Authentication

Authentication

- A trilogy: identification, authentication, authorization
- ACLs and the like are forms of authorization: what you're allowed to do
- Identification is whom you claim to be be
- Authentication is how you prove it

Forms of Authentication

- Something you know
- Something you have
- Something you are
- (Hmm, yet another trilogy)

Forms of Authentication

- Something you know: passwords
- Something you have: smart card
- Something you are: fingerprint

Something You Know

- Ancient: “what’s the secret word? (Supposedly dates to at least Roman times.)
- Modern incarnation: passwords
- Most common form of authentication

Passwords

- Everyone understands the concept
- Passwords should be sufficient
- Not really. . .

Passwords are Really Bad

- Guessable
- Forgettable
- Enumerable
- Eavesdroppable (but that isn't a word. . .)
- Replayable
- Reusable
- Leakable
- Probably a lot more reasons not to use them

Guessable Passwords

- People tend to pick bad passwords
- Their own name, phone number, spouse’s name, kids’ names, etc.
- Easy to write a password-guessing program (Morris and Thompson, CACM, Nov. 1979)

Password-Guessing Programs

- Try likely words: names, dictionaries, etc.
  Use specialized dictionaries, too: other languages, science fiction terms, etc.
- Try variants: “password” → “passw0rd” or “Password”
- Use specialized, optimized algorithm
- In uncontrolled environments, at least 40-50% of people will have guessable passwords

How Are Passwords Stored?

- Not in plaintext
  - Administrator can see them
  - Can be stolen from backup media (or recycled disk drives. . .)
  - Editor bugs can leak them
  - Something that doesn’t exist can’t be stolen!
- Use a one-way hash; compare stored hash with hash of entered password
- Read-protect the hashed passwords anyway

Guessing Mechanisms

- Online: try to log in as the user
- Offline: steal a copy of the password file and try on your own machine (or on many compromised machines—including their GPUs), or on a cloud service
- Note: that's why we read-protect the hashed passwords

Defenses

- Rate-limit online guesses
- Perhaps lock out the account—but that leaves you vulnerable to DoS attacks
- Make password-guessing inherently slow: use a slow algorithm

The Classic Unix Password-Hashing Algorithm

- Use DES (encryption algorithm with 56-bit keys in 8 bytes)
- Don’t encrypt the password, encrypt a constant (all 0s) using the password as the key
- (Why not encrypt the password?)

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- (Why not encrypt the password?)
- ☞ This is where the 8-character limit comes from
- Any decent cryptosystem can resist finding the key, given the plaintext and ciphertext
- Iterate 25 times, to really frustrate an attacker
- Guard against specialized hardware attacks by using the “salt” to modify the DES algorithm

Salt

- Pick a random number—12 bits, for classic Unix; much longer today—and use it to modify the password-hashing algorithm
- Store the salt (unprotected) with the hashed password
- Prevent the same password from hashing to the same value on different machines or for different users
- Makes dictionary of precomputed hashed passwords much more expensive
- Doesn't make the attack on a single password harder; makes attacks trying to find *some* password $4096\times$ harder

Examples of Salting

Without Salt	*With Salt*
joe →0x21763a	joe →0,0x21763a; 1,0x0e08e7; 2,0x4fea4b; ...
fred→0xc19ecf	fred→3,0xc19ecf; 4,0x55be45; 5,0xf0b015; ...
pat →0xfcef3d	pat →6,0xfcef3d; 7,0x261286; 8,0x2437ba; ...
sue →0x71ca7a	sue →9,0x71ca7a; 10,0x83f700; 11,0x04ed54; ...
...	...

Why Does Password-Guessing Work?

- People are predictable
- Passwords don't have much *information*
- According to Shannon, an 8-character word has 2.3 bits/character of information, or a total of 19 bits
- Empircally, the set of first names in the AT&T online phonebook had only 7.8 bits of information in the whole name
- 2^{19} isn't very many words to try. . .

Can We Lengthen Passwords?

- There are other possible hashing algorithms that don’t have an 8-character limit.
- Using 256-bit AES in the same way would let us use 32-character pass phrases; using HMAC would permit unlimited length
- Are long passphrases guessable?
- Running English text has entropy of 1.2-1.5 bits/character—but no one has built a guessing program to exploit that
- No one knows if it’s even possible to exploit it

Forgettable Passwords

- People forget seldom-used passwords
- What should the server do?
- Email them? Many web sites do that
- ☞ What if someone can read your email?
- ☞ Only possible if the passwords are stored in plaintext
- Reset them?
- ☞ How do you authenticate the requester?
- Password hints?
- Is it bad to write down passwords? If your threat model is electronic-only, it's a fine thing to do. If your threat model is physical, forget it. (See the movie "Ghost")
- ☞ Don't neglect the threat of abusive domestic partners

Email and Password Recovery/Reset

- Emailing a password or reset link is the most common means of password recovery or reset
- This means that protecting your email account is crucial—it controls access to most of your other accounts
- Also: high-value systems, e.g., bank accounts, can't rely on email for reset

Eavesdroppable

- Wiretapping the net isn’t hard, especially if wireless links are used
- Done on the Internet backbone in 1993-4; see CERT Advisory CA-1994-01
- Install a keystroke logger on the client
- Install a password capture device on the server
- Play games with the DNS or routing to divert the login traffic

Stealable

- Shoulder-surfing
- Bribery—trade a password for a candy bar (http://news.bbc.co.uk/2/hi/technology/3639679.stm)

Reusable Passwords

- People tend to reuse the same passwords in different places
- If one site is compromised, the password can be stolen and used elsewhere
- At the root of “phishing” attacks
- ☞ A fraud incident on Stubhub is believed to have used passwords stolen from Adobe.com.
- ☞ Reusing passwords is a much greater ill than picking weak passwords

Password Managers

- Store passwords in an encrypted file
- Who can see this file?
- How strongly is it protected?
- People use many machines today—synchronize this database? How?
- Can malware get at the database?
- How is it used?

☞ If the manager recognizes web sites, it can help protect against phishing

Password Mangers: Cloud-Based

- Simplifies use from multiple devices
- Allows for provider-based intrusion monitoring
- (Allows the provider to charge a recurring fee for access. . .)
- But: can an attacker launch guessing attacks on the password used to protect this database?

The Fundamental Problems

- Passwords have to be human-usable
- Passwords are static, and hence can be replayed

Something You Have

- Many forms of tokens
- Time-based cards
- USB widgets (“dongles”)
- Rings
- Challenge/response calculators
- Mobile phones
- Smart cards
- Mag stripe cards
- More

Disadvantages of Tokens

- They can be lost or stolen
- Lack of hardware support on many machines
- Lack of software support on many machines
- Inconvenient to use
- Cost

The Java Ring

This ring has a Java interpreter, a crypto chip, and certificate-processing code.

NSA's STU-III (Ancient!) Secure Phone

Photos courtesy of Richard Brisson

And the Crypto-Ignition Key

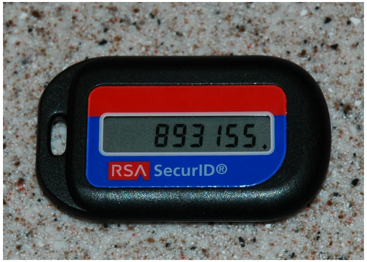
How STU-IIIs are Used

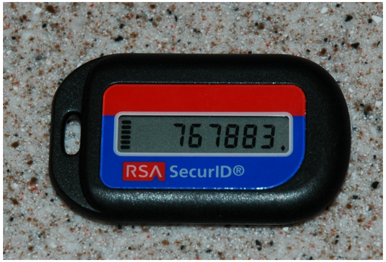
- The phones have cryptographic keying material, and are in controlled areas
- The keys also have keying material, and user's name and clearance level
- Each party's phone will display the other party's name and clearance level
- Keys are associated with particular phones
- You need both the key and access to the right phone to abuse it
- *Two-factor* authentication

Two-Factor Authentication (2FA)

- Two of the three types of authentication technology
- Use second factor to work around limitations of first
- Example: SecurID card *plus* PIN

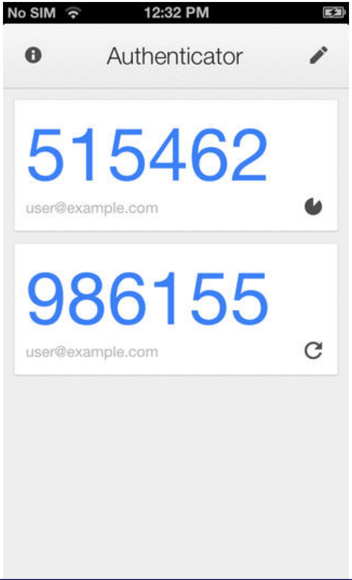
SecurID Tokens





A SecurID token on two successive time cycles. The bars on the left of the second picture indicate how many 10-second ticks remain before the display changes, in this case about a minute. In essence, the display shows $H_k(T)$, where T is the time and H_k is a keyed hash function.
Generic name: TOTP (Time-based One-Time Passwords)

Soft Tokens


No SIM 12:32 PM

Authenticator

515462

user@example.com

986155

user@example.com

- Phone apps can do the same things as dedicated tokens (CU uses Duosec)
- The partially-filled circle shows the time left for that code; there's a refresh button to generate a new one
- But—is the cryptographic secret protected as well as on dedicated tokens? There are hardware and software attacks possible now

Eavesdropping Again

- Can't someone eavesdrop on a token-based or two-factor exchange?
- Sure!
- Must use other techniques as well: encryption and/or replay protection

Replay Protection

- SecurID: code changes every minute; database prevents replay during that minute
- Challenge/response: server picks a unique number; client encrypts it
- Cryptographic protocols

Cryptographic Authentication

- Use cryptographic techniques to authenticate
- Simultaneously, negotiate a key to use to protect the session
- But where do the original cryptographic keys come from?

Cryptographic Keys are Long

- An AES key is at least 128 bits. Care to remember 32 random hex digits as your password?
- An RSA key is at least 2048 bits. Care to remember 512 random hex digits as your password?
- Solution 1: store the key on a token
- Solution 2: store the key on a computer, but encrypted

Storing Keys on Tokens

- The most secure approach (my Java ring has an RSA key pair on it)
- Proper integration with host software can be tricky
- Generally want two-factor approach: use a password to unlock the token
- Ideally, the token is tamper-resistant

Storing Keys on Hosts

- Software-only approach is useful for remote logins
- *Must* use passphrase to encrypt key
- Not very resistant to capture of encrypted key—we’re back to offline password guessing
- Can you trust the host to protect your key?

Use a Passphrase as a Key?

- Convert the user's passphrase to a key, and use it directly
- Approach used by Kerberos
- Remember the low information content of passphrases. . .
- Attack: eavesdrop on an encrypted message; guess at passphrases; see which one yields a sensible decryption
- Solution: use a SPAKE (Secure Password and Key Exchange) protocol

Why Should Tokens be Tamper-Resistant?

- Prevent extraction of key if stolen
- Note: recovery of login key *may* permit decryption of old conversations
- Prevent authorized-but-unfaithful user from *giving* away the secret—you can't give it away and still have use of it yourself.
- Folks have pointed cameras at their tokens and OCRed the digits. . . `http://smallhacks.wordpress.com/2012/11/11/reading-codes-from-rsa-secureid-token/`

Mobile Phones

- Use a phone as a token: send an SMS challenge to the phone
- Indepedent failure mode: will the attacker who has planted a keystroke logger on a computer also have access to the owner's phone?
- ☞ Eavesdropping on a phone requires very different access and technology than hacking a computer or eavesdropping on WiFi.
- Are there privacy risks from everyone having your mobile number?
- What about malware on the phone?
- Twitter's variant: app talks directly to Twitter and user; easier to use

Other Threats

- Bogus SIM cards, with the help of a deluded carrier
- SIM-jacking: persuading a naive or dishonest employee to give you a SIM card for the number of your choice
- An attacker who controls the phone network, or can introduce signaling messages into the network. (Note: *any* phone company in the world can do that; it's necessary to support mobile phones roaming.)
- Inceasing linkage between hosts and phones reduces the second factor: it's no longer independent

Federated Authentication

- Log in—via strong-but-inconvenient authentication—to Facebook, Google, etc.
- These sites vouch for your identity to other sites
- What about privacy? (Mozilla's solution tries to solve this.)
- Do you trust some other site to vouch for your users? Your employees?

FIDO2—The Coming Standard

- Designed by the FIDO (“Fast IDentity Online”) Alliance, a consortium that includes most major tech companies (Google, Microsoft, Apple, Amazon, and more)
- Originally intended to provide 2FA (two-factor authentication)
- Now intended to replace passwords entirely
- Original implementation plans stressed secure, outboard hardware; current plans support host-resident implementations, especially because modern computers have secure processing elements (TPM chip on PCs, Apple’s T2 chip on Macs, the Secure Enclave on iOS, etc.)

FIDO2 Goals

- Secure authentication
- Nothing replayable
- Nothing to memorize
- No crazy strength rules
- Phishing-proof
- Privacy-preserving
- Cross-platform

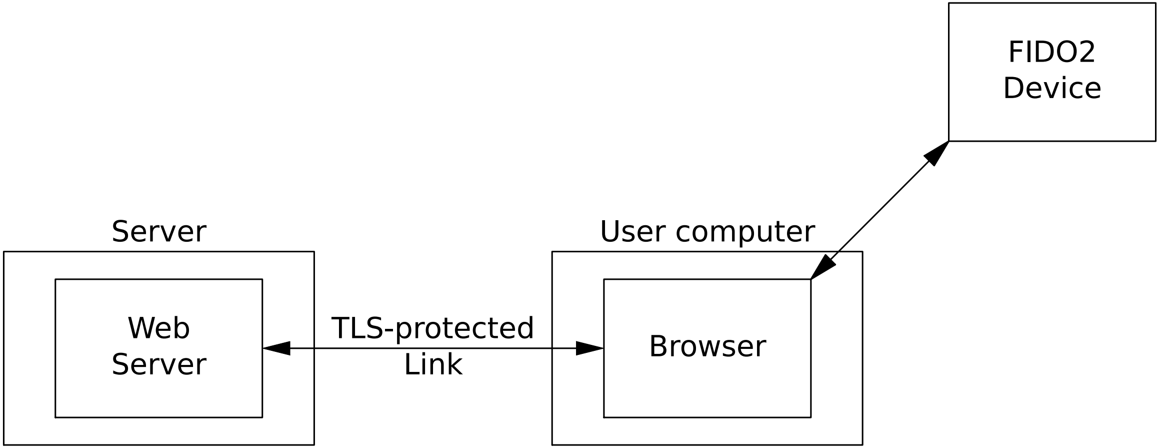
Basic Principles

- At site “registration” time, the user’s device generates a fresh key pair and sends the public key to the site
- To log in to a site, the site sends a random challenge. The user’s device digitally signs it.
- (Optionally, the device requires some user activity to activate)
- The site uses the public key to verify the signature

Details of FIDO2

- At registration time, the device receives from the browser “a hash of the origin (combination of protocol, hostname and port)”
- The user has to “activate” the device via some manual action
- The device sends the site a “key handle” along with the key. The key handle is just a pointer to the key pair, and is tied to that origin
- To authenticate, the browser sends the device the request origin and the random challenge; after (optional) activation, the device signs the whole thing and sends it back
- (There are more details—see the reading!)

Communication Path to the FIDO2 Device



Types of Devices

- Standalone FIDO2 authenticators (Yubikey is the best-known brand)
- Apps on phones
- OS services

A USB-A Yubikey authenticator

Browser-to-Device Communication

- Several standardized methods: USB, Bluetooth, NFC
- Or: display a QR code on the screen to use a phone-resident “device”
- Or: invoke the OS
- For phones or host-resident “devices”, authentication should use a biometric, e.g., a fingerprint or facial recognition
- Important point: the device *must* be secure against likely attacks

Does This Meet the Design Goals?

Security	Probably—the digital signature algorithm is almost certainly secure, though getting cryptographic protocols right is *hard*, and there are many opportunities for implementation errors
Replay-proof	The presence of a different random challenge each time means that replaying an old authentication message won't work
Memorization	The secrets are all stored on the device; users never see them
Phishing	Because the origin is part of what is signed, a fake site can't get a useful authentication value
Privacy	Every site has a different key and key handle, so there's no way to link authentications across various sites

Today's Status

- The evils of passwords have become very, very apparent
- There is a strong push to get rid of them, and it has momentum
- But will the efforts succeed?
- FIDO2 et al. have to be implemented on every web site that people log into. That will take a *very* long time.
- Passwords seem easy and cheap, and don't require (much) user training—but is that still true if you account for password recovery and compromise?

Questions?

(Red-tailed hawk, right over the campus gate at W 116th St. and Amsterdam Ave, January 18, 2023)