

CSE 484 / CSE M 584: Computer Security and Privacy

Cryptography (+ Web Security): Certificates

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Thanks to Dan Boneh, Dieter Gollmann, Dan Halperin, Yoshi Kohno, John Manferdelli, John Mitchell, Vitaly Shmatikov, Bennet Yee, and many others for sample slides and materials ...

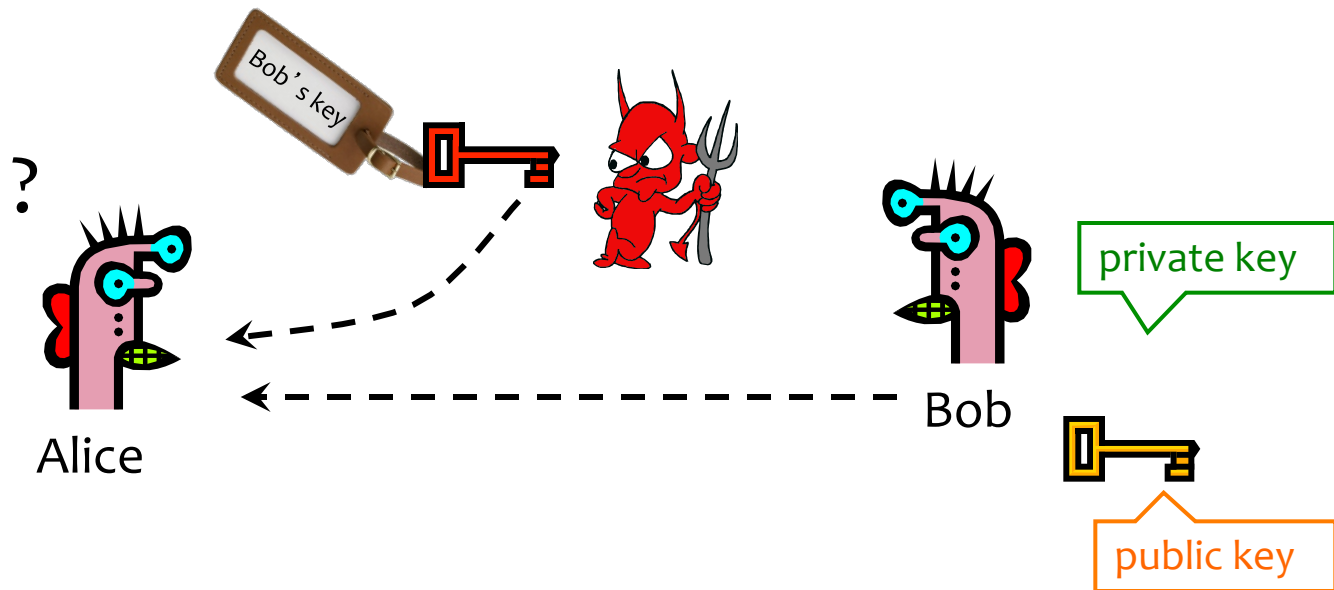
Advantages of Public Key Crypto

- Confidentiality without shared secrets
 - Very useful in open environments
 - Can use this for key establishment, with fewer “chicken-or-egg” problems
 - With symmetric crypto, two parties must share a secret before they can exchange secret messages
- Authentication without shared secrets
 - Use digital signatures to prove the origin of messages
- Encryption keys are public, but must be sure that Alice’s public key is really *her* public key
 - This is a hard problem...

Disadvantages of Public Key Crypto

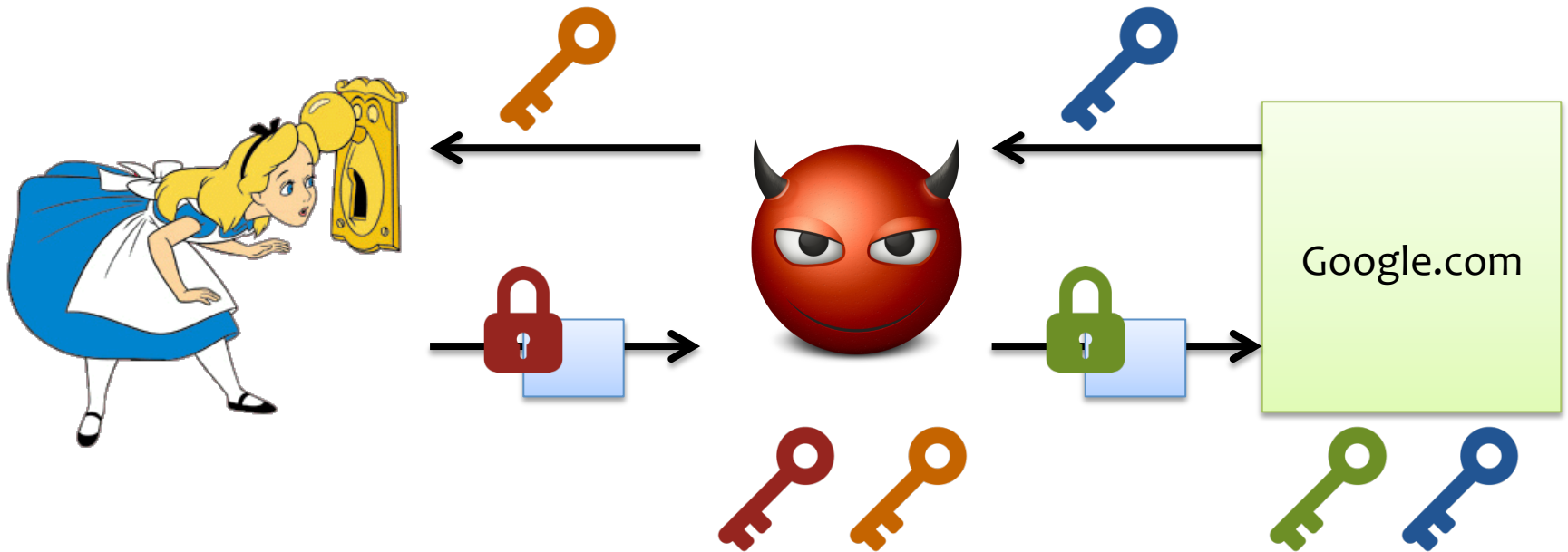
- Calculations are 2-3 orders of magnitude slower
 - Modular exponentiation is an expensive computation
 - Typical usage: use public-key cryptography to establish a shared secret, then switch to symmetric crypto
 - E.g., IPsec, SSL, SSH, ...
- Keys are longer
 - 1024+ bits (RSA) rather than 128 bits (AES)
- Relies on unproven number-theoretic assumptions
 - What if factoring is easy?
 - Factoring is *believed* to be neither P, nor NP-complete
 - (Of course, symmetric crypto also rests on unproven assumptions...)

Authenticity of Public Keys



Problem: How does Alice know that the public key she received is really Bob's public key?

Threat: Man-In-The-Middle (MITM)



Distribution of Public Keys

- Public announcement or public directory
 - Risks: forgery and tampering
- Public-key certificate
 - Signed statement specifying the key and identity
 - $\text{sig}_{\text{CA}}(\text{“Bob”}, \text{PK}_B)$
- 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

Trusted Certificate Authorities

The screenshot shows the Keychain Access application window. The title bar reads "Keychain Access". Below the title bar, there is a lock icon and the text "Click to unlock the System Roots keychain." To the right of this is a search field with a magnifying glass icon and the word "Search".

The left sidebar is divided into two sections: "Keychains" and "Category". Under "Keychains", there are four items: "login", "Local Items", "System", and "System Roots" (which is selected and highlighted). Under "Category", there are six items: "All Items", "Passwords", "Secure Notes", "My Certificates", "Keys", and "Certificates".

The main area displays the details for the selected "System Roots" keychain. It shows a certificate icon with the word "Certificate" and "Root" written on it. The details are as follows:

- Apple Root CA**
- Root certificate authority
- Expires: Friday, February 9, 2035 at 1:40:36 PM Pacific Standard Time
- ✓ This certificate is valid

Below the details is a table with three columns: "Name", "Kind", and "Expires". The table contains the following data:

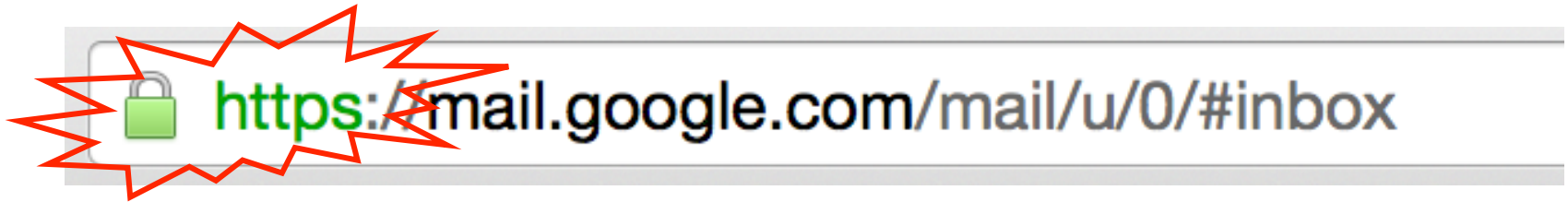
Name	Kind	Expires
AdminCA-CD-T01	certificate	Jan 25, 2016, 4:36:19 AM
AffirmTrust Commercial	certificate	Dec 31, 2030, 6:06:06 AM
AffirmTrust Networking	certificate	Dec 31, 2030, 6:08:24 AM
AffirmTrust Premium	certificate	Dec 31, 2040, 6:10:36 AM
AffirmTrust Premium ECC	certificate	Dec 31, 2040, 6:20:24 AM
America Onli...cation Authority 1	certificate	Nov 19, 2037, 12:43:00 PM
America Onli...cation Authority 2	certificate	Sep 29, 2037, 7:08:00 AM
Apple Root CA	certificate	Feb 9, 2035, 1:40:36 PM
Apple Root CA - G2	certificate	Apr 30, 2039, 11:10:09 AM
Apple Root CA - G3	certificate	Apr 30, 2039, 11:19:06 AM
Apple Root Certificate Authority	certificate	Feb 9, 2025, 4:18:14 PM
Application CA G2	certificate	Mar 31, 2016, 7:59:59 AM
ApplicationCA	certificate	Dec 12, 2017, 7:00:00 AM

At the bottom of the window, there is a toolbar with a "+" button, an "i" button, and a "Copy" button. To the right of the toolbar, it says "213 items".

Hierarchical Approach

- Single CA certifying every public key is impractical
- Instead, use a trusted **root authority**
 - For example, Verisign
 - Everybody must know the public key for verifying root authority's signatures
- Root authority signs certificates for lower-level authorities, lower-level authorities sign certificates for individual networks, and so on
 - Instead of a single certificate, 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?

You encounter this every day...




SSL/TLS: Encryption & authentication for connections

(More on this later!)

Example of a Certificate

GeoTrust Global CA
↳ Google Internet Authority G2
↳ *.google.com

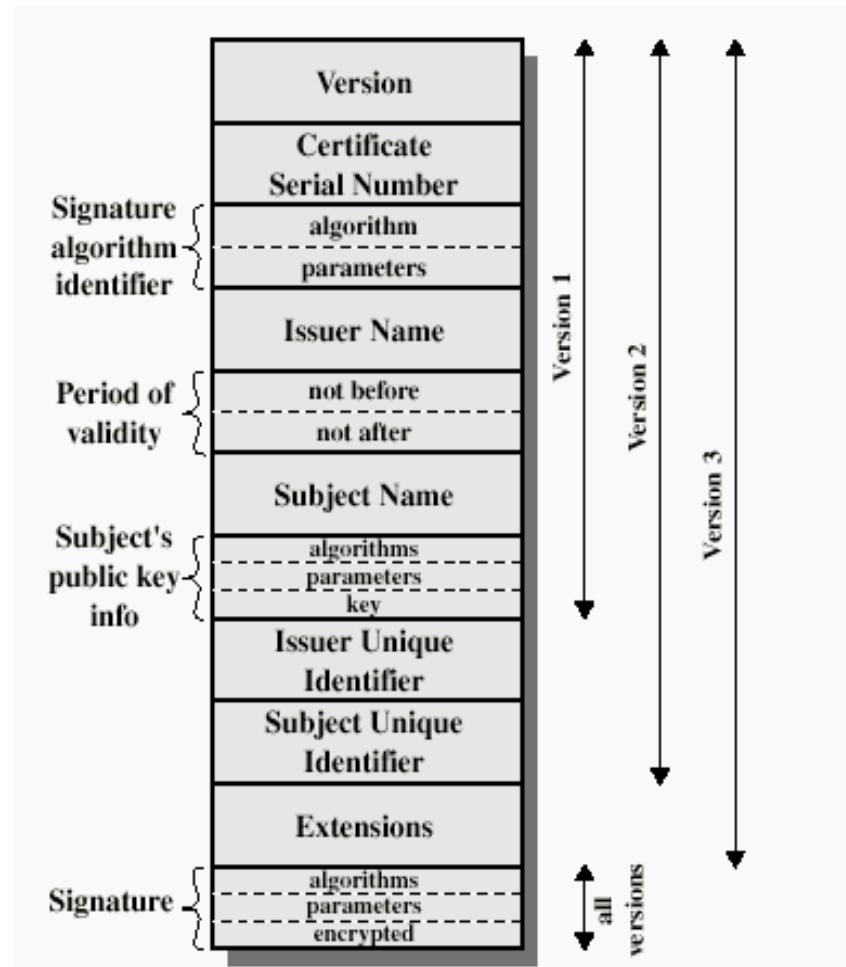
 ***.google.com**
Issued by: Google Internet Authority G2
Expires: Monday, July 6, 2015 at 5:00:00 PM Pacific Daylight Time
✔ This certificate is valid

▼ **Details**

Subject Name	
Country	US
State/Province	California
Locality	Mountain View
Organization	Google Inc
Common Name	*.google.com
<hr/>	
Issuer Name	
Country	US
Organization	Google Inc
Common Name	Google Internet Authority G2
Serial Number	6082711391012222858
Version	3

Signature Algorithm	SHA-1 with RSA Encryption (1.2.840.113549.1.1.5)
Parameters	none
Not Valid Before	Wednesday, April 8, 2015 at 6:40:10 AM Pacific Daylight Time
Not Valid After	Monday, July 6, 2015 at 5:00:00 PM Pacific Daylight Time
<hr/>	
Public Key Info	
Algorithm	Elliptic Curve Public Key (1.2.840.10045.2.1)
Parameters	Elliptic Curve secp256r1 (1.2.840.10045.3.1.7)
Public Key	65 bytes : 04 CB DD C1 CE AC D6 20 ...
Key Size	256 bits
Key Usage	Encrypt, Verify, Derive
Signature	256 bytes : 34 8B 7D 64 5A 64 08 5B ...

X.509 Certificate



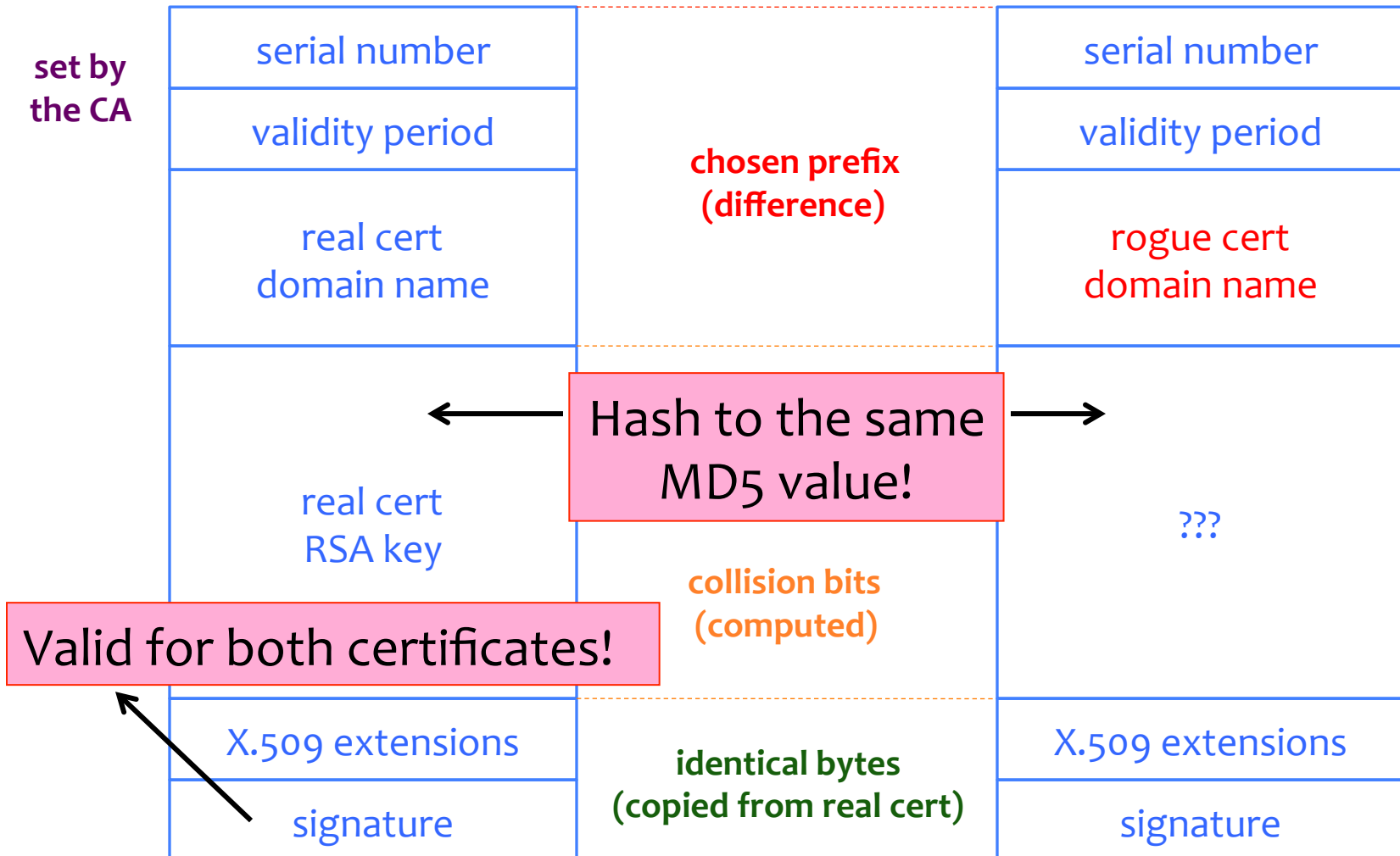
Many Challenges...

- 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
- Etc...



<https://mail.google.com/mail/u/0/#inbox>

Colliding Certificates



DigiNotar is a Dutch Certificate Authority. They sell SSL 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

More Rogue Certs



- In Jan 2013, a rogue *.google.com certificate was issued by an intermediate CA that gained its authority from the Turkish root CA TurkTrust
 - TurkTrust accidentally issued intermediate CA certs to customers who requested regular certificates
 - Ankara transit authority used its certificate to issue a fake *.google.com certificate in order to filter SSL traffic from its network
- This rogue *.google.com certificate was trusted by every browser in the world

Certificate Revocation

- Revocation is very important
- Many valid reasons to revoke a certificate
 - Private key corresponding to the certified public key has been compromised
 - User stopped paying his certification fee to this CA and CA no longer wishes to certify him
 - CA's private key has been compromised!
- Expiration is a form of revocation, too
 - Many deployed systems don't bother with revocation
 - Re-issuance of certificates is a big revenue source for certificate authorities

Certificate Revocation Mechanisms

- Certificate revocation list (CRL)
 - CA periodically issues a signed list of revoked certificates
 - Credit card companies used to issue thick books of canceled credit card numbers
 - Can issue a “delta CRL” containing only updates
- Online revocation service
 - When a certificate is presented, recipient goes to a special online service to verify whether it is still valid
 - Like a merchant dialing up the credit card processor

Attempt to Fix CA Problems: Convergence

- Background observation:
 - Attacker will have a hard time mounting man-in-the-middle attacks against **all** clients around the world
- Basic idea:
 - Lots of nodes around the world obtaining SSL/TLS certificates from servers
 - Check responses across servers, and also observe unexpected changes from existing certificates

<http://convergence.io/>

Keybase

- Basic idea:
 - Rely on existing trust of a person's ownership of other accounts (e.g., Twitter, GitHub, website)
 - Each user publishes signed proofs to their linked account



<https://keybase.io/>

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, MD5, SHA-256)
- Goal: Privacy and Integrity
 - Encrypt-then-MAC
- Goal: Authenticity (and Integrity)
 - Digital signatures (e.g., RSA, DSS)