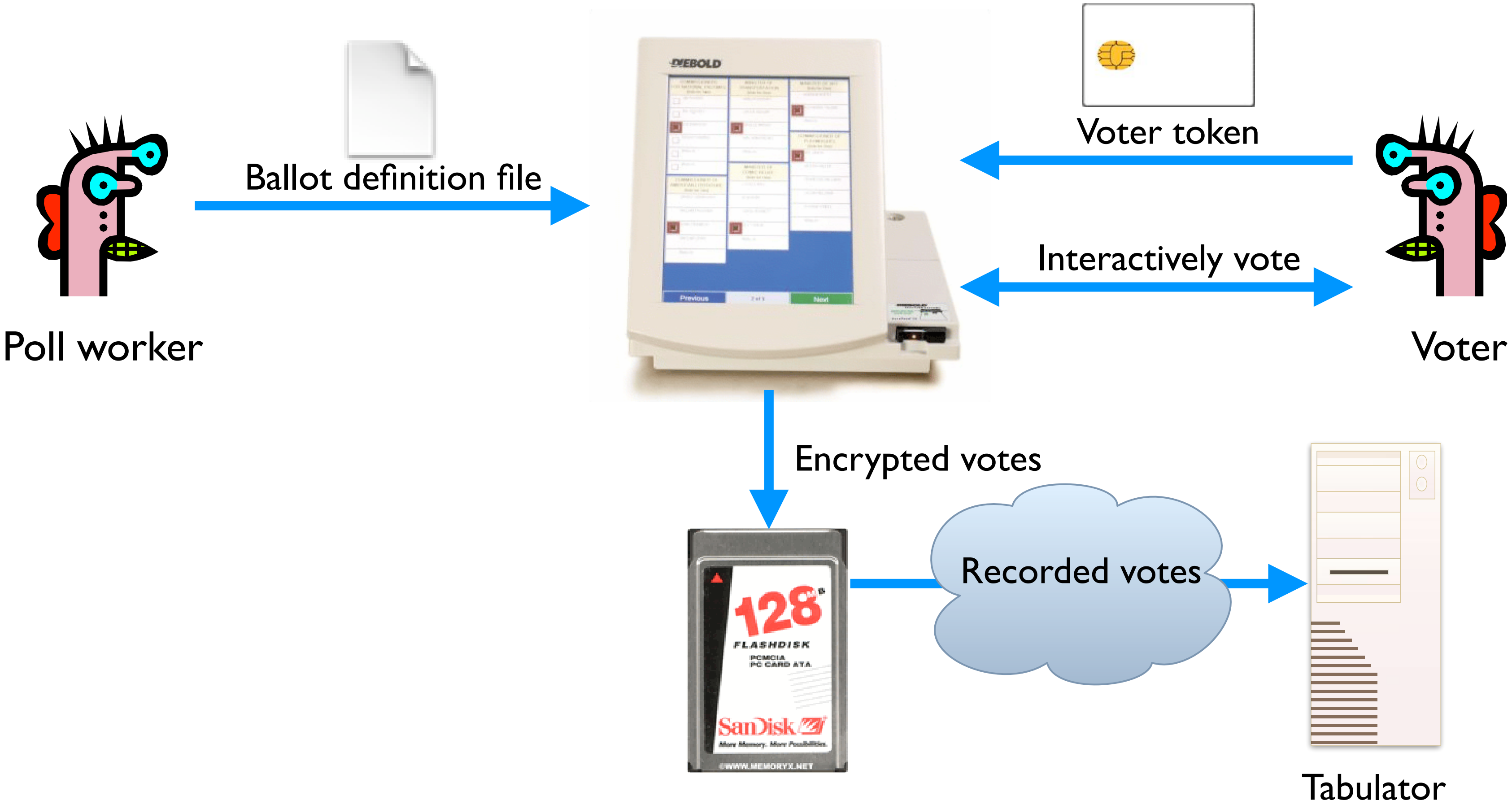
Example attack: A regular voter could make his or her own voter token and vote multiple times.



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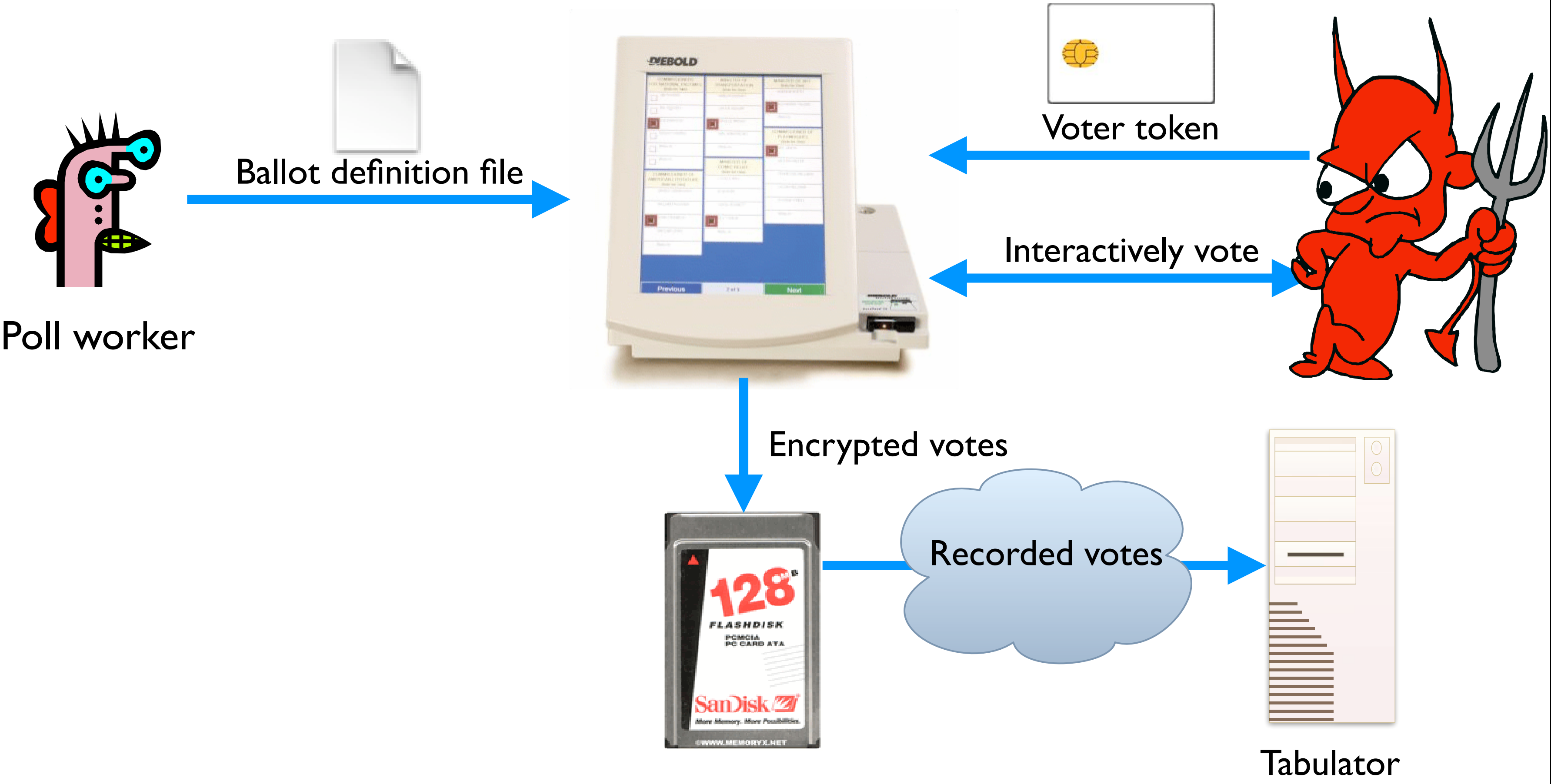

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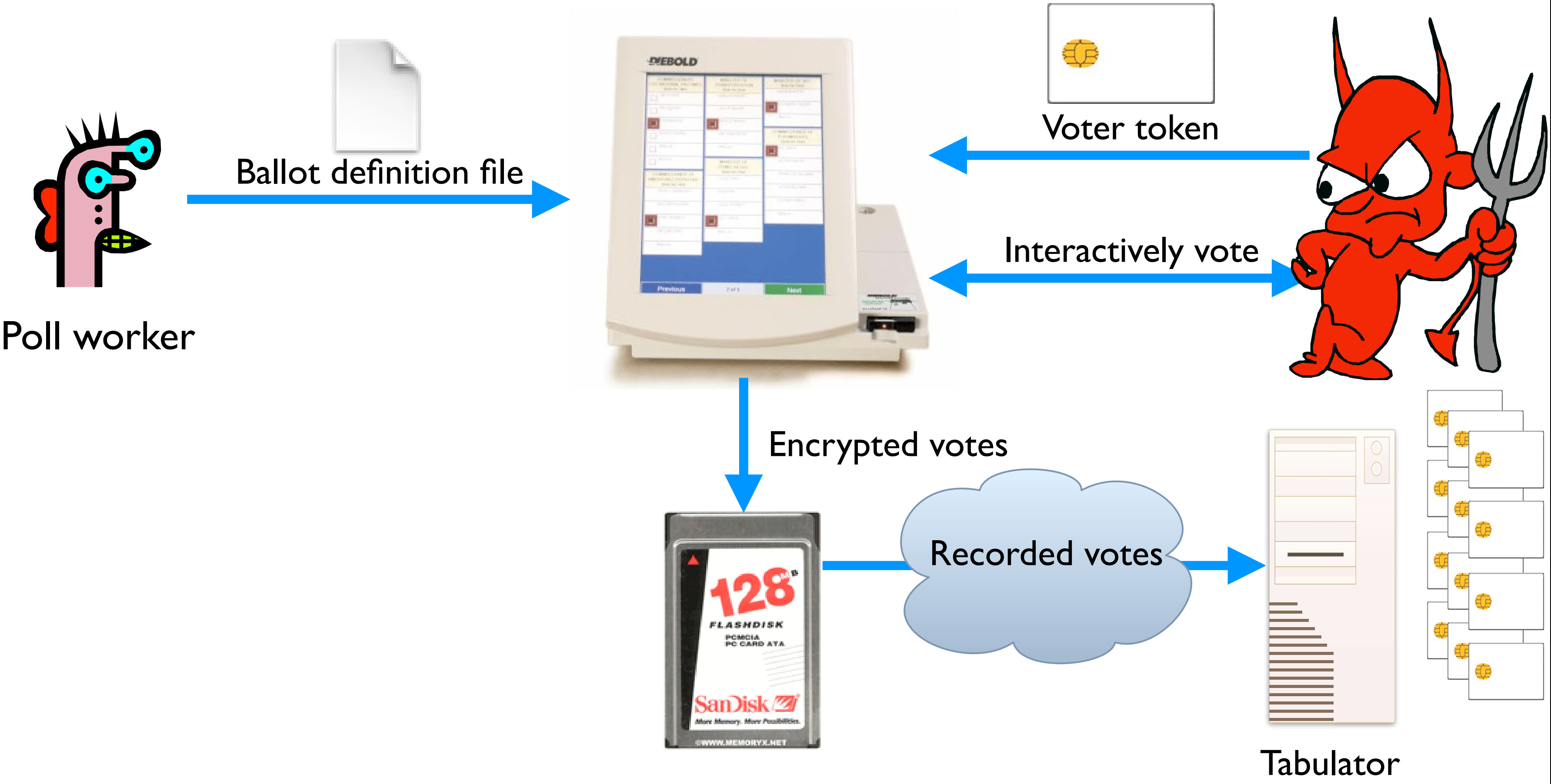

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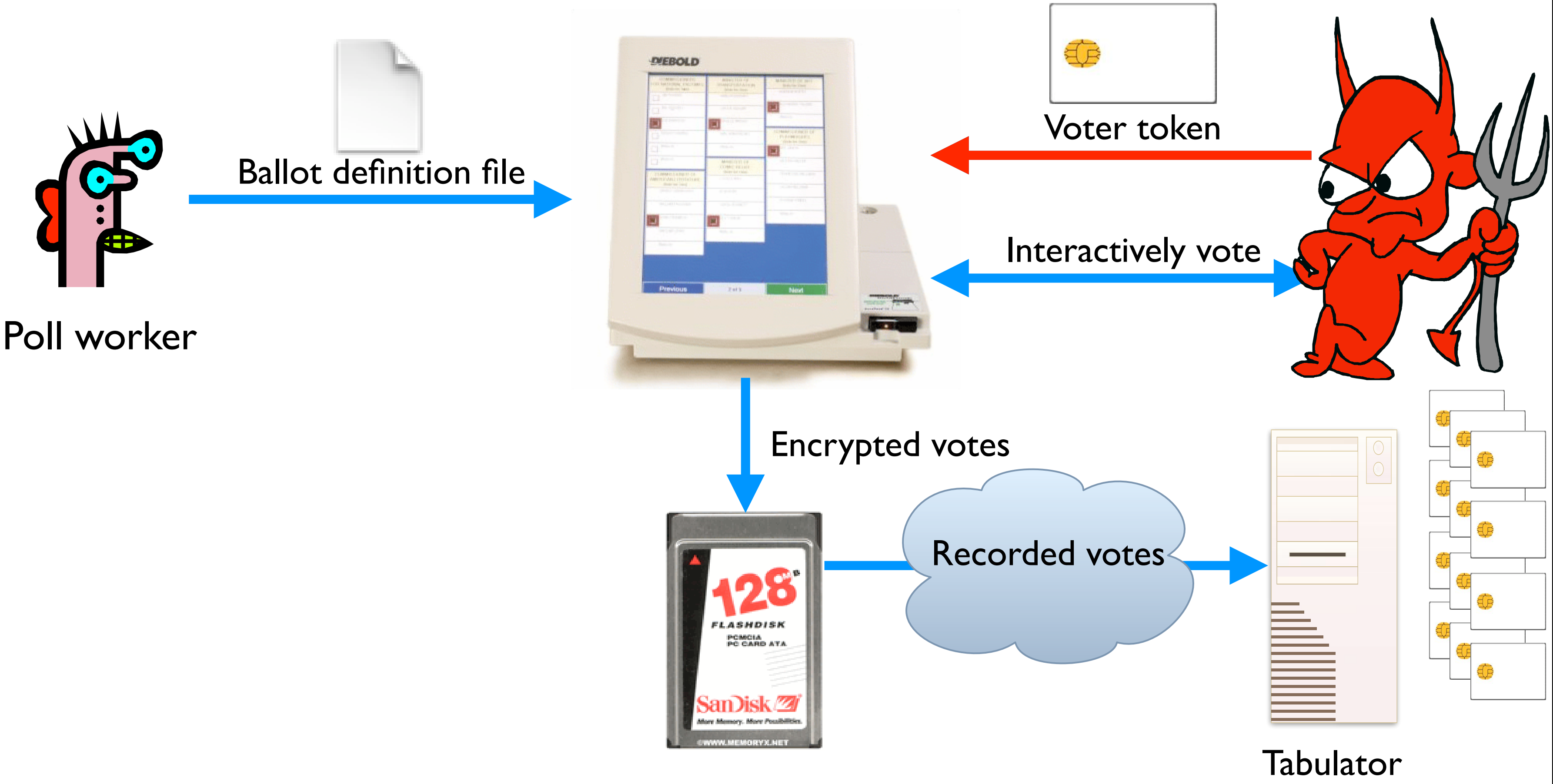

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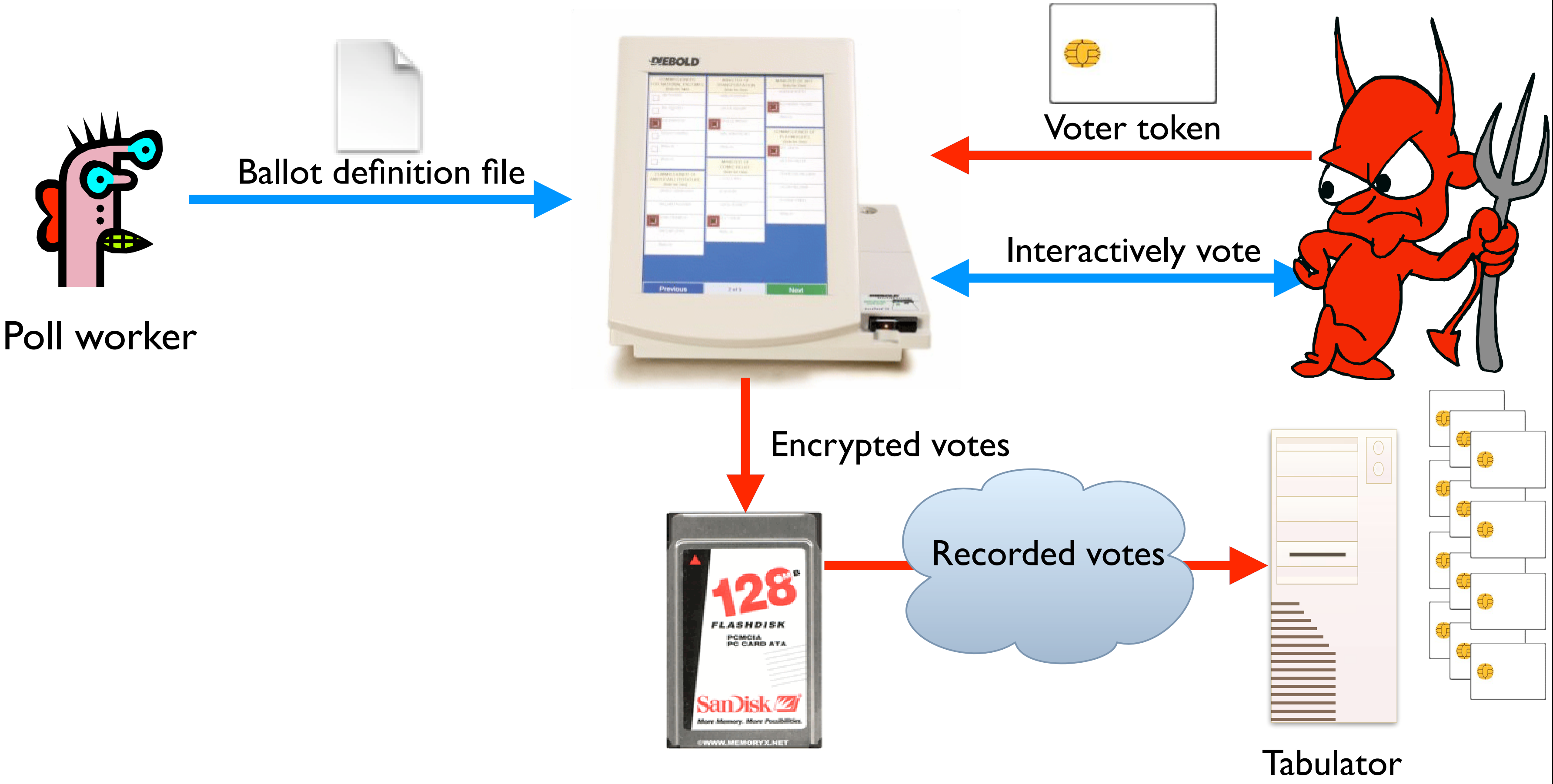

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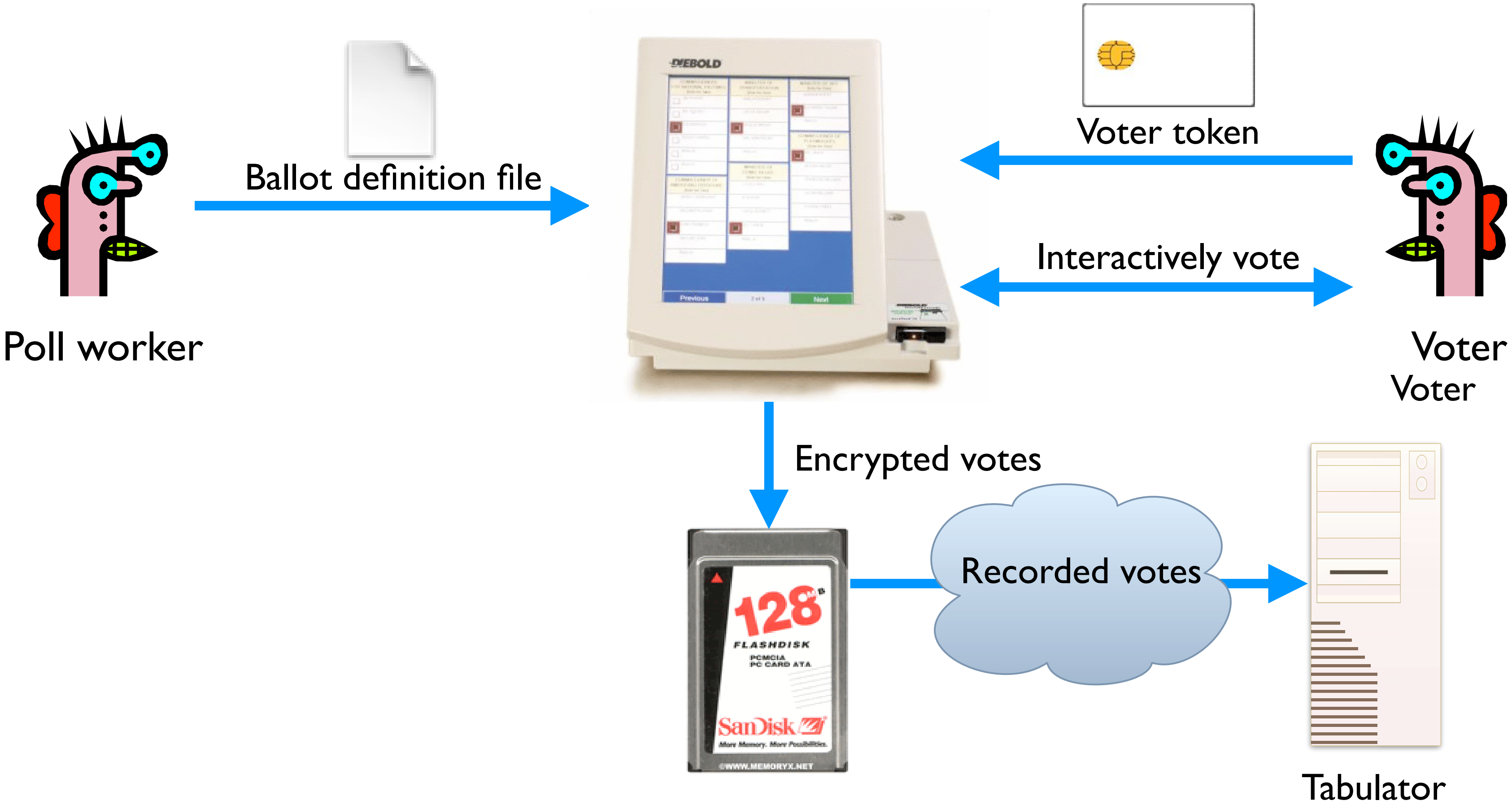
Example attack: A poll worker could determine how voters vote.



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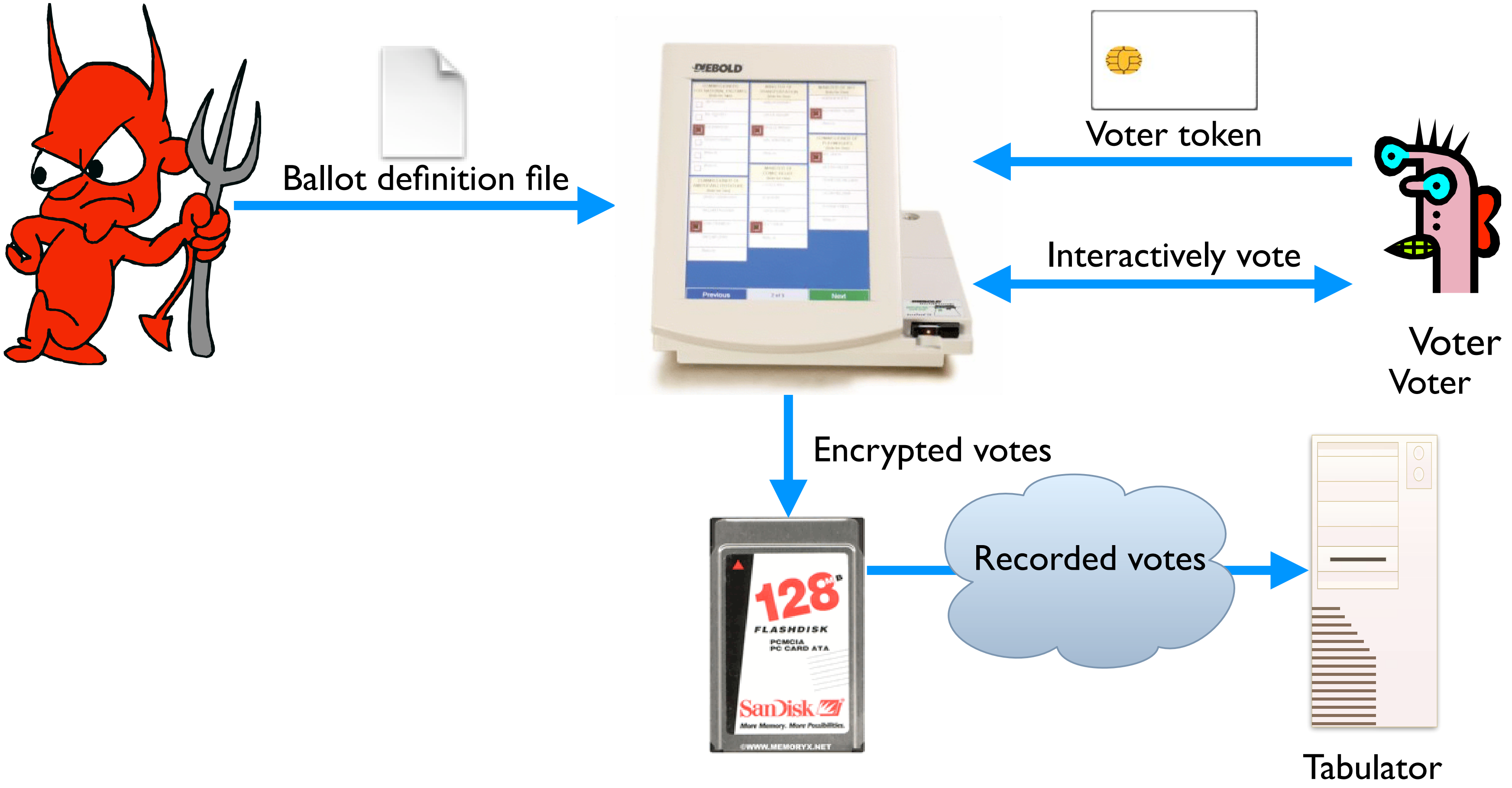

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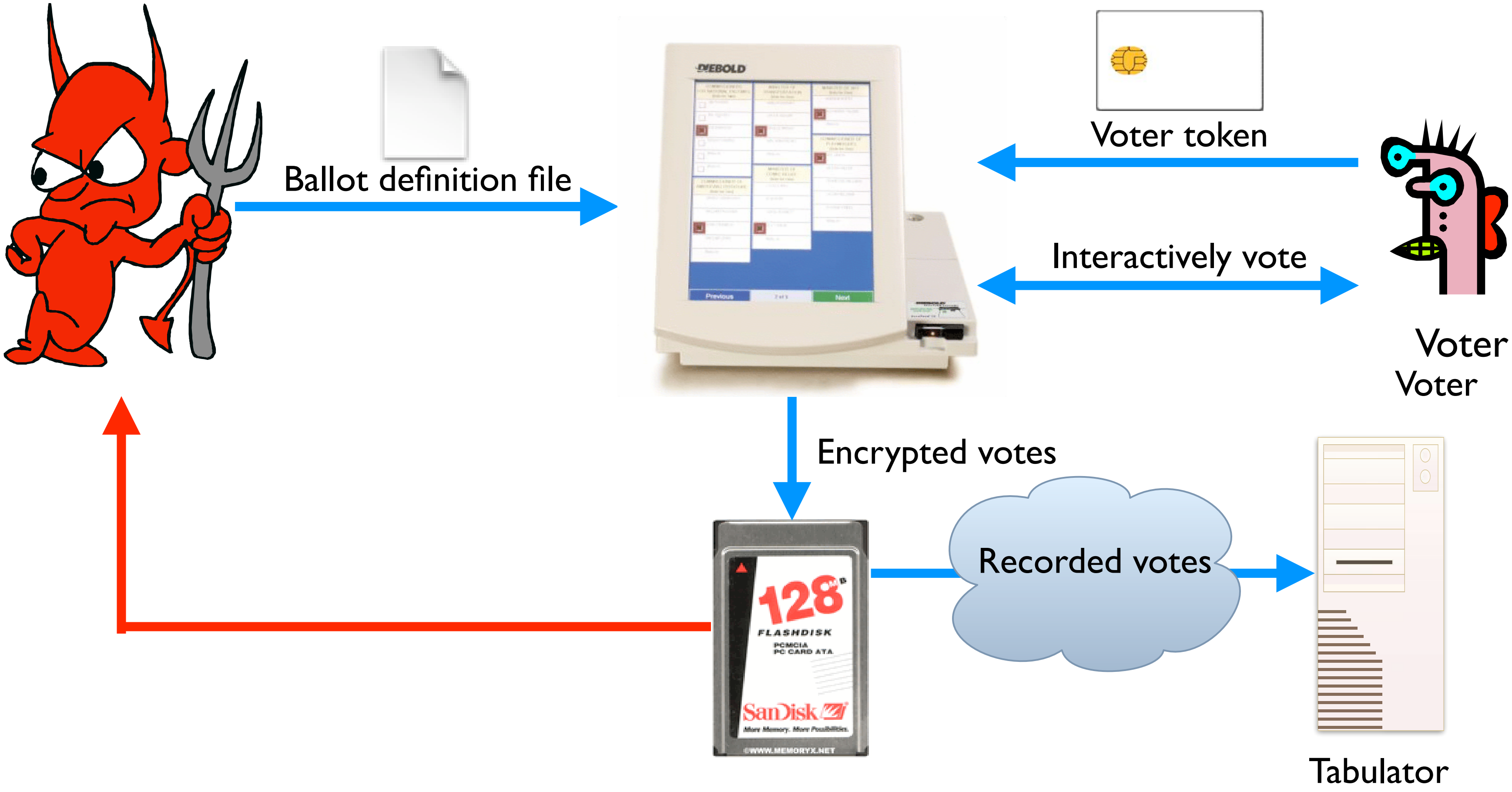

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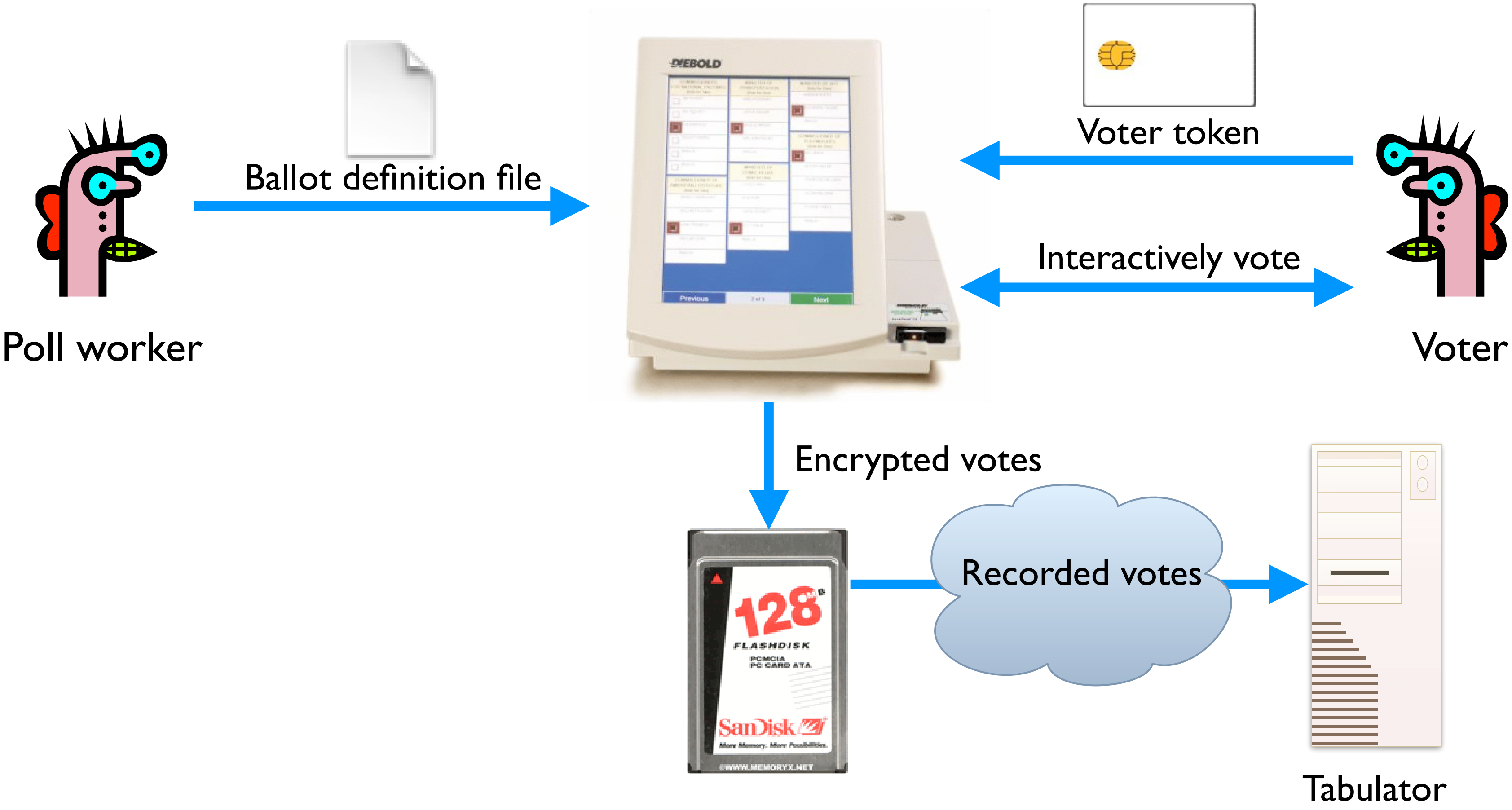

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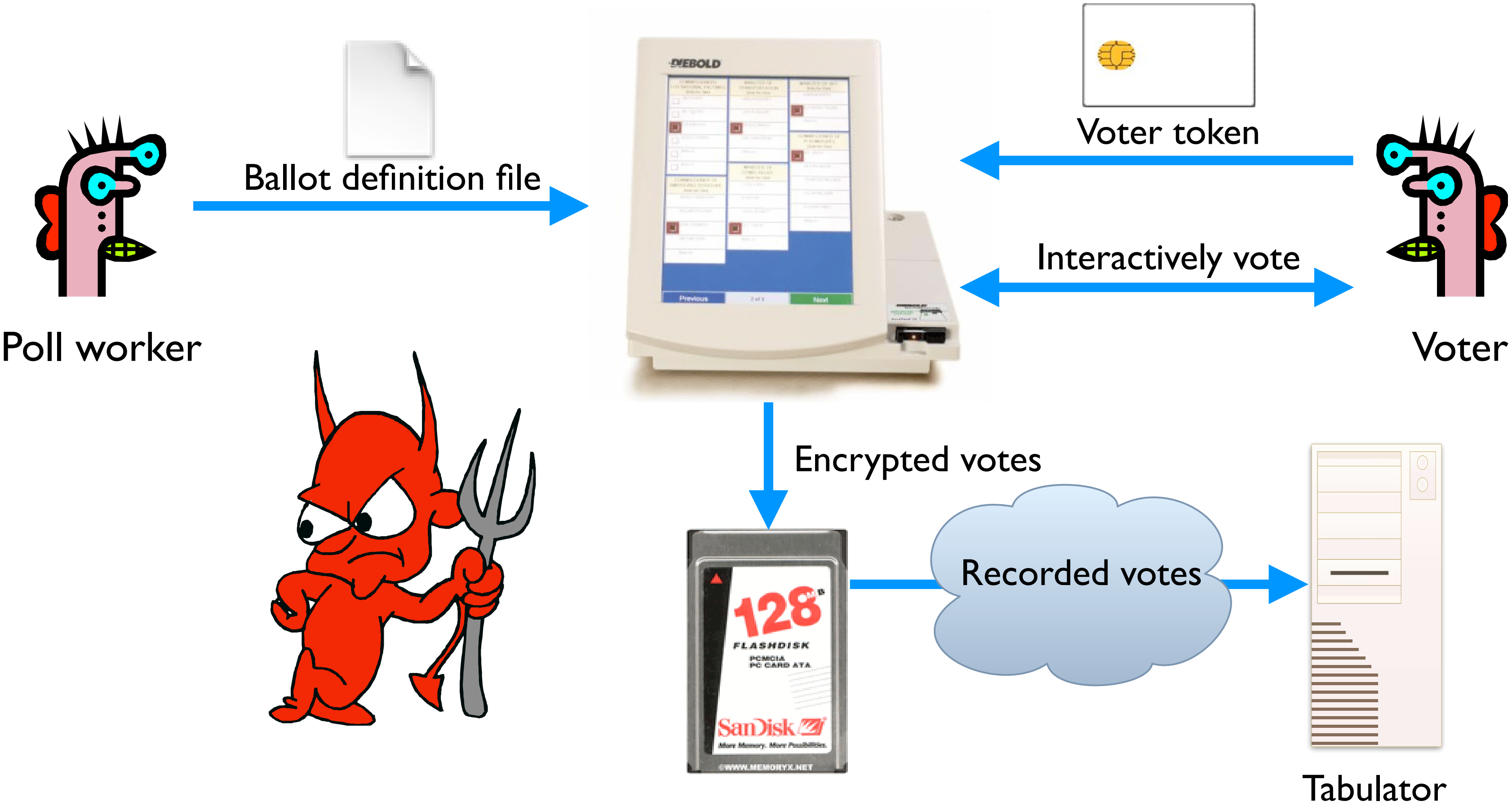

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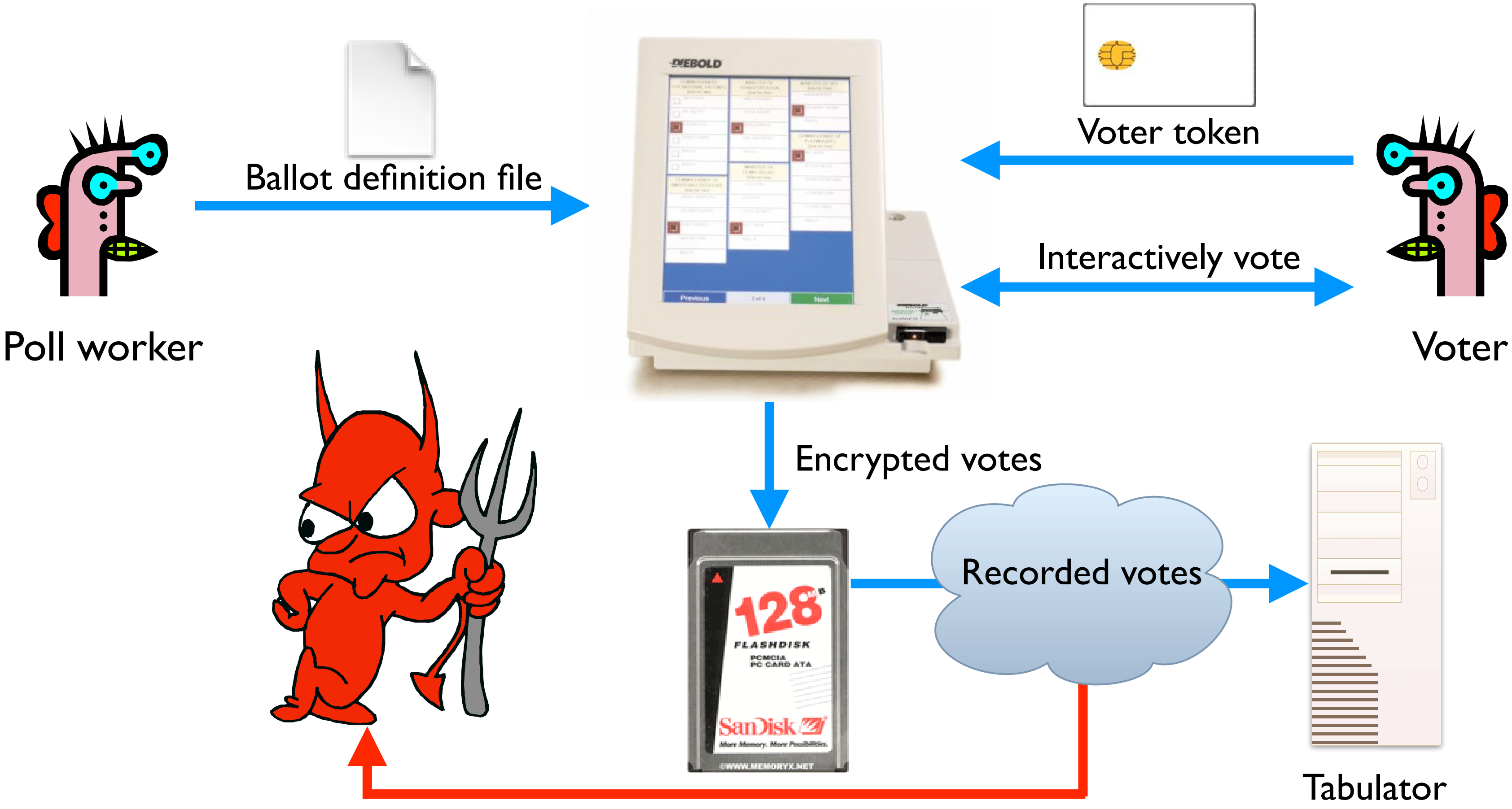


Whole-System is Critical

- 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

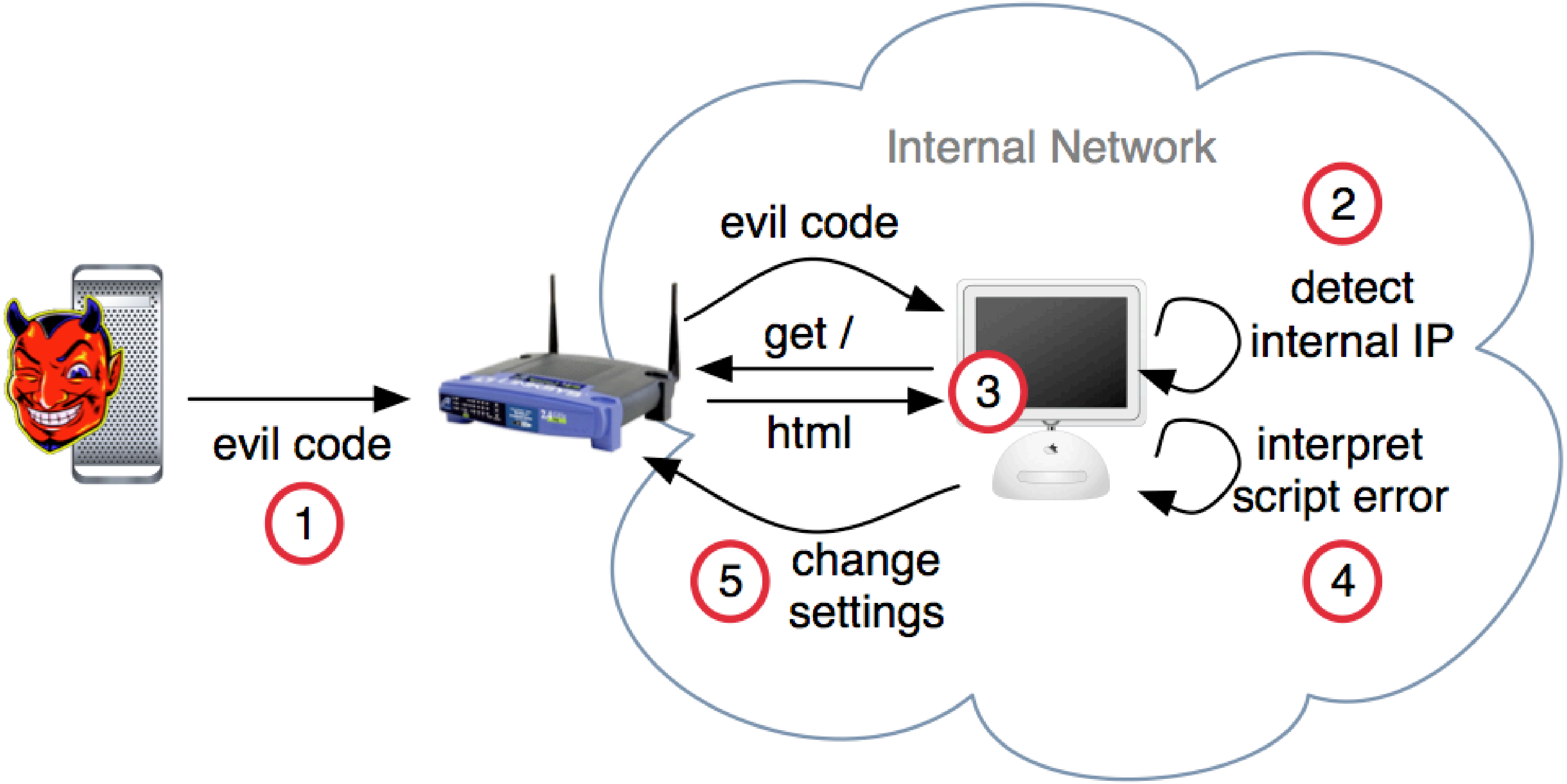
Security is Subtle

- 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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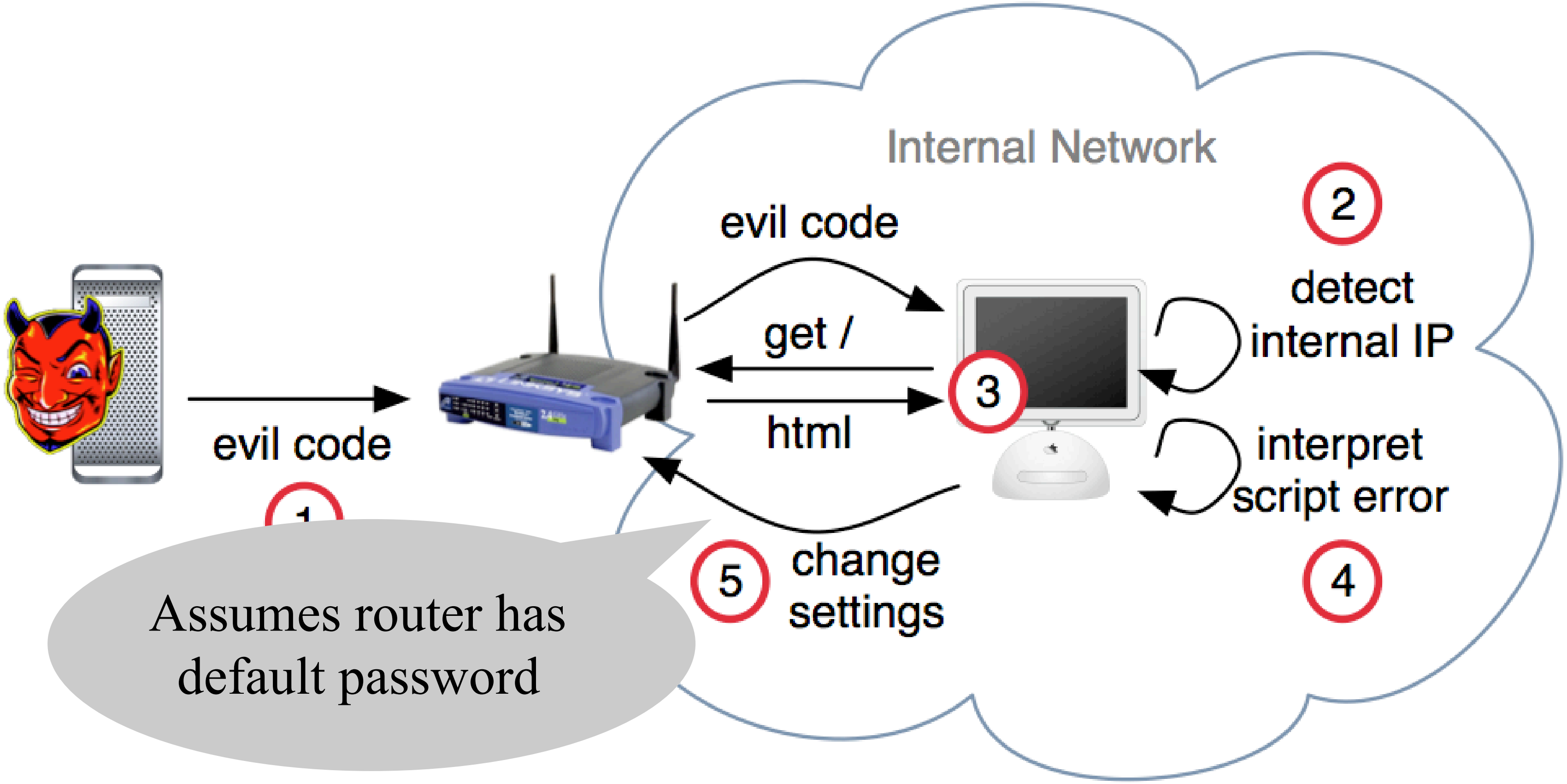

Assumes router has default password

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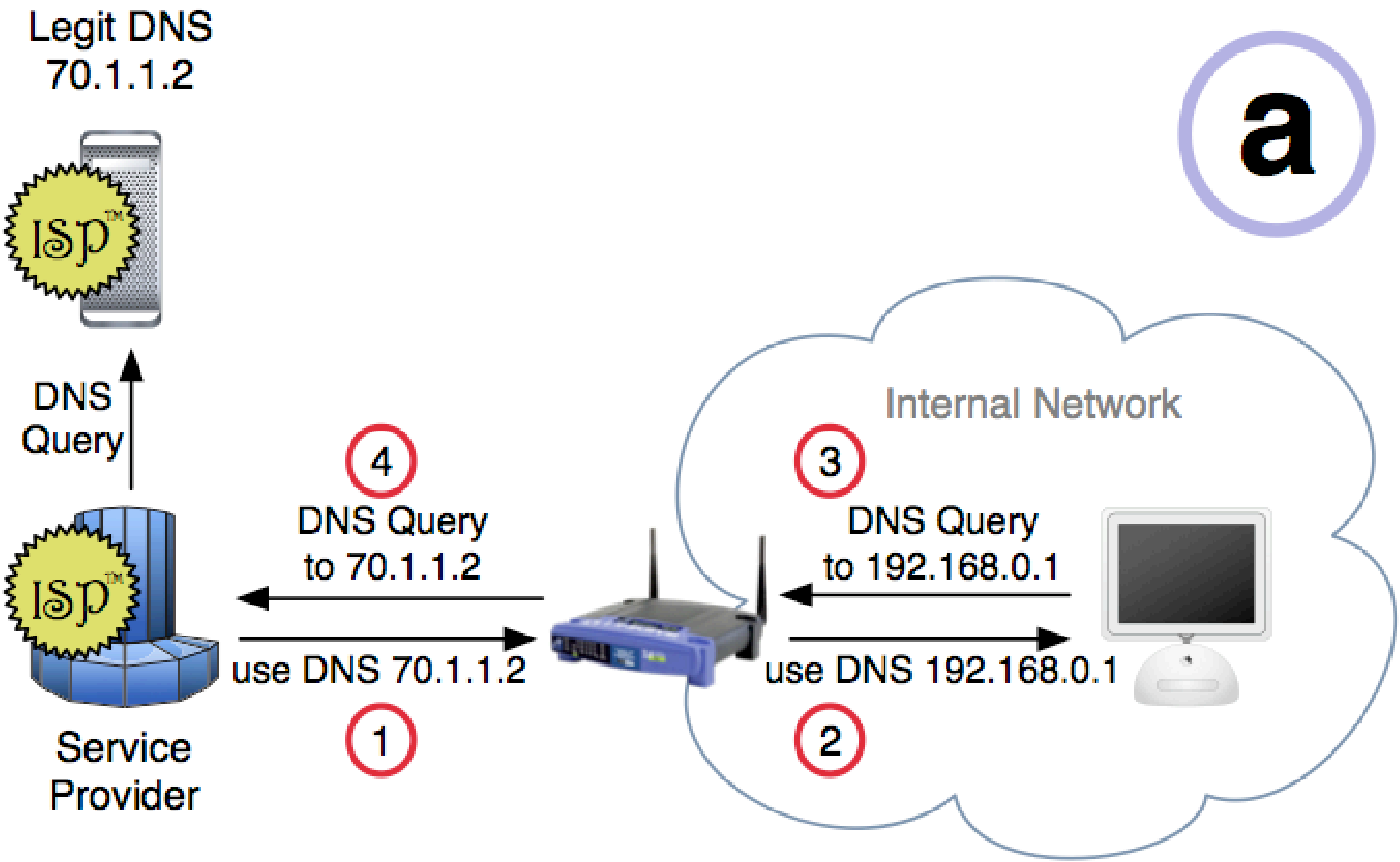

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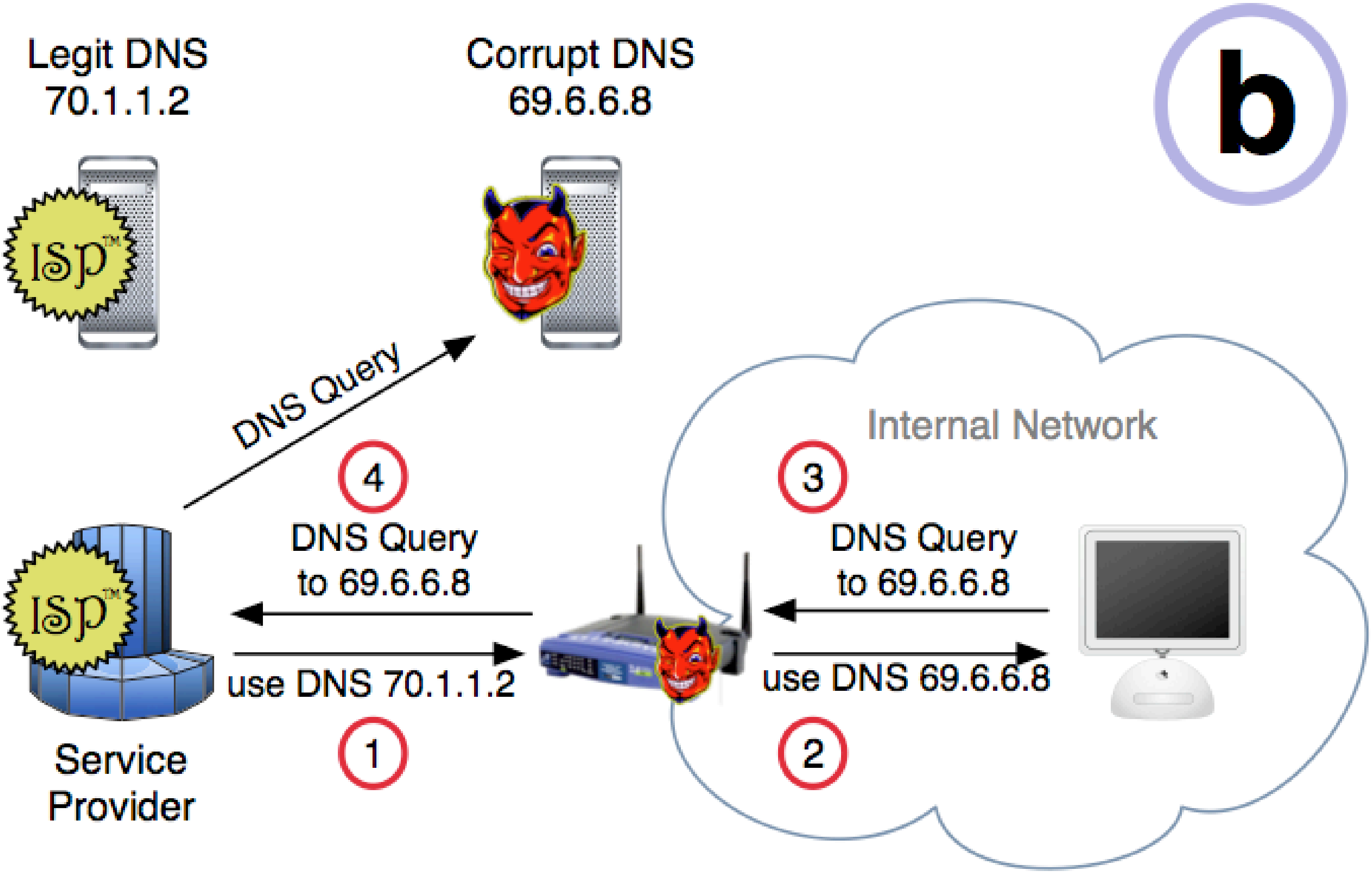
Another Example: Drive-By Pharming



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

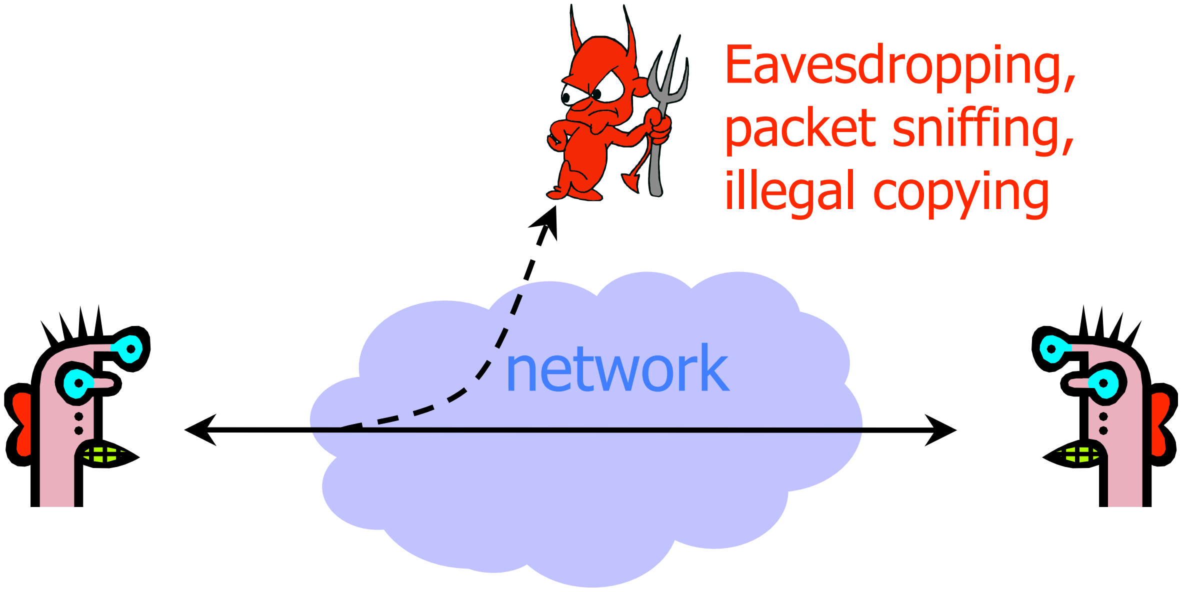
- Thinking about security; the “big picture”
  - The hardest part: Getting the “security mindset”
- Software security, buffer overflow attacks
- Cryptography
  - Block ciphers, stream ciphers, hash functions, MACs, public key encryption, digital signatures, PKI, key exchange, protocols (SSL/TLS, IPsec, 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

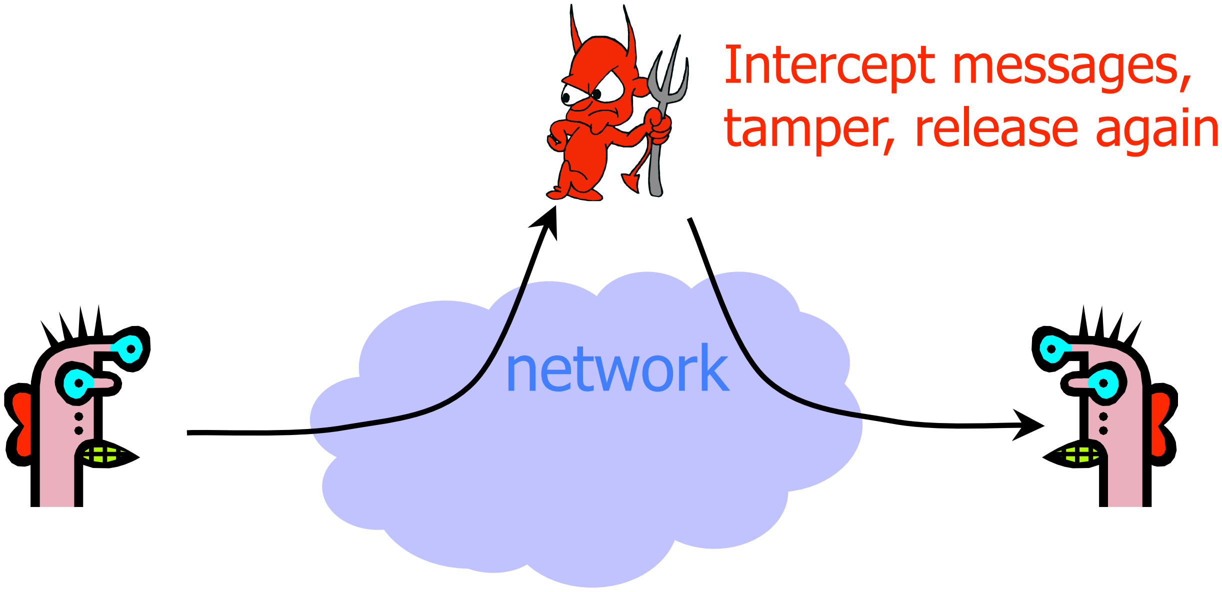
Attack on Confidentiality

- Confidentiality is concealment of information



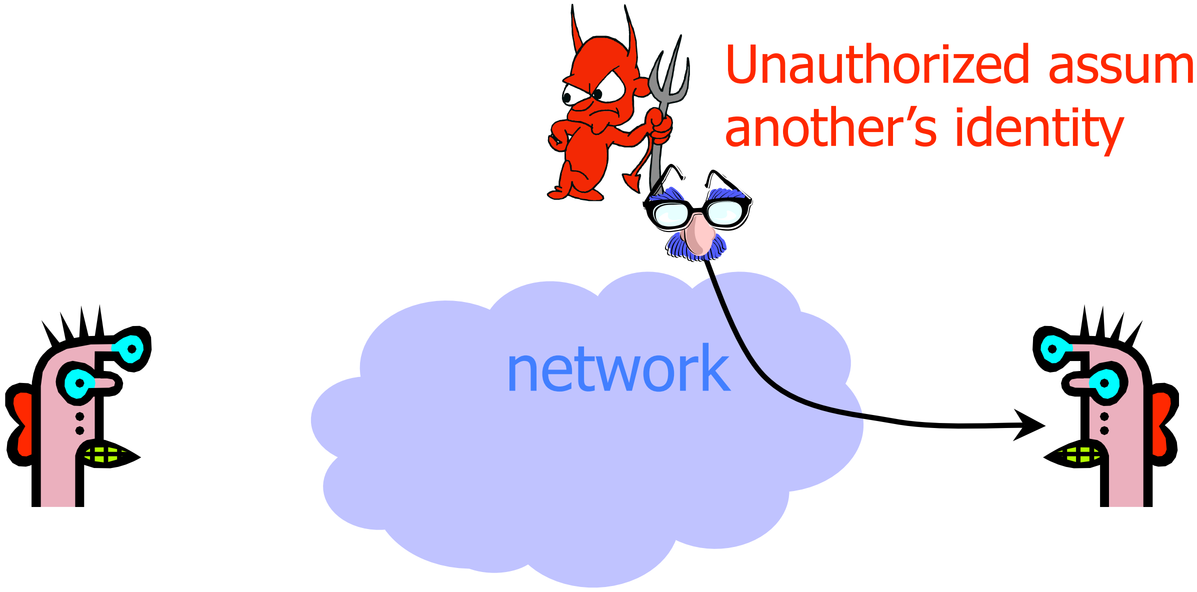
Attack on Integrity

- Integrity is prevention of unauthorized changes



Attack on Authenticity

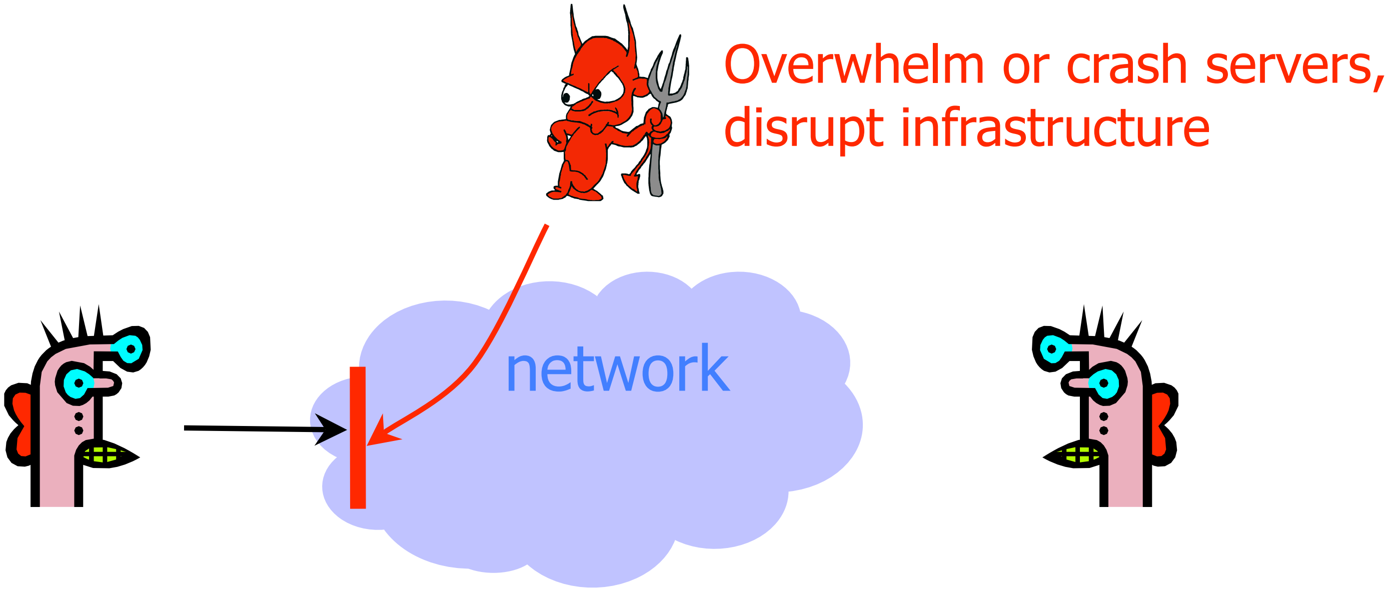
- Authenticity is identification and assurance of origin of information



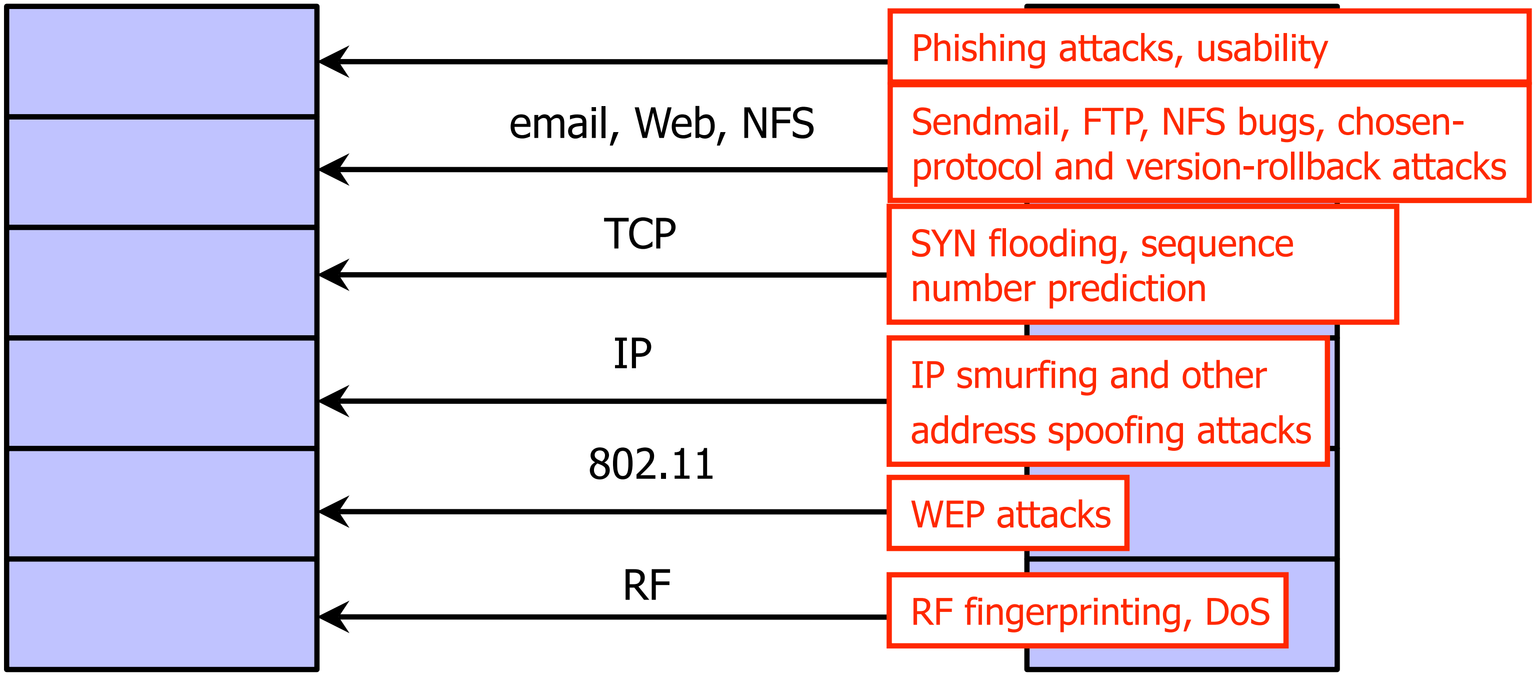
Unauthorized assumption of another's identity

Attack on Availability

- Availability is ability to use information or resources desired


Overwhelm or crash servers, disrupt infrastructure

Protocol Stack



people

application

transport

network

data link

physical

email, Web, NFS

TCP

IP

802.11

RF

Phishing attacks, usability

Sendmail, FTP, NFS bugs, chosen-protocol and version-rollback attacks

SYN flooding, sequence number prediction

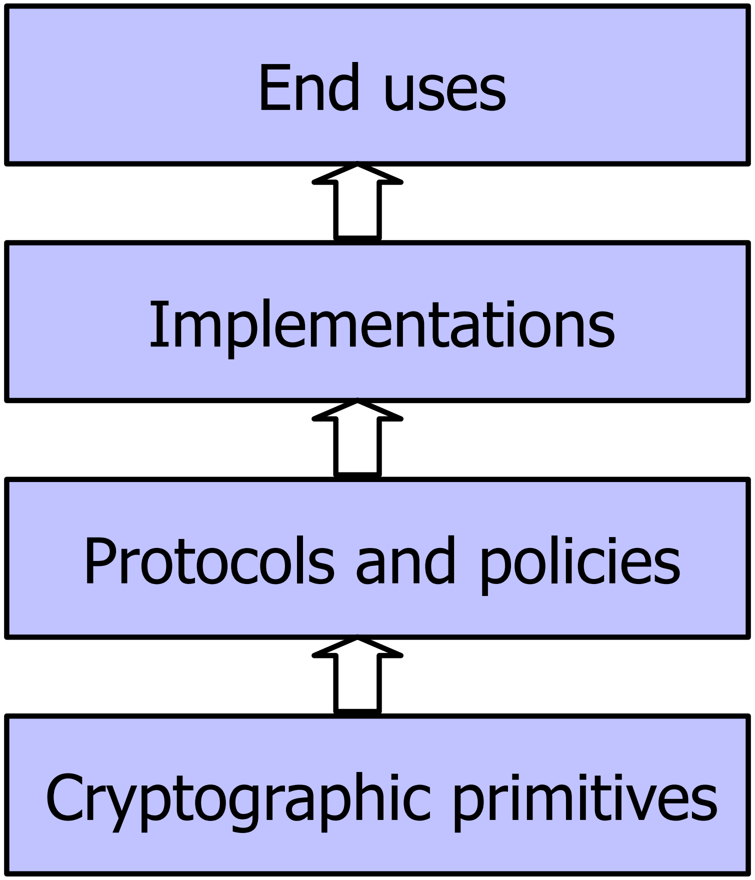
IP smurfing and other address spoofing attacks

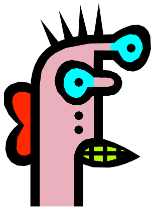
WEP attacks

RF fingerprinting, DoS

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

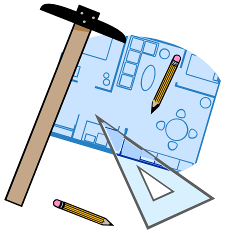
Defenses



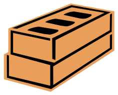


People — End uses — Password managers, user-centered design company policies, ...

Systems — Implementations — Firewalls, intrusion detection…



Blueprints — Protocols and policies — SSL, IPSec, access control…



Building blocks — Cryptographic primitives — RSA, DSS, SHA-1…

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 <u>critical</u> 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 :-(