

CSci 5271  
Introduction to Computer Security  
More crypto protocols and failures

Stephen McCamant  
University of Minnesota, Computer Science & Engineering

## Outline

- More cross-site risks, cont'd
- Confidentiality and privacy
- Even more web risks
- Announcements intermission
- More crypto protocols
- More causes of crypto failure

## Content sniffing

- Browsers determine file type from headers, extension, and content-based guessing
  - Latter two for ~ 1% server errors
- Many sites host "untrusted" images and media
- Inconsistencies in guessing lead to a kind of XSS
  - E.g., "chimera" PNG-HTML document

## Cross-site request forgery

- Certain web form on `bank.com` used to wire money
- Link or script on `evil.com` loads it with certain parameters
  - Linking is exception to same-origin
- If I'm logged in, money sent automatically
- Confused deputy, cookies are ambient authority

## CSRF prevention

- Give site's forms random-nonce tokens
  - E.g., in POST hidden fields
  - Not in a cookie, that's the whole point
- Reject requests without proper token
  - Or, ask user to re-authenticate
- XSS can be used to steal CSRF tokens

## Open redirects

- Common for one page to redirect clients to another
- Target should be validated
  - With authentication check if appropriate
- Open redirect*: target supplied in parameter with no checks
  - Doesn't directly hurt the hosting site
  - But reputation risk, say if used in phishing
  - We teach users to trust by site

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## Site perspective

- Protect confidentiality of authenticators
  - Passwords, session cookies, CSRF tokens
- Duty to protect some customer info
  - Personally identifying info ("identity theft")
  - Credit-card info (Payment Card Industry Data Security Standards)
  - Health care (HIPAA), education (FERPA)
  - Whatever customers reasonably expect

## You need to use SSL

- Finally coming around to view that more sites need to support HTTPS
  - Special thanks to WiFi, NSA
- If you take credit cards (of course)
- If you ask users to log in
  - Must be protecting something, right?
  - Also important for users of Tor et al.

## Server-side encryption

- Also consider encrypting data "at rest"
- (Or, avoid storing it at all)
- Provides defense in depth
  - Reduce damage after another attack
- May be hard to truly separate keys
  - OWASP example: public key for website → backend credit card info

## Adjusting client behavior

- HTTPS and password fields are basic hints
- Consider disabling autocomplete
  - Usability tradeoff, save users from themselves
  - Finally standardized in HTML5
- Consider disabling caching
  - Performance tradeoff
  - Better not to have this on user's disk
  - Or proxy? You need SSL

## User vs. site perspective

- User privacy goals can be opposed to site goals
- Such as in tracking for advertisements
- Browser makers can find themselves in the middle
  - Of course, differ in institutional pressures

## Third party content / web bugs

- Much tracking involves sites other than the one in the URL bar
  - For fun, check where your cookies are coming from
- Various levels of cooperation
- Web bugs are typically 1x1 images used only for tracking



## Cookies arms race

- Privacy-sensitive users like to block and/or delete cookies
- Sites have various reasons to retain identification
- Various workarounds:
  - Similar features in Flash and HTML5
  - Various channels related to the cache
  - Evercookie: store in n. places, regenerate if subset are deleted

## Browser fingerprinting

- Combine various server or JS-visible attributes passively
  - User agent string (10 bits)
  - Window/screen size (4.83 bits)
  - Available fonts (13.9 bits)
  - Plugin versions (15.4 bits)

(Data from [panopticlick.eff.org](http://panopticlick.eff.org), far from exhaustive)

## History stealing

- History of what sites you've visited is not supposed to be JS-visible
- But, many side-channel attacks have been possible
  - Query link color
  - CSS style with external image for visited links
  - Slow-rendering timing channel
  - Harvesting bitmaps
  - User perception (e.g. fake CAPTCHA)

## Browser and extension choices

- More aggressive privacy behavior lives in extensions
  - Disabling most JavaScript (NoScript)
  - HTTPS Everywhere (allow-list)
  - Tor Browser Bundle
- Default behavior is much more controversial
  - Concern not to kill advertising support as an economic model

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## Misconfiguration problems

- Default accounts
- Unneeded features
- Framework behaviors
  - Don't automatically create variables from query fields

## Openness tradeoffs

- Error reporting
  - Few benign users want to see a stack backtrace
- Directory listings
  - Hallmark of the old days
- Readable source code of scripts
  - Doesn't have your DB password in it, does it?

## Using vulnerable components

- Large web apps can use a lot of third-party code
- Convenient for attackers too
  - OWASP: two popular vulnerable components downloaded 22m times
- Hiding doesn't work if it's popular
- Stay up to date on security announcements

## Clickjacking

- Fool users about what they're clicking on
  - Circumvent security confirmations
  - Fabricate ad interest
- Example techniques:
  - Frame embedding
  - Transparency
  - Spoof cursor
  - Temporal "bait and switch"

## Crawling and scraping

- A lot of web content is free-of-charge, but proprietary
  - Yours in a certain context, if you view ads, etc.
- Sites don't want it downloaded automatically (*web crawling*)
- Or parsed and user for another purpose (*screen scraping*)
- High-rate or honest access detectable

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## Upcoming activities

- Exercise set 3 will be out tonight and due a week from Wednesday
- Third project meetings will be this Wednesday through next Tuesday

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## Abstract protocols

- Outline of what information is communicated in messages
  - Omit most details of encoding, naming, sizes, choice of ciphers, etc.
- Describes honest operation
  - But must be secure against adversarial participants
- Seemingly simple, but many subtle problems

## Protocol notation

$A \rightarrow B : N_B, \{T_0, B, N_B\}_{K_B}$

- $A \rightarrow B$ : message sent from Alice intended for Bob
- $B$  (after  $:$ ): Bob's name
- $\{\dots\}_K$ : encryption with key  $K$

## Needham-Schroeder

Mutual authentication via nonce exchange, assuming public keys (core):

$A \rightarrow B : \{N_A, A\}_{E_B}$   
 $B \rightarrow A : \{N_A, N_B\}_{E_A}$   
 $A \rightarrow B : \{N_B\}_{E_B}$

## Needham-Schroeder MITM

$A \rightarrow C : \{N_A, A\}_{E_C}$   
 $C \rightarrow B : \{N_A, A\}_{E_B}$   
 $B \rightarrow C : \{N_A, N_B\}_{E_A}$   
 $C \rightarrow A : \{N_A, N_B\}_{E_A}$   
 $A \rightarrow C : \{N_B\}_{E_C}$   
 $C \rightarrow B : \{N_B\}_{E_B}$

## Certificates, Denning-Sacco

- A certificate signed by a trusted third-party  $S$  binds an identity to a public key
  - $C_A = \text{Sign}_S(A, K_A)$
- Suppose we want to use  $S$  in establishing a session
  - $A \rightarrow S : A, B$
  - key  $K_{AB}$ :  $S \rightarrow A : C_A, C_B$
  - $A \rightarrow B : C_A, C_B, \{\text{Sign}_A(K_{AB})\}_{K_B}$

## Attack against Denning-Sacco

$A \rightarrow S : A, B$   
 $S \rightarrow A : C_A, C_B$   
 $A \rightarrow B : C_A, C_B, \{\text{Sign}_A(K_{AB})\}_{K_B}$   

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 $B \rightarrow S : B, C$   
 $S \rightarrow B : C_B, C_C$   
 $B \rightarrow C : C_A, C_C, \{\text{Sign}_A(K_{AB})\}_{K_C}$   
By re-encrypting the signed key, Bob can pretend to be Alice to Charlie

## Envelopes analogy

- Encrypt then sign, or vice-versa?
- On paper, we usually sign inside an envelope, not outside. Two reasons:
  - Attacker gets letter, puts in his own envelope (c.f. attack against X.509)
  - Signer claims "didn't know what was in the envelope" (failure of non-repudiation)

## Design robustness principles

- Use timestamps or nonces for freshness
- Be explicit about the context
- Don't trust the secrecy of others' secrets
- Whenever you sign or decrypt, beware of being an oracle
- Distinguish runs of a protocol

## Implementation principles

- Ensure unique message types and parsing
- Design for ciphers and key sizes to change
- Limit information in outbound error messages
- Be careful with out-of-order messages

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## Random numbers and entropy

- Cryptographic RNGs use cipher-like techniques to provide indistinguishability
- But rely on truly random seeding to stop brute force
  - Extreme case: no entropy → always same "randomness"
- Modern best practice: seed pool with 256 bits of entropy
  - Suitable for security levels up to  $2^{256}$

## Netscape RNG failure

- Early versions of Netscape SSL (1994-1995) seeded with:
  - Time of day
  - Process ID
  - Parent process ID
- Best case entropy only 64 bits
  - (Not out of step with using 40-bit encryption)
- But worse because many bits guessable

## Debian/OpenSSL RNG failure (1)

- OpenSSL has pretty good scheme using `/dev/urandom`
- Also mixed in some uninitialized variable values
  - "Extra variation can't hurt"
- From modern perspective, this was the original sin
  - Remember undefined behavior discussion?
- But had no immediate ill effects

## Debian/OpenSSL RNG failure (2)

- Debian maintainer commented out some lines to fix a Valgrind warning
  - "Potential use of uninitialized value"
- Accidentally disabled most entropy (all but 16 bits)
- Brief mailing list discussion didn't lead to understanding
- Broken library used for ~2 years before discovery

## Detected RSA/DSA collisions

- 2012: around 1% of the SSL keys on the public net are breakable
  - Some sites share complete keypairs
  - RSA keys with one prime in common (detected by large-scale GCD)
- One likely culprit: insufficient entropy in key generation
  - Embedded devices, Linux `/dev/urandom` vs. `/dev/random`
- DSA signature algorithm also very vulnerable

## Newer factoring problem (CCS'17)

- An Infineon RSA library used primes of the form  $p = k \cdot M + (65537^a \bmod M)$
- Smaller problems: fingerprintable, less entropy
- Major problem: can factor with a variant of Coppersmith's algorithm
  - E.g., 3 CPU months for a 1024-bit key

## Side-channel attacks

- Timing analysis:
  - Number of 1 bits in modular exponentiation
  - Unpadding, MAC checking, error handling
  - Probe cache state of AES table entries
- Power analysis
  - Especially useful against smartcards
- Fault injection

## WEP "privacy"

- First WiFi encryption standard: Wired Equivalent Privacy (WEP)
- F&S: designed by a committee that contained no cryptographers
- Problem 1: note "privacy": what about integrity?
  - Nope: stream cipher + CRC = easy bit flipping

## WEP shared key

- Single key known by all parties on network
- Easy to compromise
- Hard to change
- Also often disabled by default
- Example: a previous employer

## WEP key size and IV size

- Original sizes: 40-bit shared key (export restrictions) plus 24-bit IV = 64-bit RC4 key
  - Both too small
- 128-bit upgrade kept 24-bit IV
  - Vague about how to choose IVs
  - Least bad: sequential, collision takes hours
  - Worse: random or everyone starts at zero

## WEP RC4 related key attacks

- Only true crypto weakness
- RC4 "key schedule" vulnerable when:
  - RC4 keys very similar (e.g., same key, similar IV)
  - First stream bytes used
- Not a practical problem for other RC4 users like SSL
  - Key from a hash, skip first output bytes

## Newer problem with WPA (CCS'17)

- Session key set up in a 4-message handshake
- Key reinstallation attack: replay #3
  - Causes most implementations to reset nonce and replay counter
  - In turn allowing many other attacks
  - One especially bad case: reset key to 0
- Protocol state machine behavior poorly described in spec
  - Outside the scope of previous security proofs

## Trustworthiness of primitives

- Classic worry: DES S-boxes
- Obviously in trouble if cipher chosen by your adversary
- In a public spec, most worrying are unexplained elements
- Best practice: choose constants from well-known math, like digits of  $\pi$

## Dual\_EC\_DRBG (1)

- Pseudorandom generator in NIST standard, based on elliptic curve
- Looks like provable (slow enough!) but strangely no proof
- Specification includes long unexplained constants
- Academic researchers find:
  - Some EC parts look good
  - But outputs are statistically distinguishable

## Dual\_EC\_DRBG (2)

- Found 2007: special choice of constants allows prediction attacks
  - Big red flag for paranoid academics
- Significant adoption in products sold to US govt. FIPS-140 standards
  - Semi-plausible rationale from RSA (EMC)
- NSA scenario basically confirmed by Snowden leaks
  - NIST and RSA immediately recommend withdrawal