Web Security
[Certificates and Overview]

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Admin

• Today:
  – Transition to web security

• Lab 1 due on Friday
  – See FAQs on discussion board
Cryptography Summary

• Goal: Privacy
  – Symmetric keys:
    • One-time pad, Stream ciphers
    • Block ciphers (e.g., DES, AES) → modes: EBC, CBC, CTR
  – Public key crypto (e.g., Diffie-Hellman, RSA)

• Goal: Integrity
  – MACs, often using hash functions (e.g., SHA-256)

• Goal: Privacy and Integrity
  – Encrypt-then-MAC

• Goal: Authenticity (and Integrity)
  – Digital signatures (e.g., RSA, DSS)
Problem: How does Alice know that the public key she received is really Bob’s public key?
Threat: Person-in-the-Middle
Distribution of Public Keys

• Public announcement or public directory
  – Risks: forgery and tampering

• Public-key certificate
  – Signed statement specifying the key and identity
    • \( \text{sig}_{CA}(\text{“Bob”}, PK_B) \)

• Common approach: certificate authority (CA)
  – Single agency responsible for certifying public keys
  – After generating a private/public key pair, user proves his identity and knowledge of the private key to obtain CA’s certificate for the public key (offline)
  – Every computer is pre-configured with CA’s public key
You encounter this every day...

SSL/TLS: Encryption & authentication for connections
Example of a Certificate
Hierarchical Approach

• Single CA certifying every public key is impractical
• Instead, use a trusted root authority (e.g., Verisign)
  – Everybody must know the root’s public key
  – Instead of single cert, use a certificate chain
    • \( \text{sig}_{\text{Verisign}}(\text{“AnotherCA”}, \text{PK}_{\text{AnotherCA}}) \)
    • \( \text{sig}_{\text{AnotherCA}}(\text{“Alice”}, \text{PK}_A) \)

– What happens if root authority is ever compromised?
Trusted(?) Certificate Authorities
Turtles All The Way Down...

The saying holds that the world is supported by a chain of increasingly large turtles. Beneath each turtle is yet another: it is "turtles all the way down".

[Image from Wikipedia]
Many Challenges...

• Hash collisions
• Weak security at CAs
  – Allows attackers to issue rogue certificates
• Users don’t notice when attacks happen
  – We’ll talk more about this later in the course
• How do you revoke certificates?
Attacking CAs

Security of DigiNotar servers:
- All core certificate servers controlled by a single admin password (Prod@dm1n)
- Software on public-facing servers out of date, unpatched
- No anti-virus (could have detected attack)

Somehow, somebody managed to get a rogue SSL certificate from them on July 10th, 2011. This certificate was issued for domain name .google.com.

What can you do with such a certificate? Well, you can impersonate Google — assuming you can first reroute Internet traffic for google.com to you. This is something that can be done by a government or by a rogue ISP. Such a reroute would only affect users within that country or under that ISP.
Consequences

• Attacker needs to first divert users to an attacker-controlled site instead of Google, Yahoo, Skype, but then...
  – For example, use DNS to poison the mapping of mail.yahoo.com to an IP address

• ... “authenticate” as the real site

• ... decrypt all data sent by users
  – Email, phone conversations, Web browsing
Attempt to Fix CA Problems: Certificate Transparency

- **Problem:** browsers will think nothing is wrong with a rogue certificate until revoked

- **Goal:** make it impossible for a CA to issue a bad certificate for a domain *without the owner of that domain knowing*
  
  – (Then what?)

- **Approach:** auditable certificate logs

[www.certificate-transparency.org](http://www.certificate-transparency.org)
Attempt to Fix CA Problems: Certificate Pinning

- **Trust on first access**: tells browser how to act on subsequent connections
- **HPKP** – HTTP Public Key Pinning
  - Use these keys!
  - HTTP response header field “Public-Key-Pins”
- **HSTS** – HTTP Strict Transport Security
  - Only access server via HTTPS
  - HTTP response header field "Strict-Transport-Security"
Web+Browser Security
Big Picture: Browser and Network

Browser

OS

Hardware

request

reply

website

Network
Where Does the Attacker Live?

Mitigation: SSL/TLS (not covered further)

Mitigation: Browser security model + web app security (today + next week)
Web Attacker

- Controls a malicious website (attacker.com)
  - Can even obtain SSL/TLS certificate for site
- User visits attacker.com – why?
  - Phishing email, enticing content, search results, placed by an ad network, blind luck ...
- Attacker has no other access to user machine!
- Variation: good site honest.com, but:
  - An iframe with malicious content included
  - Website has been compromised