CIS 4360, Spring 2026

Public-key Infrastructure

Viet Tung Hoang

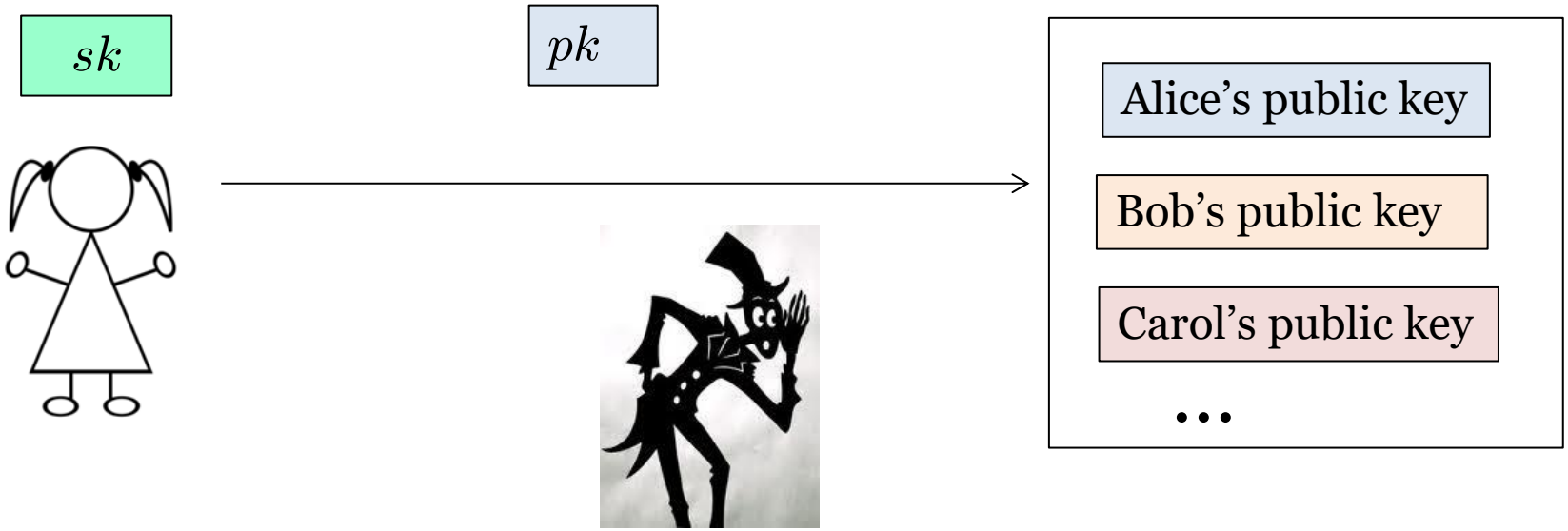
The slides are loosely based on material from Prof. Mihir Bellare (UCSD) and Prof. Stefano Tessaro (UW).

Agenda

1. **Certificate Authority (CA)**

2. Dealing with Rogue CAs

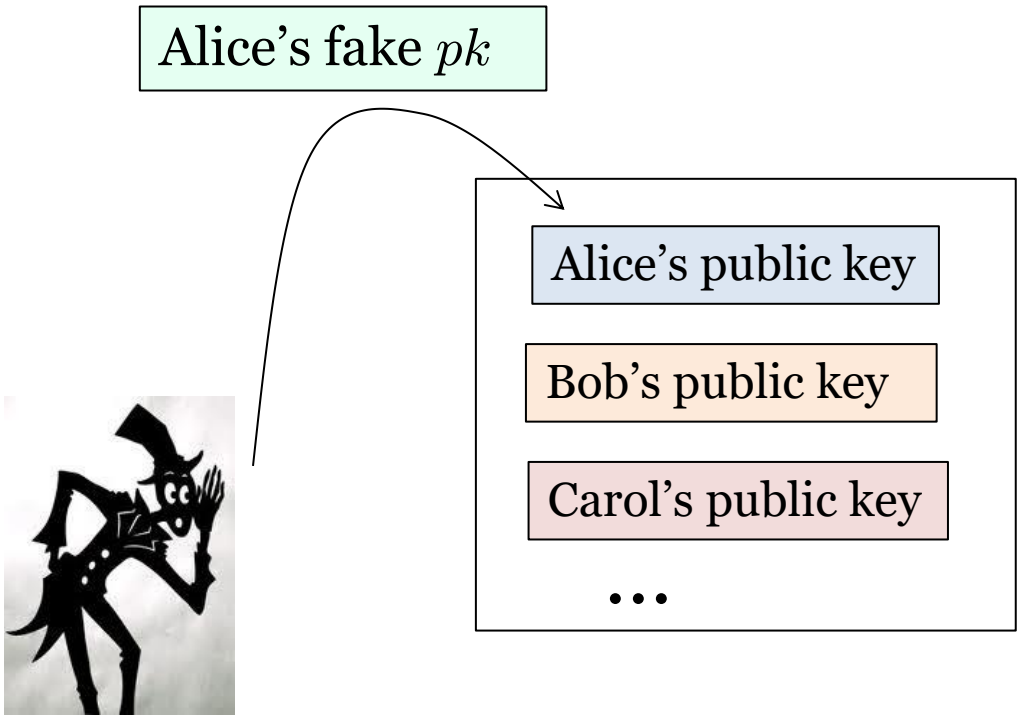
Previously



Alice generates a pair of secret key and public key.

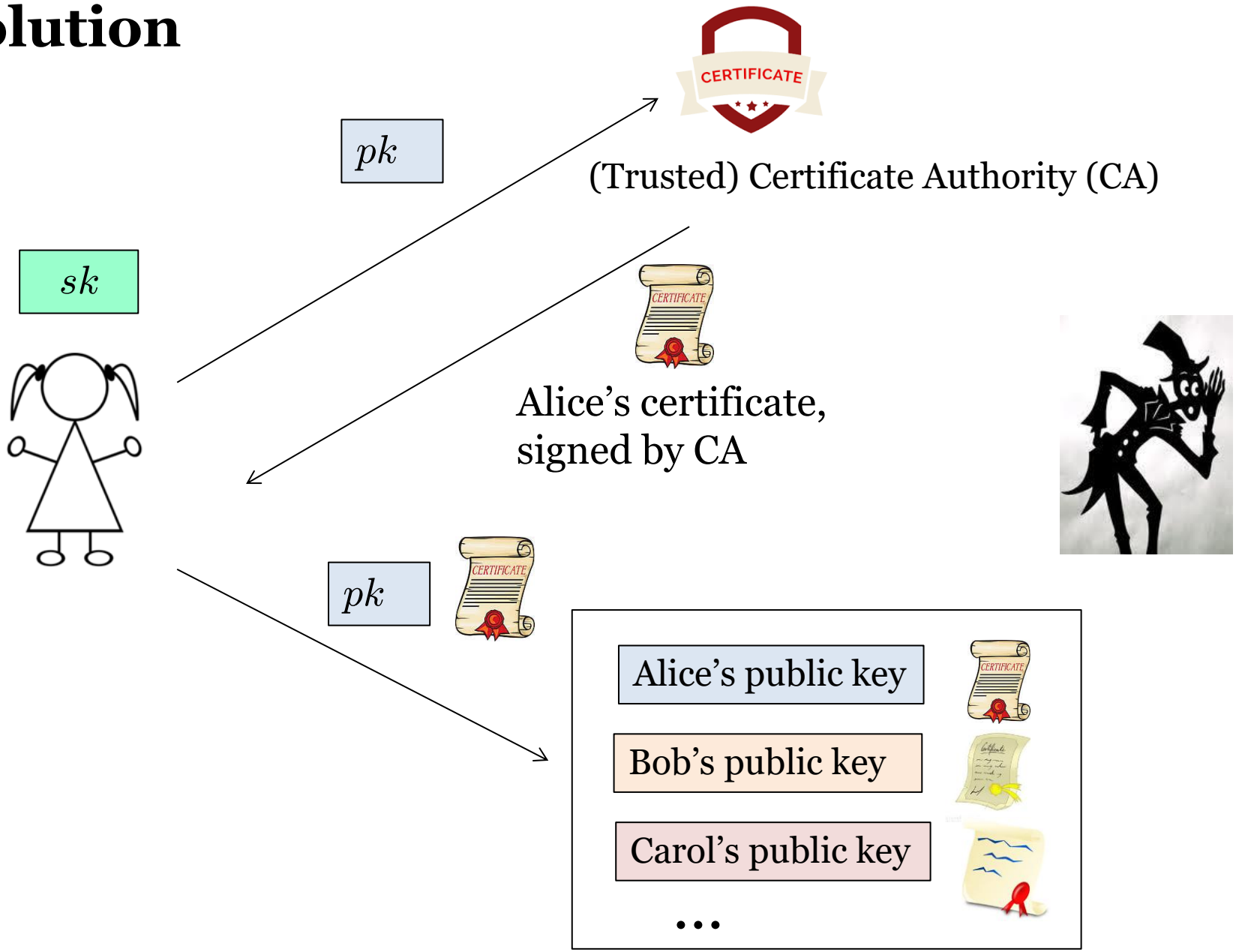
She keeps sk to herself, and stores pk in a public, trusted database.

Problem



The adversary may replace Alice's real key with its fake one

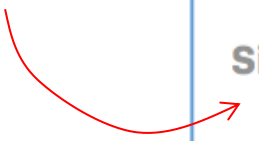
Solution


CERTIFICATE
pk
(Trusted) Certificate Authority (CA)
sk
CERTIFICATE
Alice's certificate,
signed by CA
pk
CERTIFICATE
Alice's public key
CERTIFICATE
Bob's public key
Carol's public key
...

An Example of X.509 Certificate

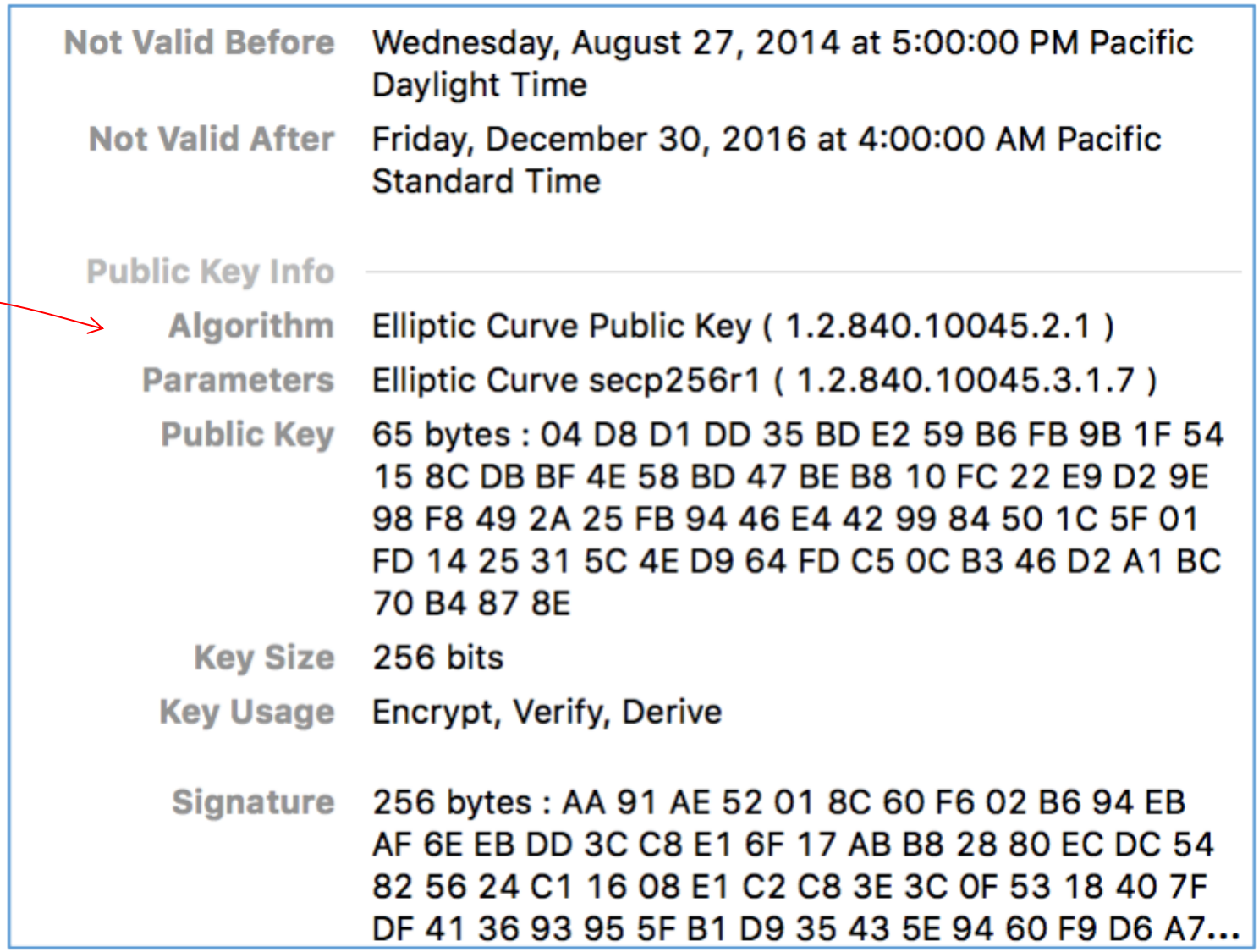
Subject Name	
Country	US
State/Province	CA
Locality	Menlo Park
Organization	Facebook, Inc.
Common Name	*.facebook.com
Issuer Name	
Country	US
Organization	DigiCert Inc
Organizational Unit	www.digicert.com
Common Name	DigiCert SHA2 High Assurance Server CA
Serial Number	0E CB 09 39 B2 B1 01 54 B8 95 70 C7 B2 2B 7A 47
Version	3
Signature Algorithm	SHA-256 with RSA Encryption (1.2.840.113549.1.1.11)

PKCS#1 signature with SHA-256



Source: Boneh-Shoup's book "A Graduate Course in Applied Crypto"

An Example of X.509 Certificate



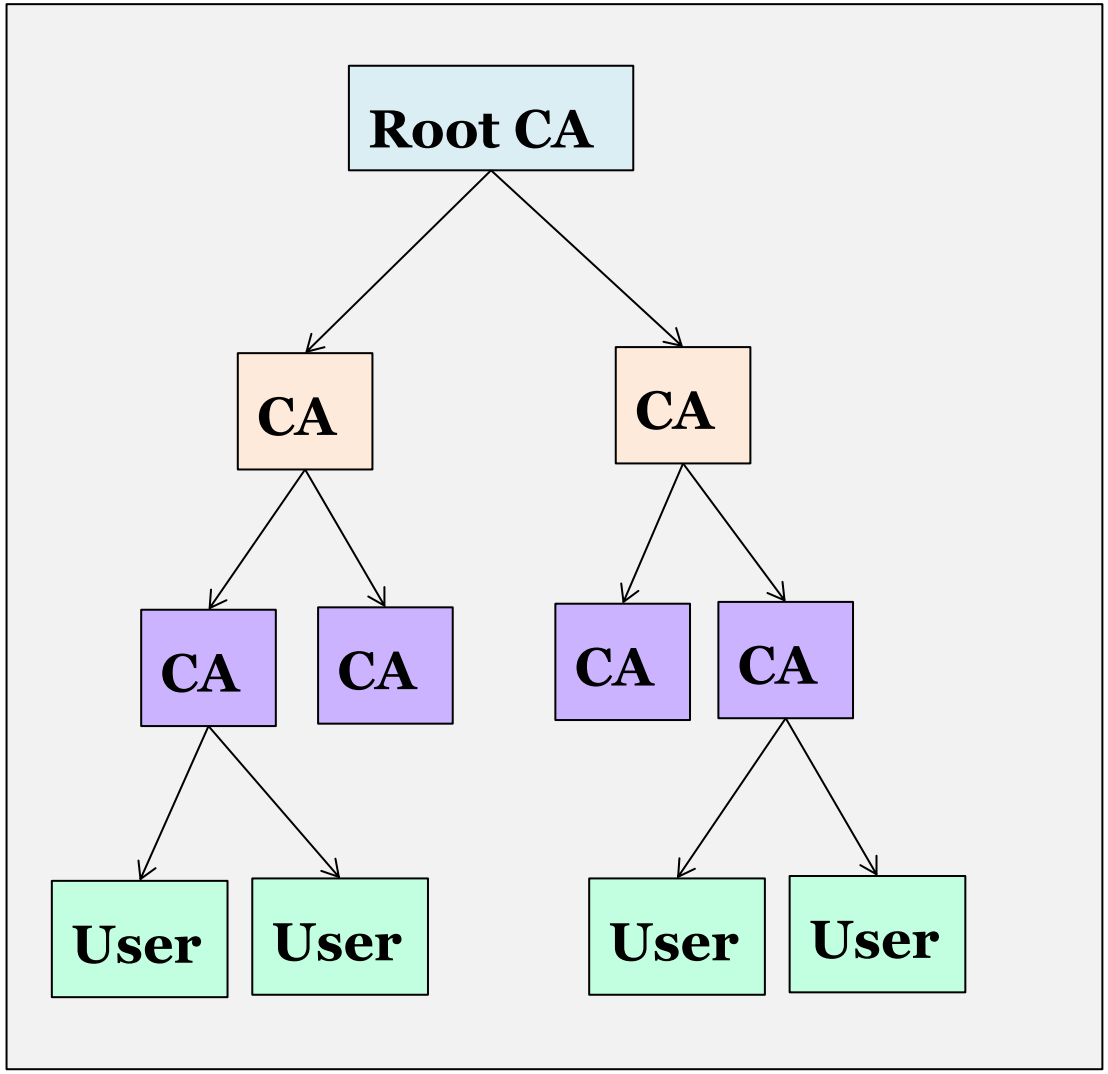
Not Valid Before	Wednesday, August 27, 2014 at 5:00:00 PM Pacific Daylight Time
Not Valid After	Friday, December 30, 2016 at 4:00:00 AM Pacific Standard Time
Public Key Info	
Algorithm	Elliptic Curve Public Key (1.2.840.10045.2.1)
Parameters	Elliptic Curve secp256r1 (1.2.840.10045.3.1.7)
Public Key	65 bytes : 04 D8 D1 DD 35 BD E2 59 B6 FB 9B 1F 54 15 8C DB BF 4E 58 BD 47 BE B8 10 FC 22 E9 D2 9E 98 F8 49 2A 25 FB 94 46 E4 42 99 84 50 1C 5F 01 FD 14 25 31 5C 4E D9 64 FD C5 0C B3 46 D2 A1 BC 70 B4 87 8E
Key Size	256 bits
Key Usage	Encrypt, Verify, Derive
Signature	256 bytes : AA 91 AE 52 01 8C 60 F6 02 B6 94 EB AF 6E EB DD 3C C8 E1 6F 17 AB B8 28 80 EC DC 54 82 56 24 C1 16 08 E1 C2 C8 3E 3C 0F 53 18 40 7F DF 41 36 93 95 5F B1 D9 35 43 5E 94 60 F9 D6 A7...

ElGammal on EC group

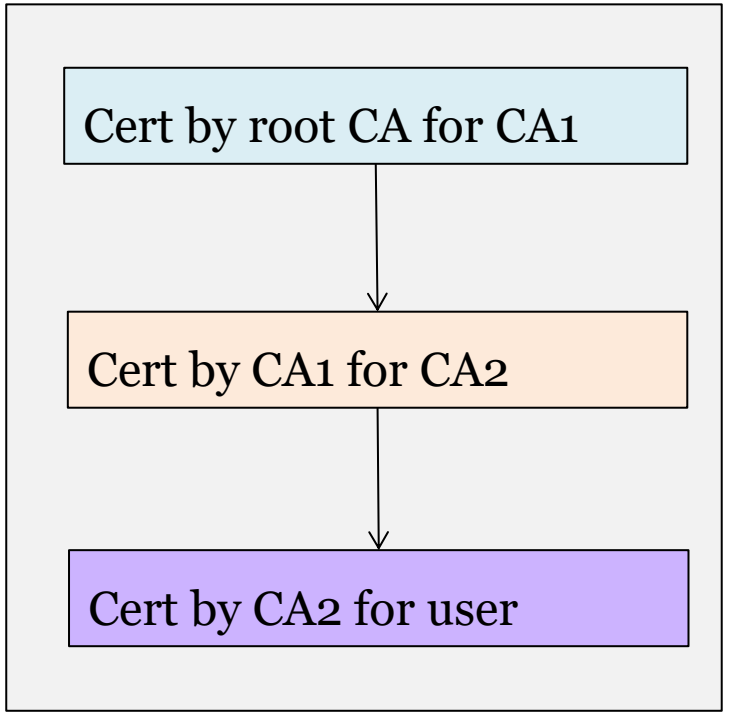
Source: Boneh-Shoup's book "A Graduate Course in Applied Crypto"

Certificate Chain

CA hierarchy

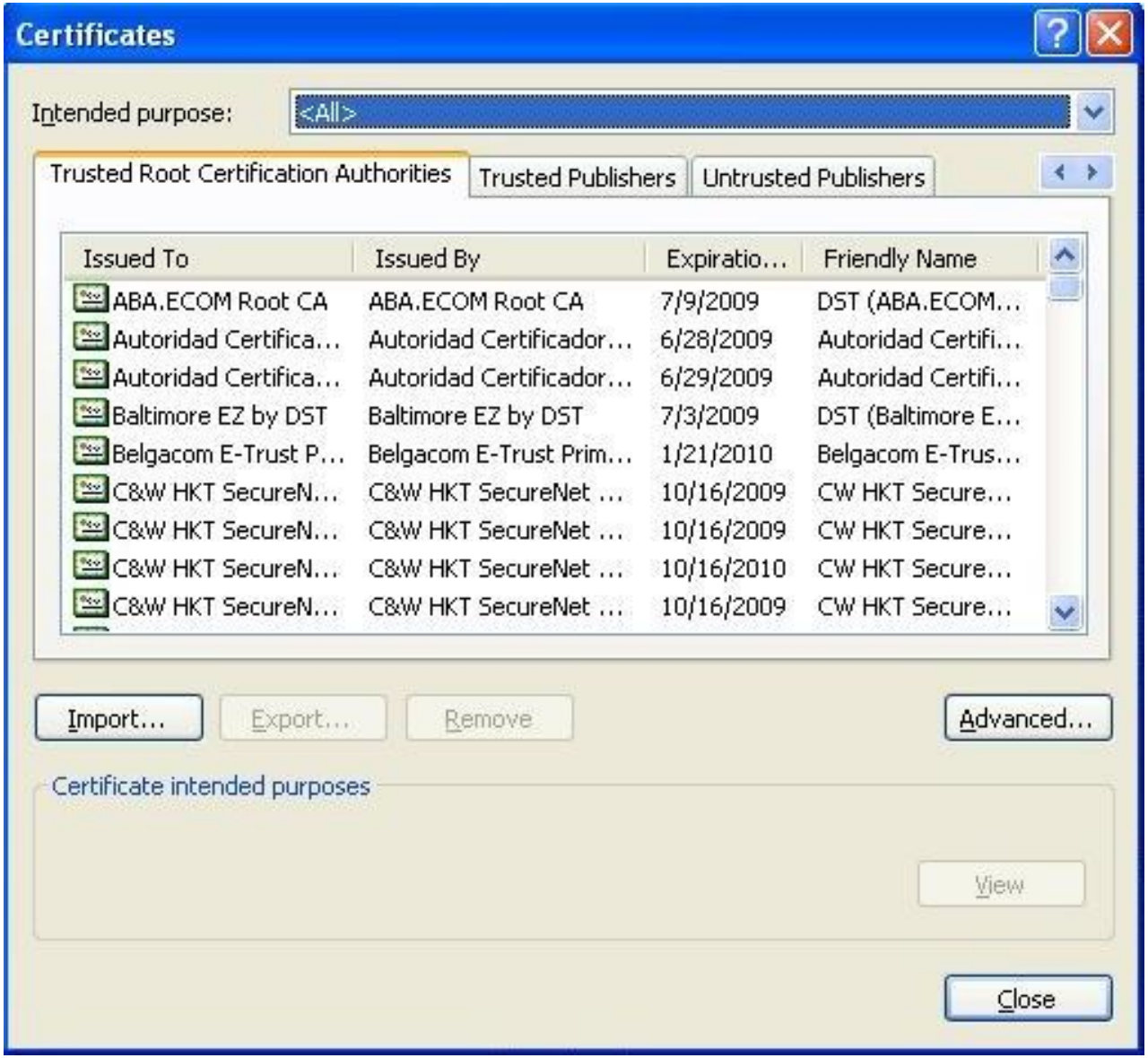


User's certificate

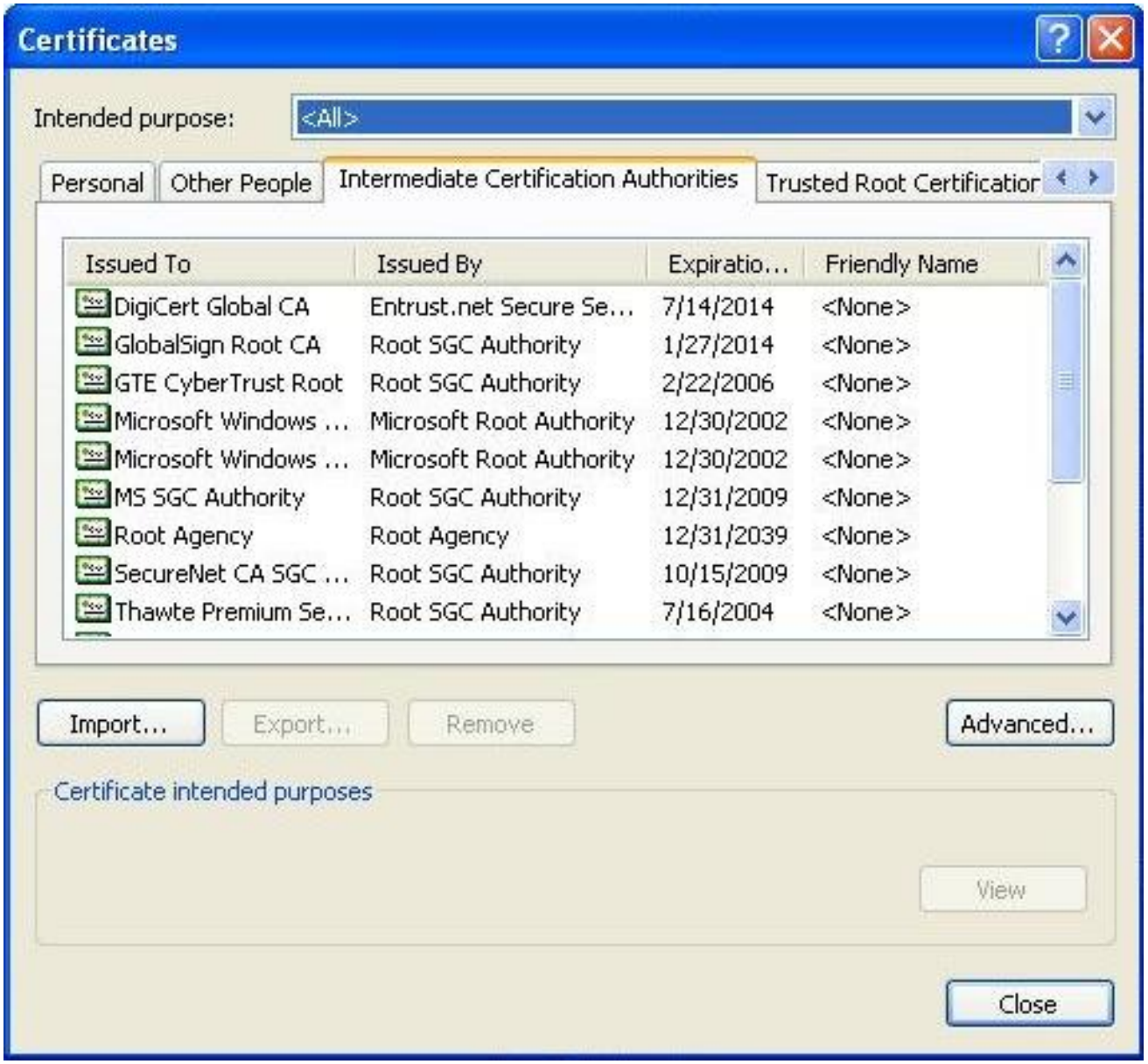


Only need to know public key of root CAs to verify

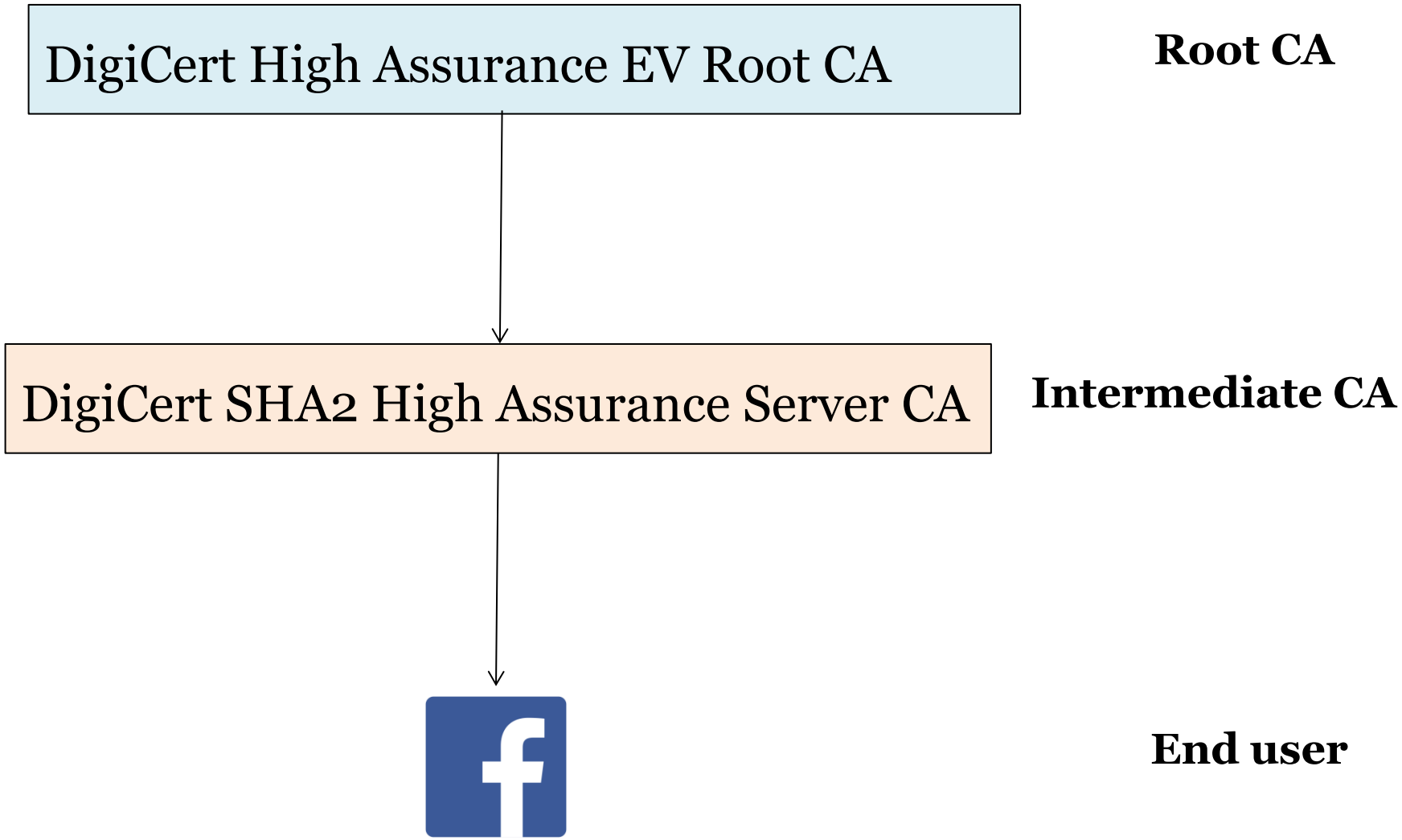
Certificate Chain Example



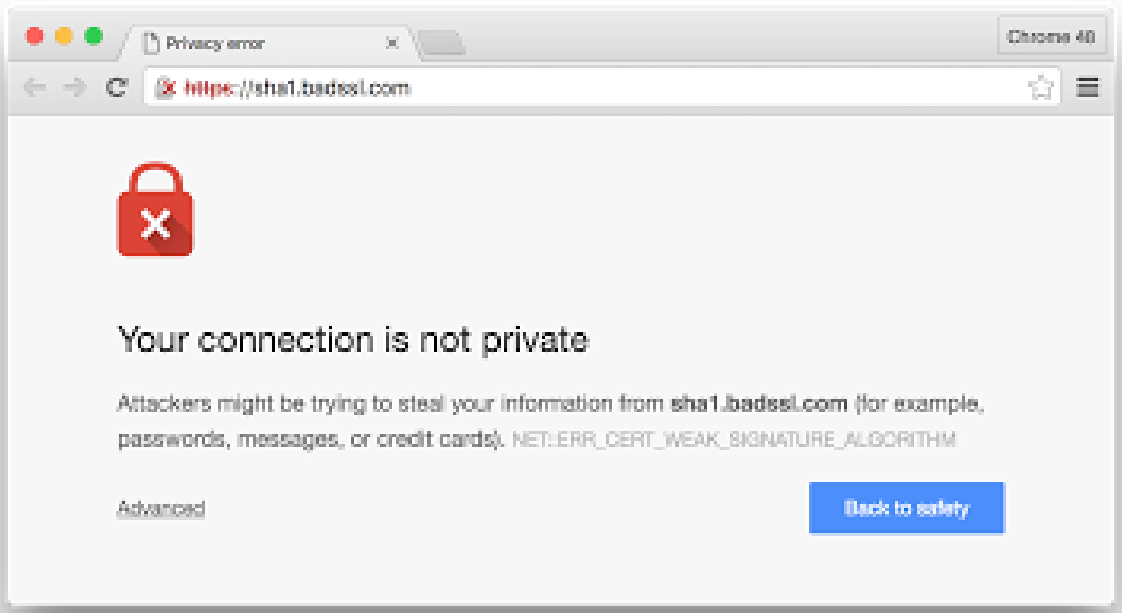
Certificate Chain Example



Certificate Chain Example



Usability Issue



Modern browsers complain if certificates are not valid

But users still can bypass the warning, and many people do

Man-in-the-middle (MITM) attacks are still a threat on large scale

Real-world MITM Attacks

https://www.schneier.com/blog/archives/2013/09/new_nsa_leak_sh.html

Blog >

New NSA Leak Shows MITM Attacks Against Major Internet Services

The Brazilian television show "Fantastico" exposed an NSA training presentation that discusses how the agency runs man-in-the-middle attacks on the Internet. The point of the story was that the NSA engages in economic espionage against Petrobras, the Brazilian giant oil company, but I'm more interested in the tactical details.

The video on the webpage is long, and includes what I classroom, but a few screen shots are important. The how the NSA's MITM attack works:

> However, in some cases GCHQ and the NSA and controversial route -- on at least one occa Google directly by performing a man-in-the-mi security certificates. One document published NSA presentation that also contains some GC done" to apparently snoop on SSL traffic. The

www.netresec.com/?page=Blog&month=2014-09&post=Analysis-of-Chinese-MITM-on-Goo

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Thursday, 04 September 2014 23:55:00 (UTC/GMT)

Analysis of Chinese MITM on Google

The Chinese are running a MITM attack on SSL encrypted traffic between Chinese universities and Google. We've performed technical analysis of the attack, on request from GreatFire.org, and can confirm that it is a real SSL MITM against www.google.com and that it is being performed from within China.

We were contacted by GreatFire.org yesterday (September 3) with a request to analyze two packet captures from suspected MITM-attacks before they finalized their blog post. The conclusions from our analysis is now published as part of GreatFire.org's great blog post titled "Authorities launch man-in-the-middle attack on Google".

Agenda

1. Certificate Authority (CA)

2. Dealing with Rogue CAs

When CAs Get Hacked

Comodo hacker: I hacked DigiNotar too; other CAs breached

The hacker behind this year'

PETER BRIGHT - 9/6/2011, 5:36 PM

Digital certificate breach at Indian authority also targeted Yahoo domains, possibly others

The full scope of the security breach is currently unknown, a Google security engineer said

Lucian Constantin (IDG News Service) on 11 July, 2014 01:22

VeriSign issues fraudulent Microsoft certificates

John Fontana (Computerworld)
26 March, 2001 11:09

Certificate Pinning

DigiCert CA

Want: Only accepts Facebook certificate from DigiCert

Approach 1: Advertise via HTTPs Header:

-SHA-256(DigiCert cert)

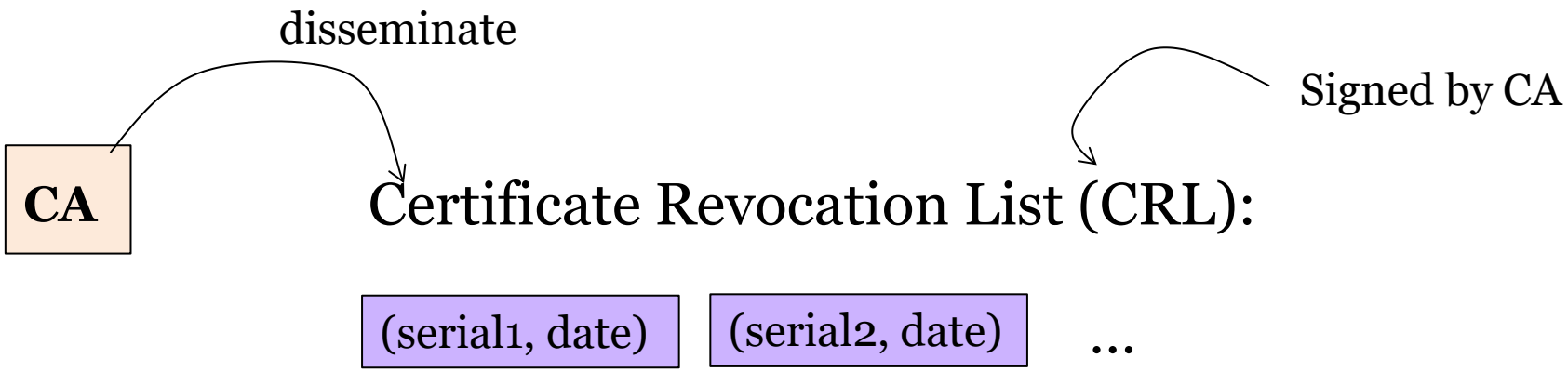
-Validity period

Cert of DigiCert from root CA, not Facebook's cert

Approach 2:

Pre-configure browsers

Certificate Revocation

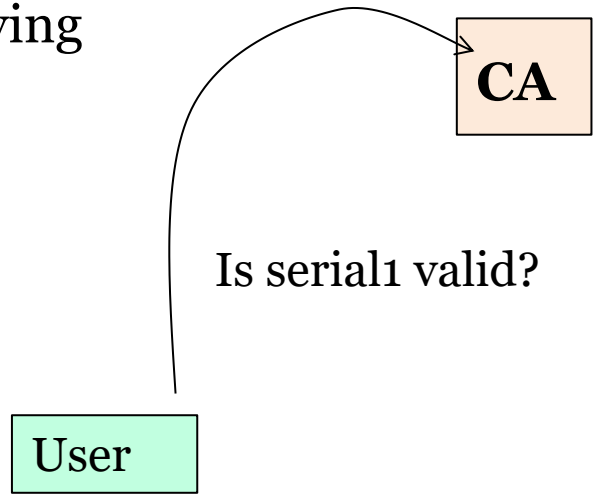


- One should download CRL from CA before validating cert
- Before Alice trusts Bob, she should make sure he's not in the CRL

Improve Bandwidth Efficiency

- CLR is huge → bandwidth issue

- **Solution**: Online querying



Where to Download CLR or Query?

Information can be found in certificate

URL to download CRL

URL to query