CSE 484 / CSE M 584: Computer Security and Privacy

Cryptography (+ Web Security): Certificates

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Franziska (Franzi) Roesner
franzi@cs.washington.edu

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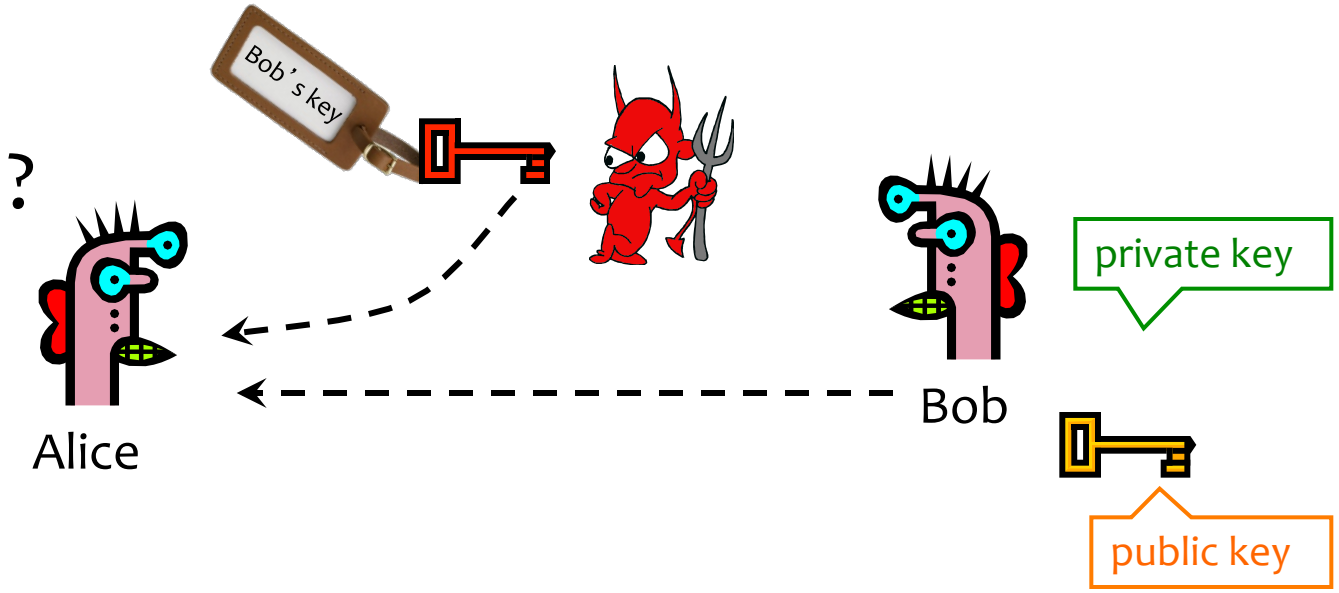
Advantages of Public Key Crypto

- 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

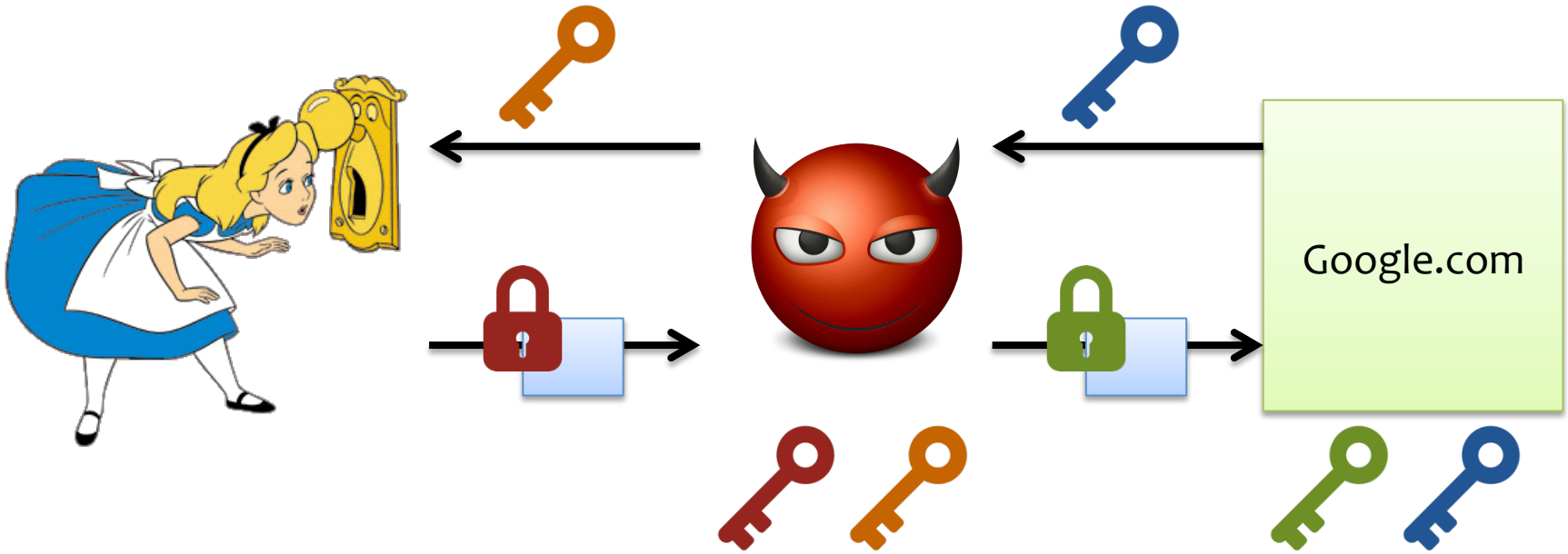
- Calculations are 2-3 orders of magnitude slower
  - Modular exponentiation is an expensive computation
  - Typical usage: use public-key cryptography to establish a shared secret, then switch to symmetric crypto
    - E.g., IPsec, SSL, SSH, …
- Keys are longer
  - 1024+ bits (RSA) rather than 128 bits (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?

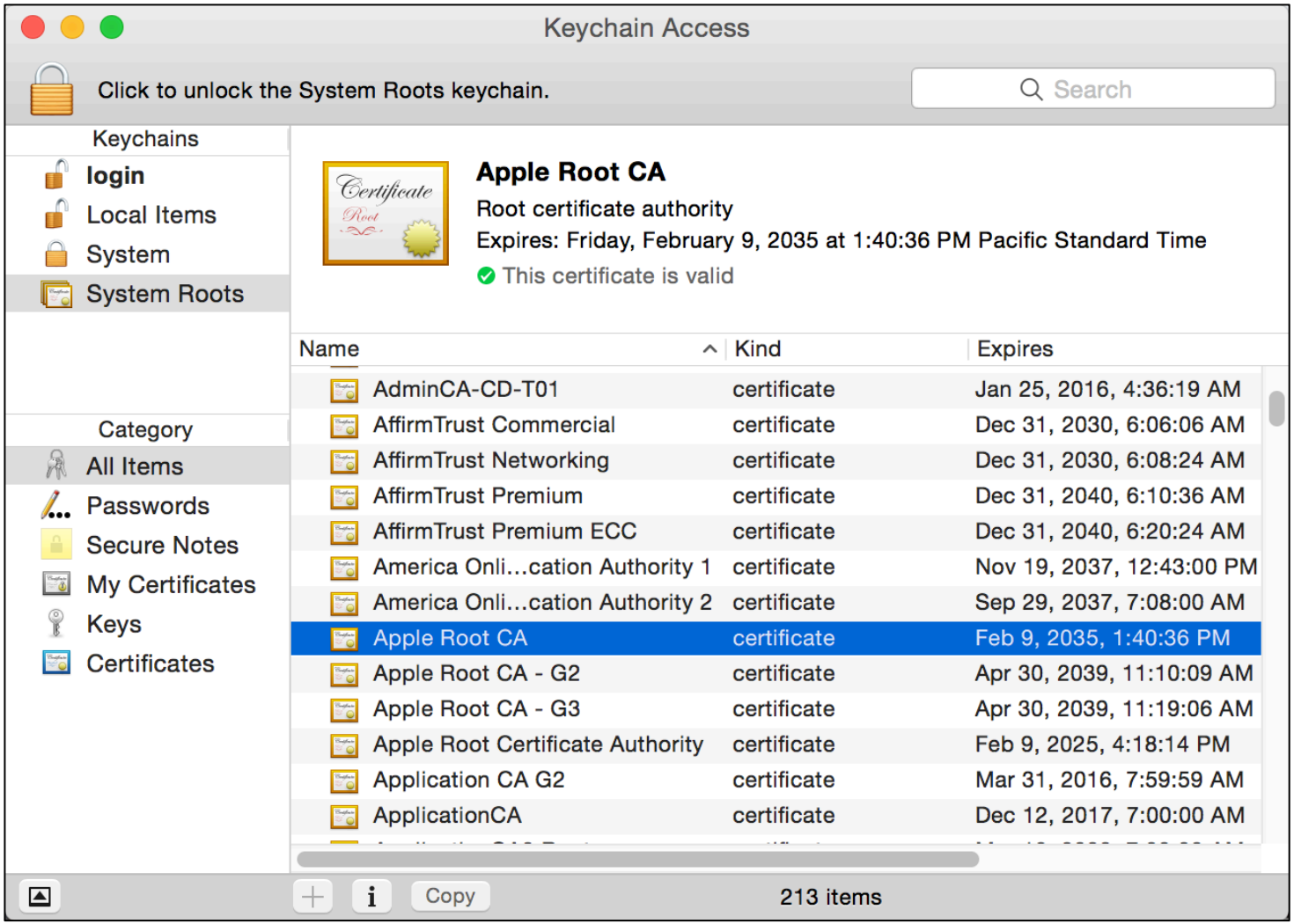
Threat: Man-In-The-Middle (MITM)



Distribution of Public Keys

- Public announcement or public directory
  - Risks: forgery and tampering
- Public-key certificate
  - Signed statement specifying the key and identity
    - sig_{CA}("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

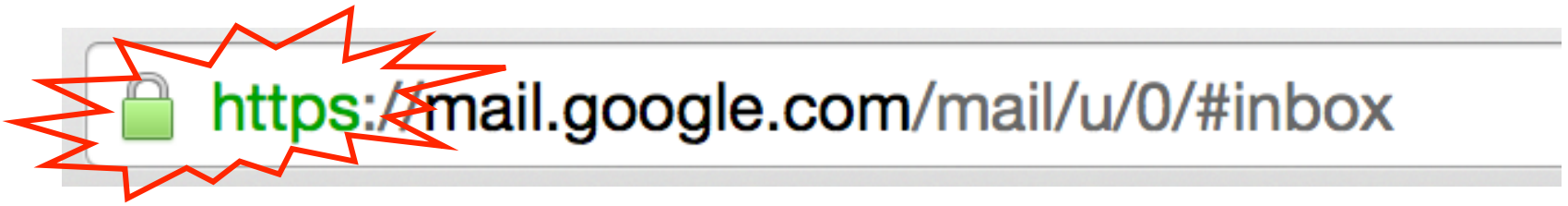
Trusted Certificate Authorities



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
    - $sig_{Verisign}$("AnotherCA", $PK_{AnotherCA}$), $sig_{AnotherCA}$("Alice", PK_A)
  - What happens if root authority is ever compromised?

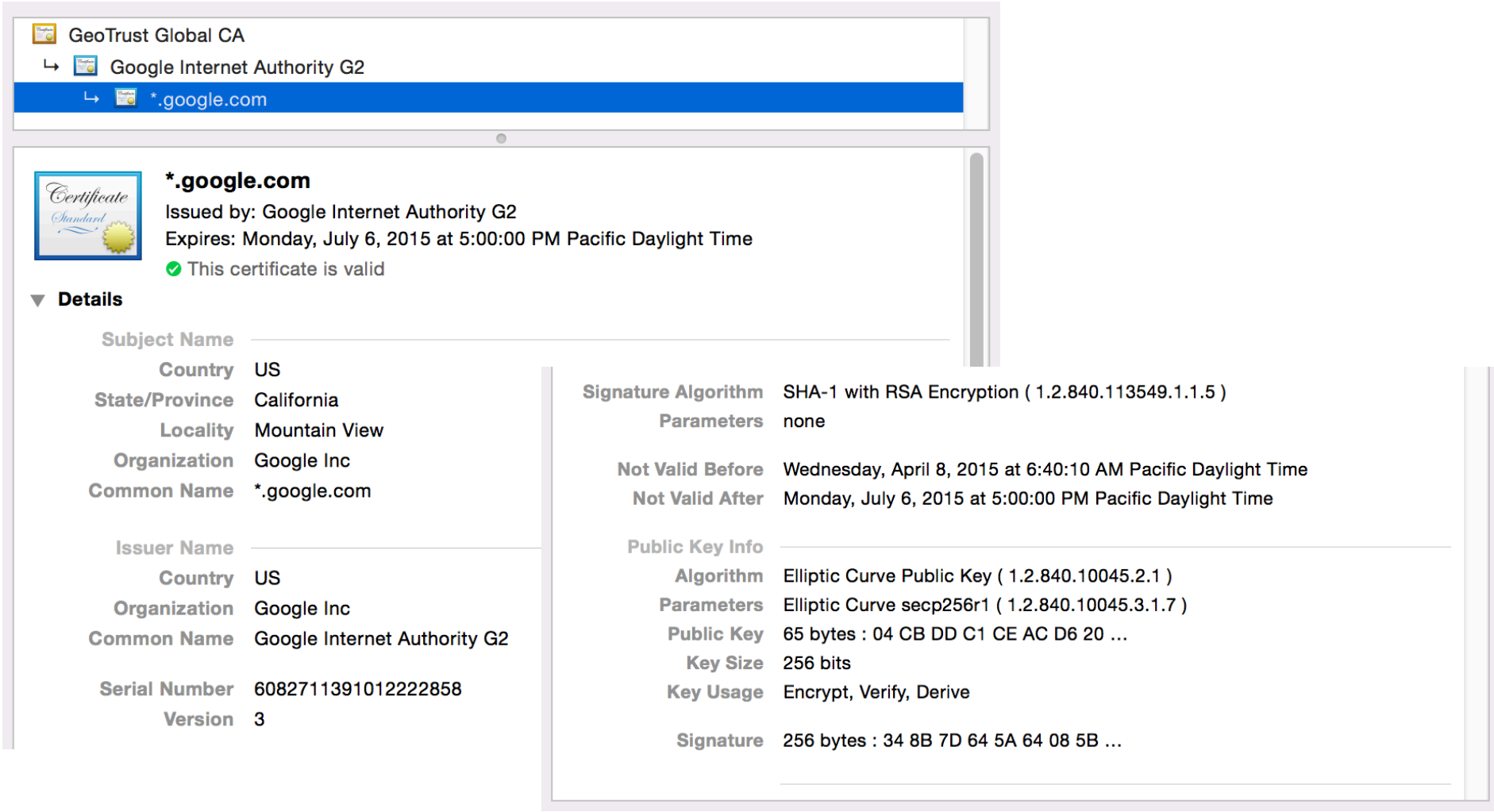
You encounter this every day…



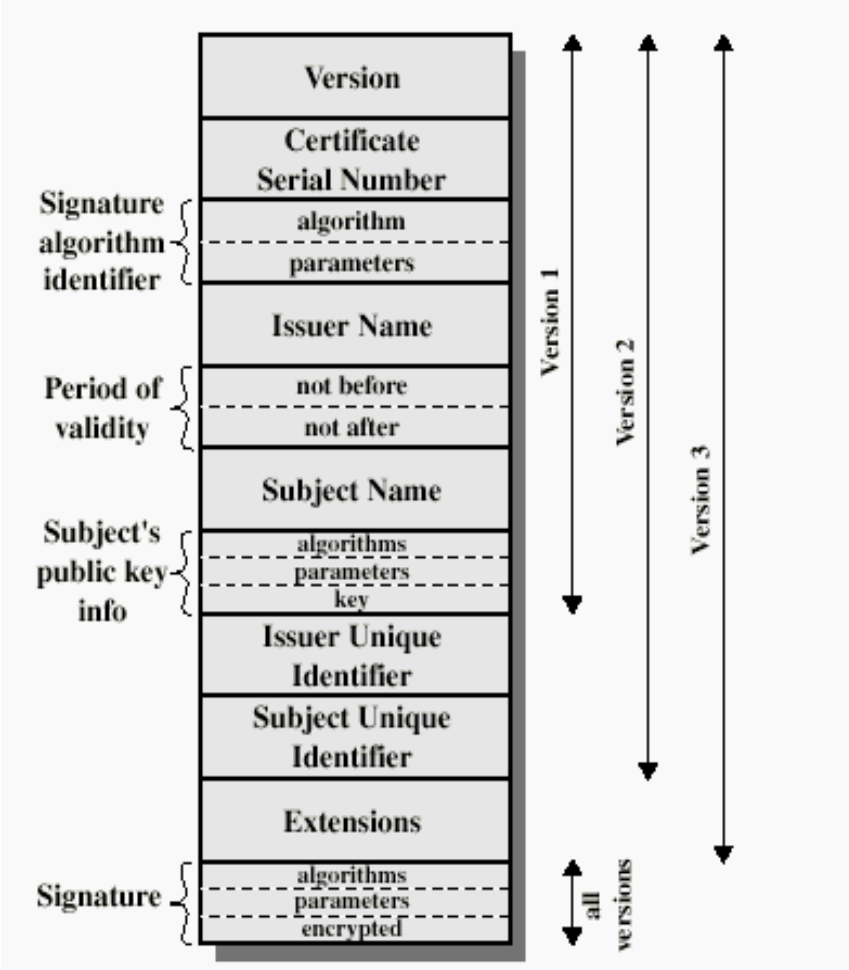
SSL/TLS: Encryption & authentication for connections

(More on this later!)

Example of a Certificate



X.509 Certificate

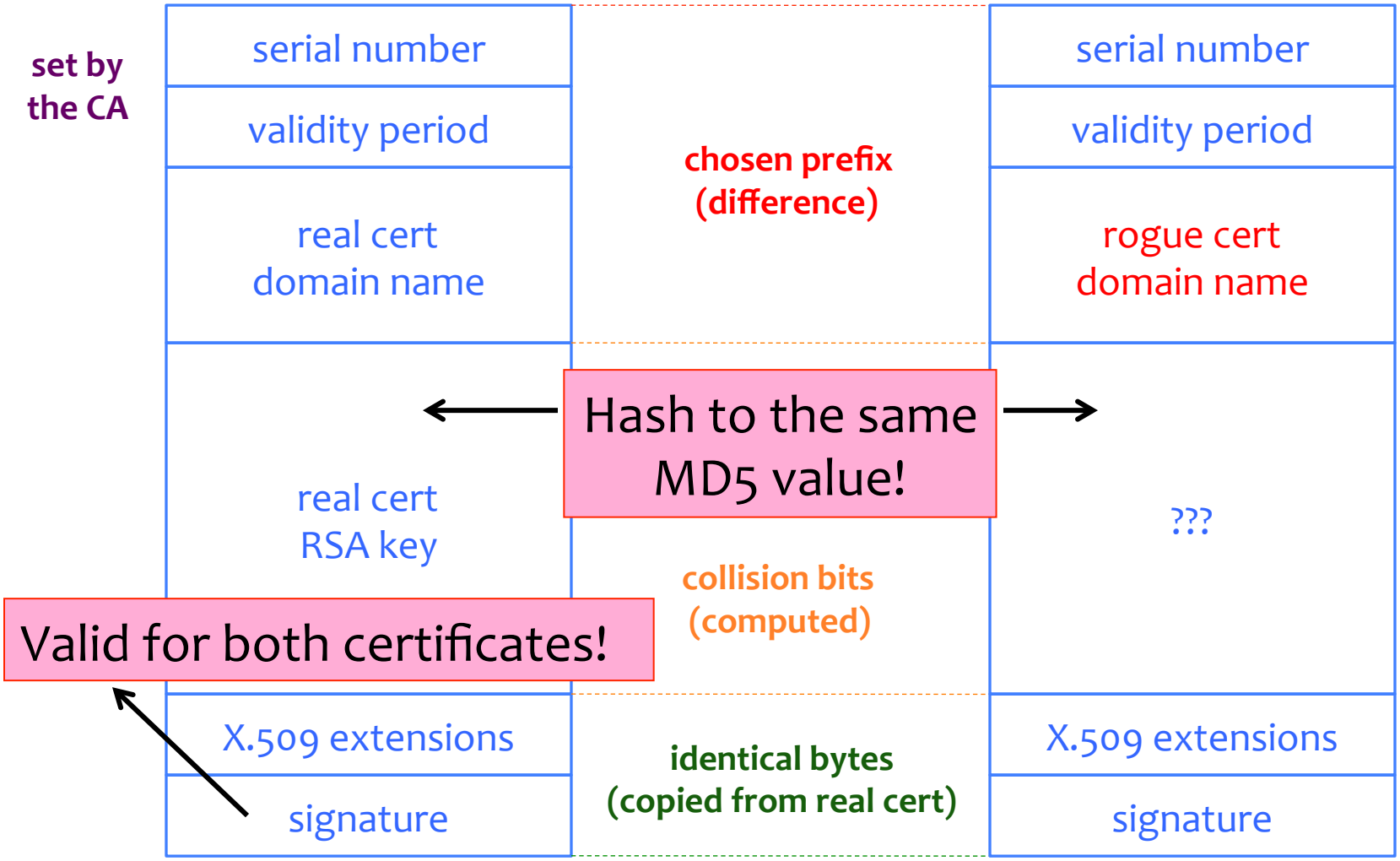


Many Challenges…

- 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…

[Sotirov et al. "Rogue Certificates"]

Colliding Certificates



Attacking CAs

DigiNotar Hacked by Black.Spook and Iranian Hackers Posted by Mikko @ 09:05 GMT | Comments

DigiNotar is a Dutch Certificate Authority. They sell SSL certificates.

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.

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)

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

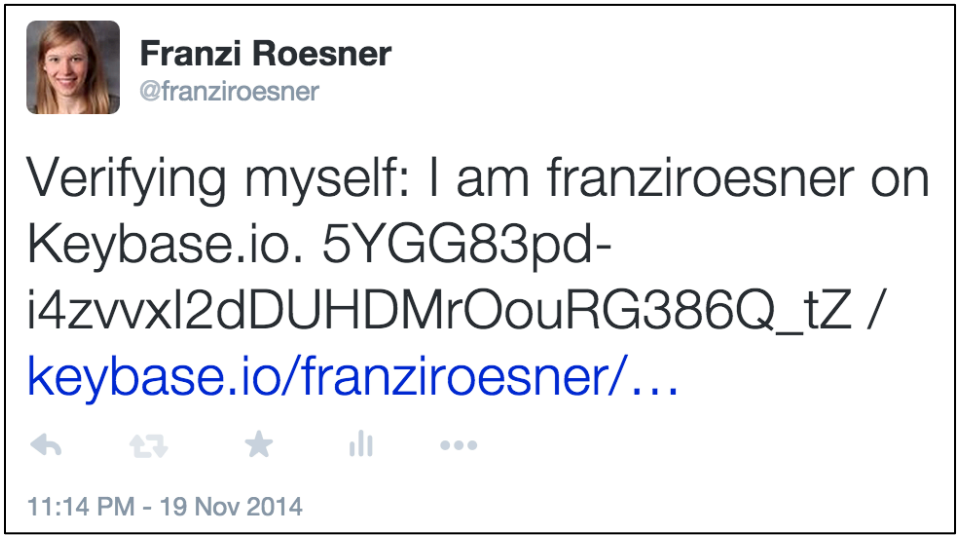
Attempt to Fix CA Problems: Convergence

- 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)