CSE 484 / CSE M 584: Computer Security and Privacy

Crypto meets Web Security: Certificates and SSL/TLS

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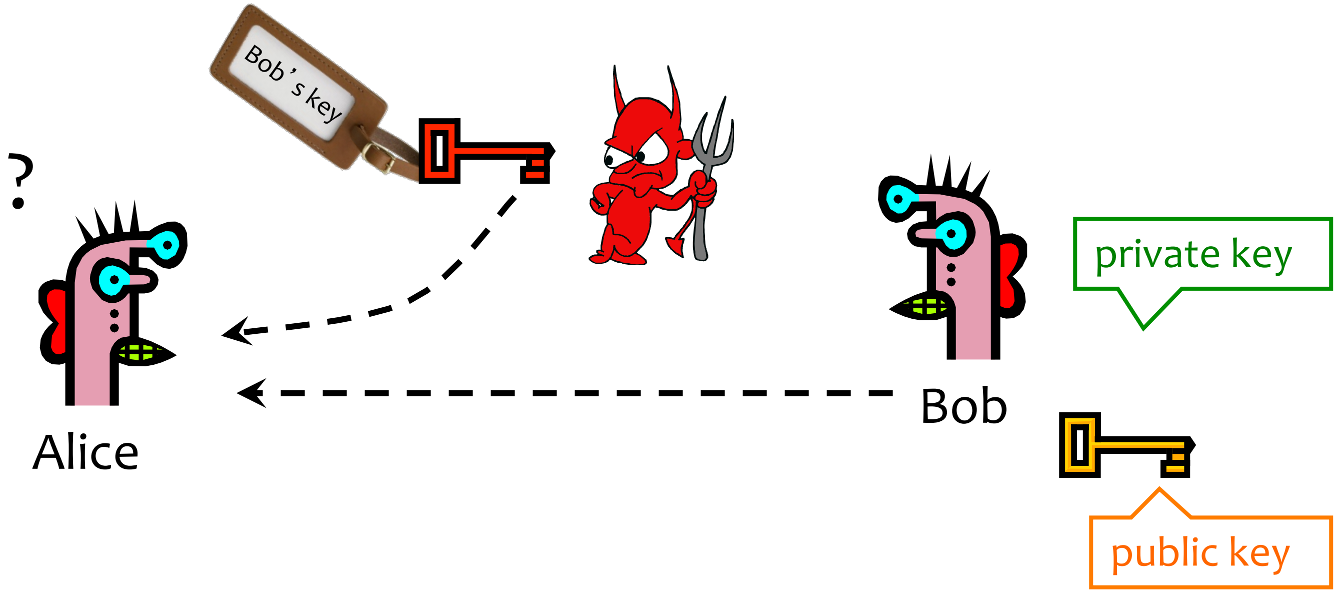
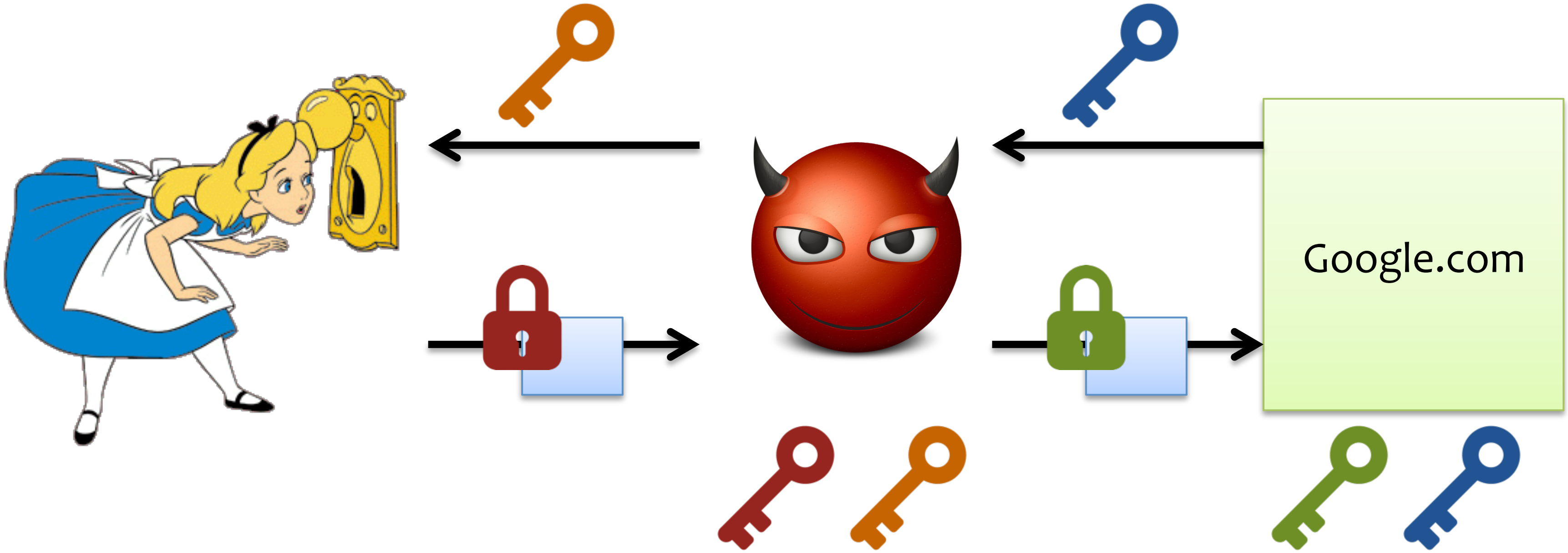
Authenticity of Public Keys



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

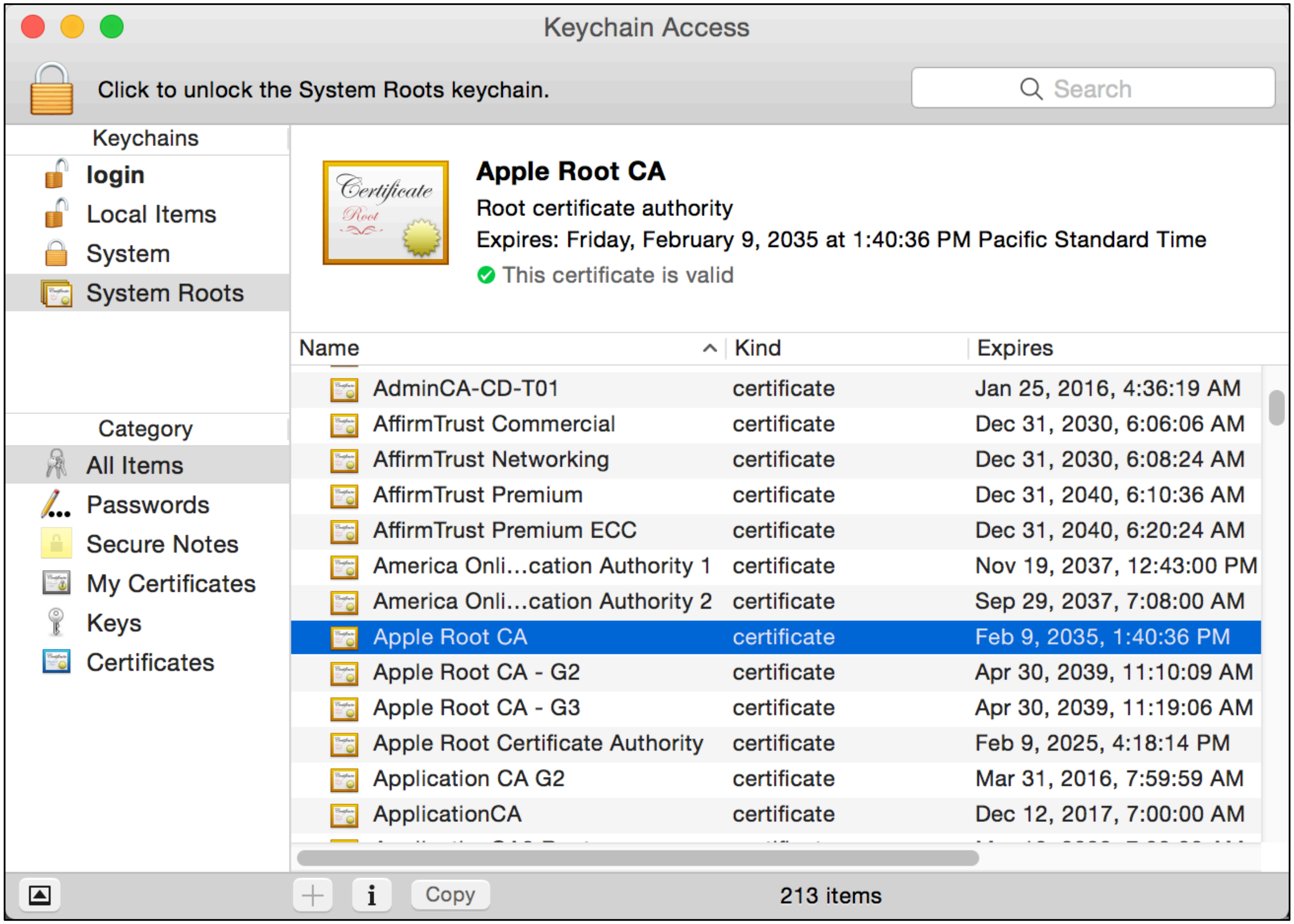
Threat: Man-In-The-Middle (MITM)



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



Click to unlock the System Roots keychain.

Apple Root CA

Root certificate authority

Expires: Friday, February 9, 2035 at 1:40:36 PM Pacific Standard Time

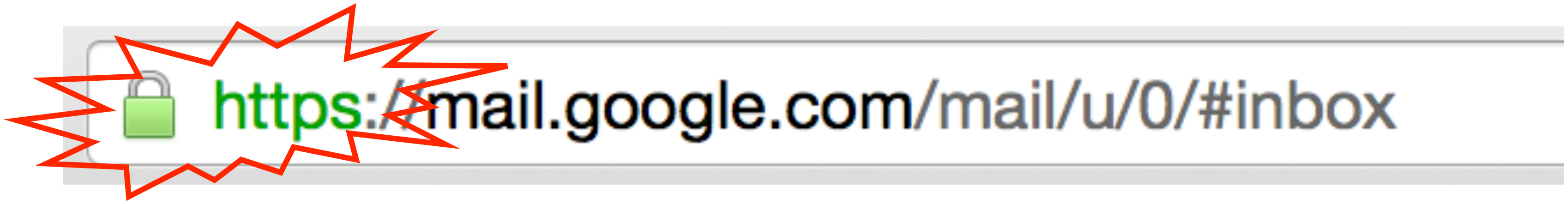
✓ This certificate is valid

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

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
    - $\text{sig}_{\text{Verisign}}$(“AnotherCA”, $\text{PK}_{\text{AnotherCA}}$), $\text{sig}_{\text{AnotherCA}}$(“Alice”, PK_{A})
  - What happens if root authority is ever compromised?

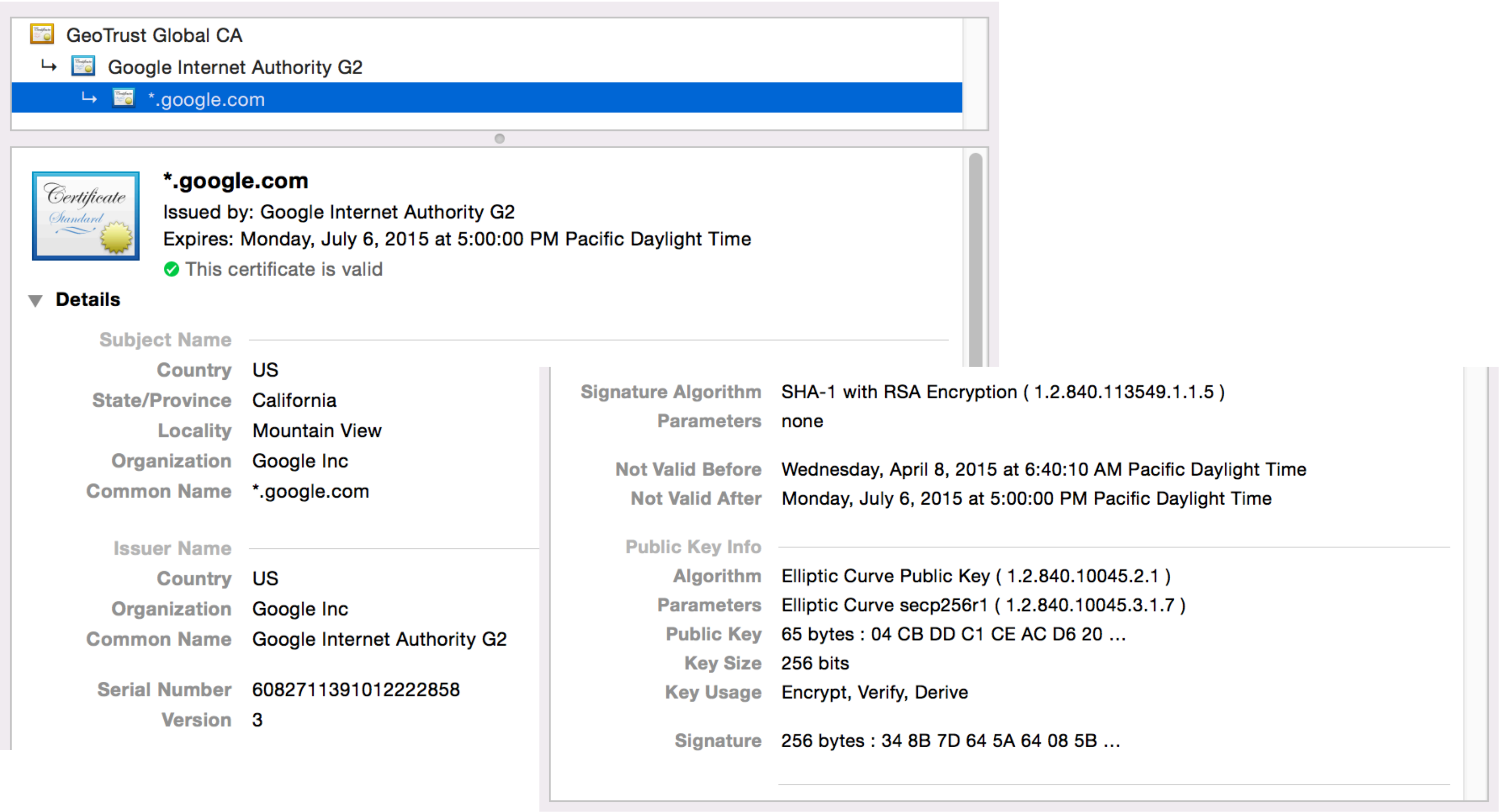
You encounter this every day…


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

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

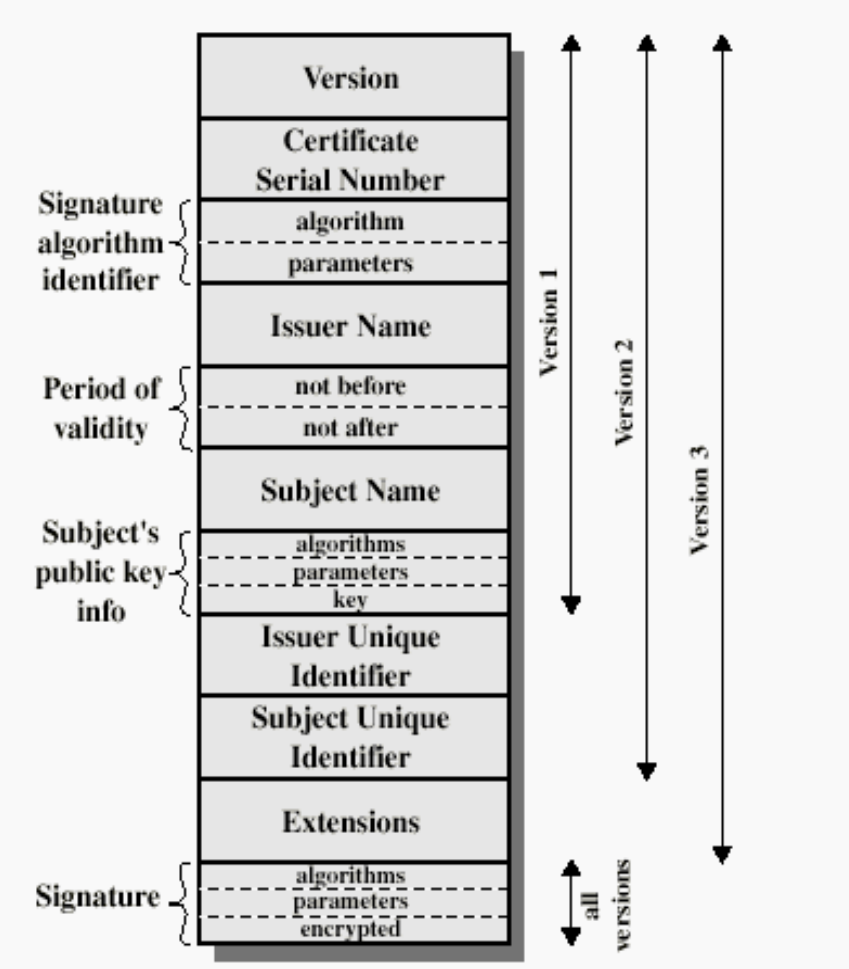
✓ This certificate is valid

▼ **Details**

Subject Name	
Country	US
State/Province	California
Locality	Mountain View
Organization	Google Inc
Common Name	*.google.com
Issuer Name	
Country	US
Organization	Google Inc
Common Name	Google Internet Authority G2
Serial Number	608271139101222858
Version	3

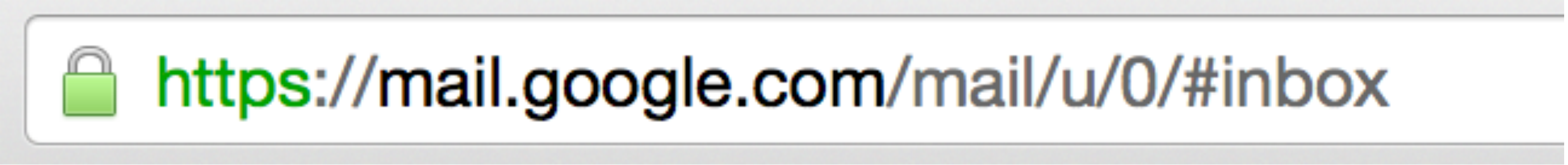
Signature Algorithm	SHA-1 with RSA Encryption (1.2.840.113549.1.1.5)
Parameters	none
Not Valid Before	Wednesday, April 8, 2015 at 6:40:10 AM Pacific Daylight Time
Not Valid After	Monday, July 6, 2015 at 5:00:00 PM Pacific Daylight Time
Public Key Info	
Algorithm	Elliptic Curve Public Key (1.2.840.10045.2.1)
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…
[more examples in section]

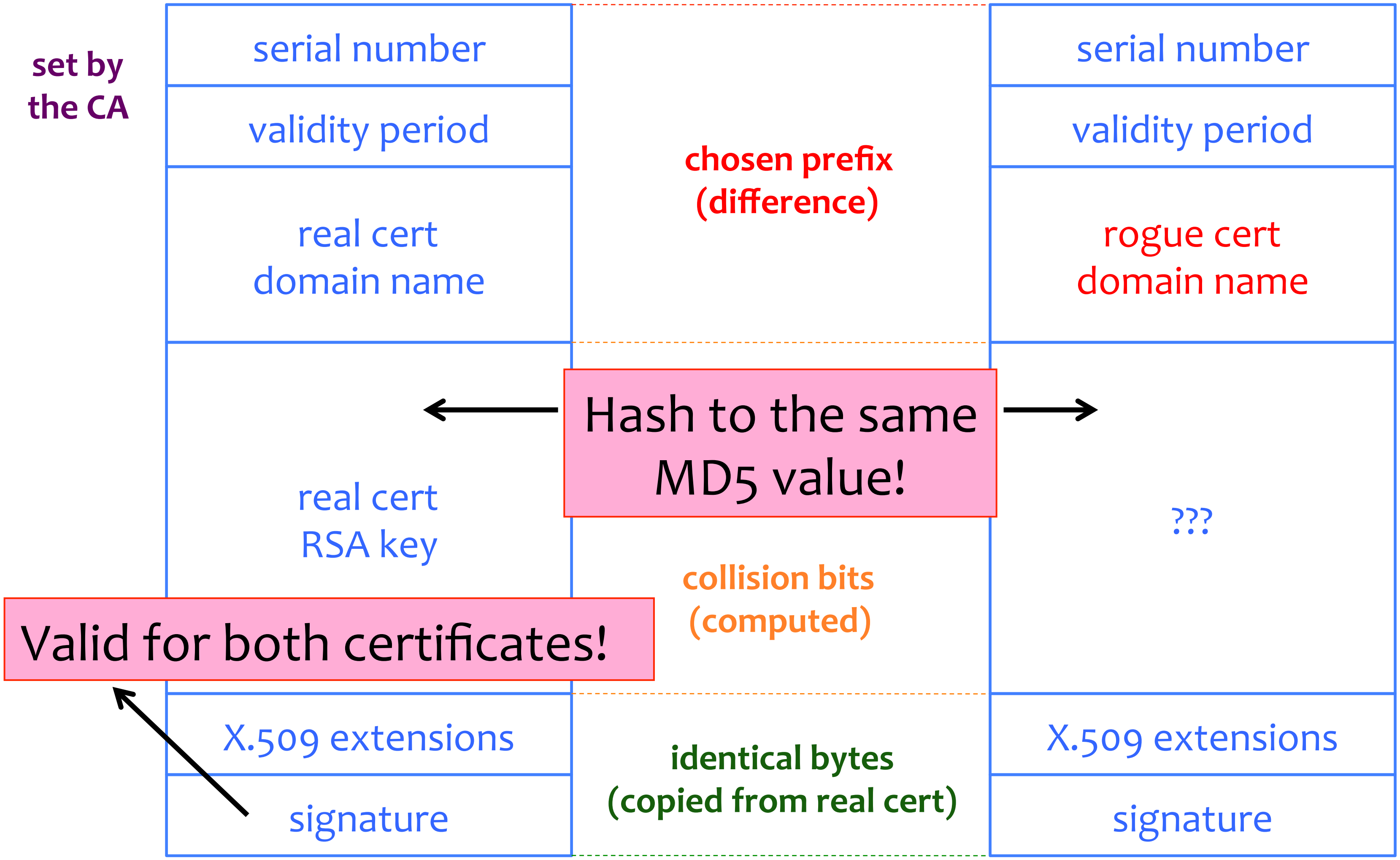
- Hash collisions
- Weak security at CAs
  - Allows attackers to issue rogue certificates
- Users don’t notice when attacks happen
  - We’ll talk more about this later
- Etc…



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

[Sotirov et al. "Rogue Certificates"]

Colliding Certificates



set by the CA

serial number | serial number

validity period | validity period

real cert domain name | rogue cert domain name

chosen prefix (difference)

real cert RSA key | ???

Hash to the same MD5 value!

collision bits (computed)

Valid for both certificates!

X.509 extensions | X.509 extensions

signature | signature

identical bytes (copied from real cert)

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

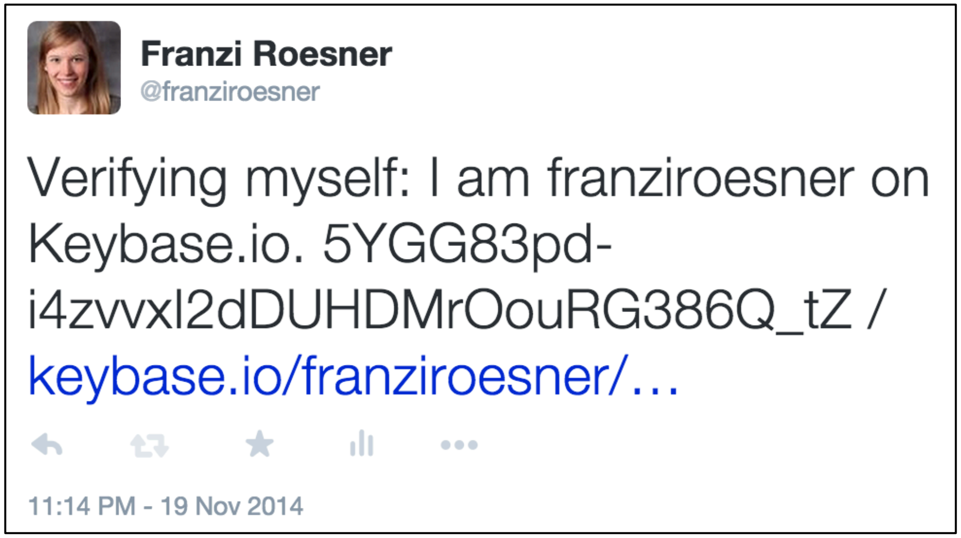
Attempt to Fix CA Problems: Convergence

- 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



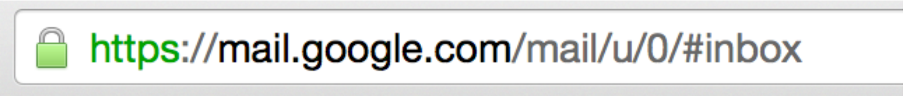
Franzi Roesner
@franziroesner

Verifying myself: I am franziroesner on Keybase.io. 5YGG83pd-i4zvvxl2dDUHDMrOouRG386Q_tZ / keybase.io/franziroesner/…

11:14 PM - 19 Nov 2014

https://keybase.io/

SSL/TLS



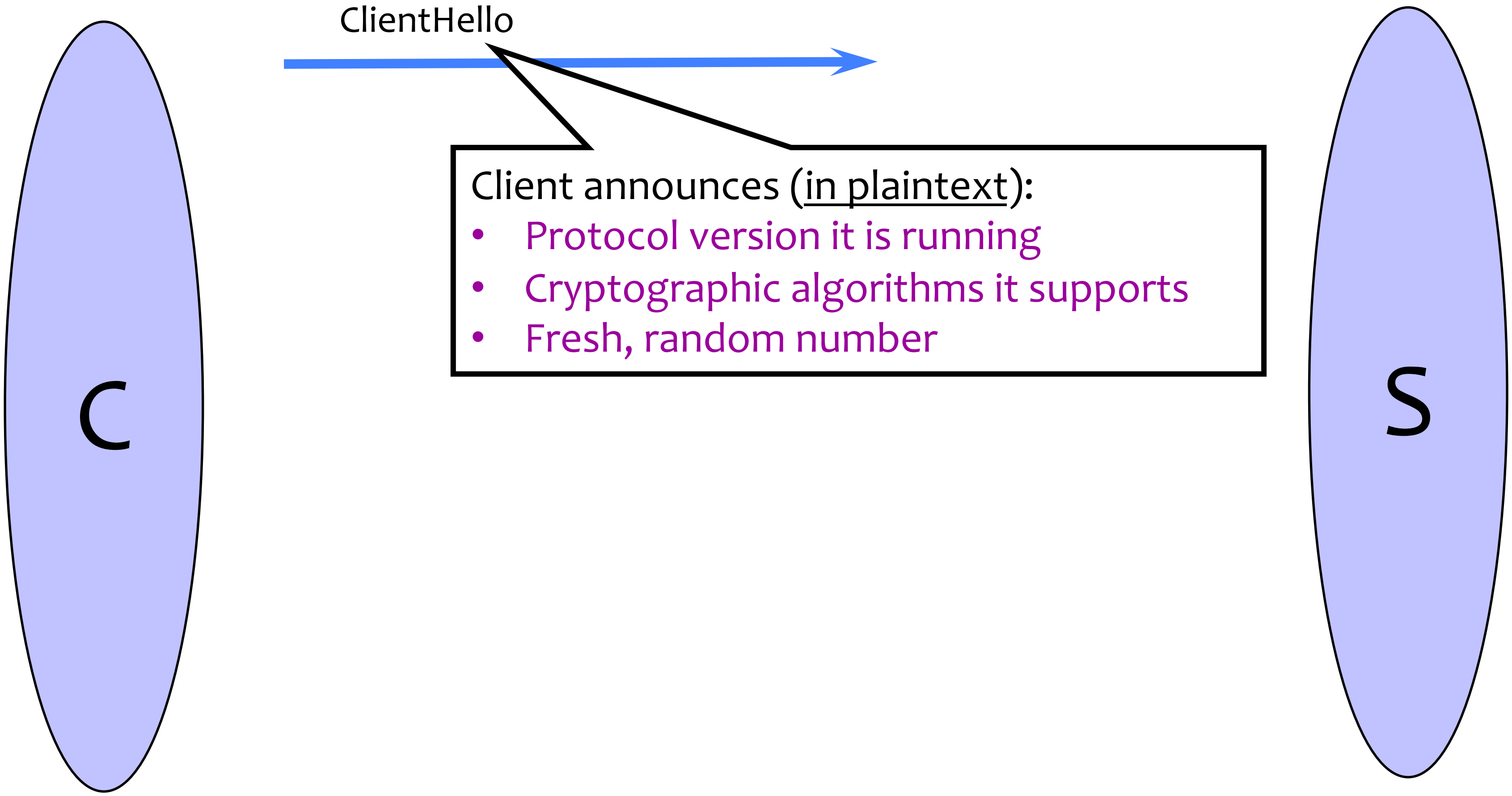
https://mail.google.com/mail/u/0/#inbox

- Secure Sockets Layer and Transport Layer Security protocols
  - Same protocol design, different crypto algorithms
- De facto standard for Internet security
  - "The primary goal of the TLS protocol is to provide privacy and data integrity between two communicating applications"
- Deployed in every Web browser; also VoIP, payment systems, distributed systems, etc.

TLS Basics

- TLS consists of two protocols
  - Familiar pattern for key exchange protocols
- Handshake protocol
  - Use public-key cryptography to establish a shared secret key between the client and the server
- Record protocol
  - Use the secret symmetric key established in the handshake protocol to protect communication between the client and the server

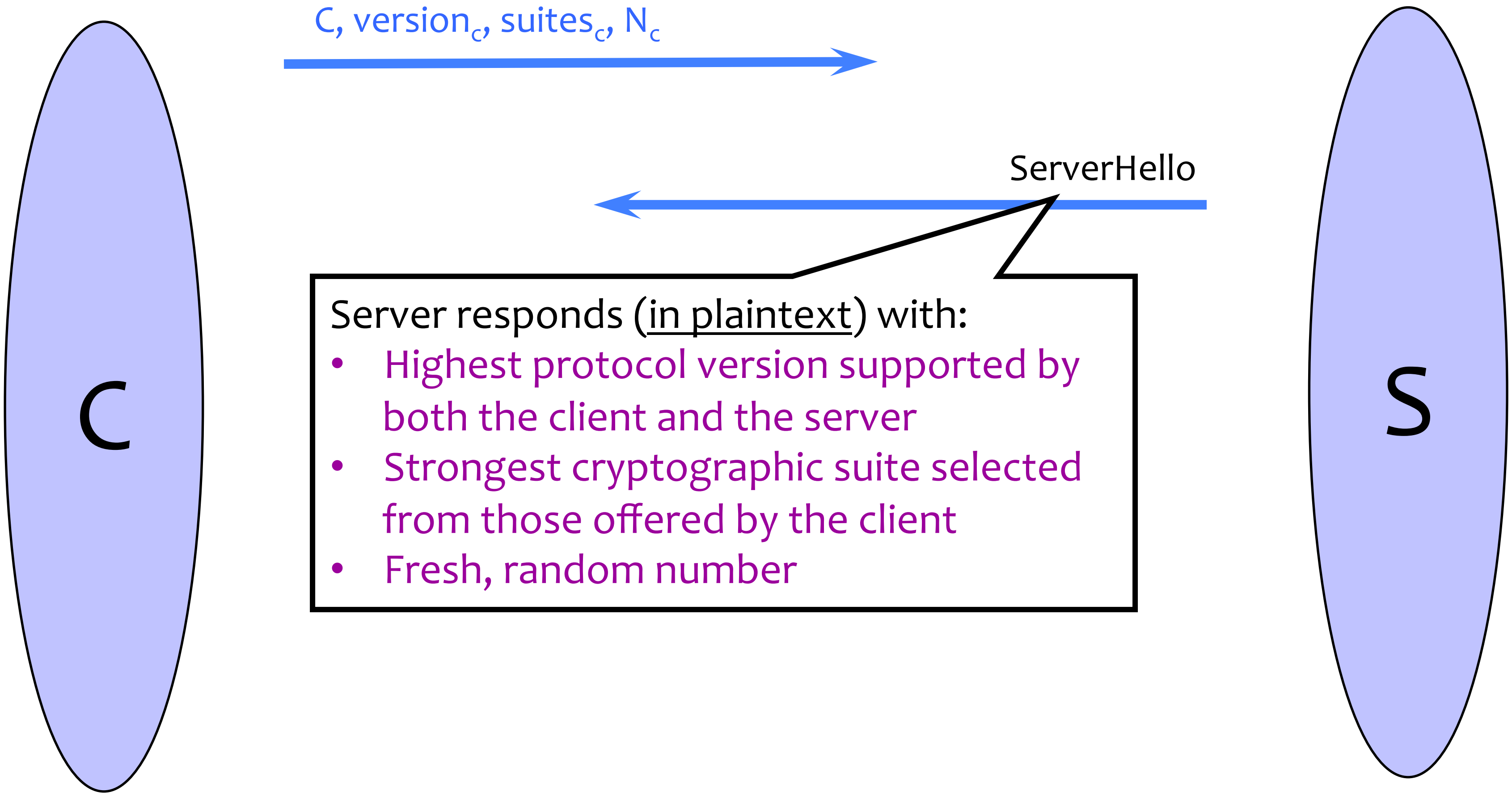
Basic Handshake Protocol



Client announces (in plaintext):

- Protocol version it is running
- Cryptographic algorithms it supports
- Fresh, random number

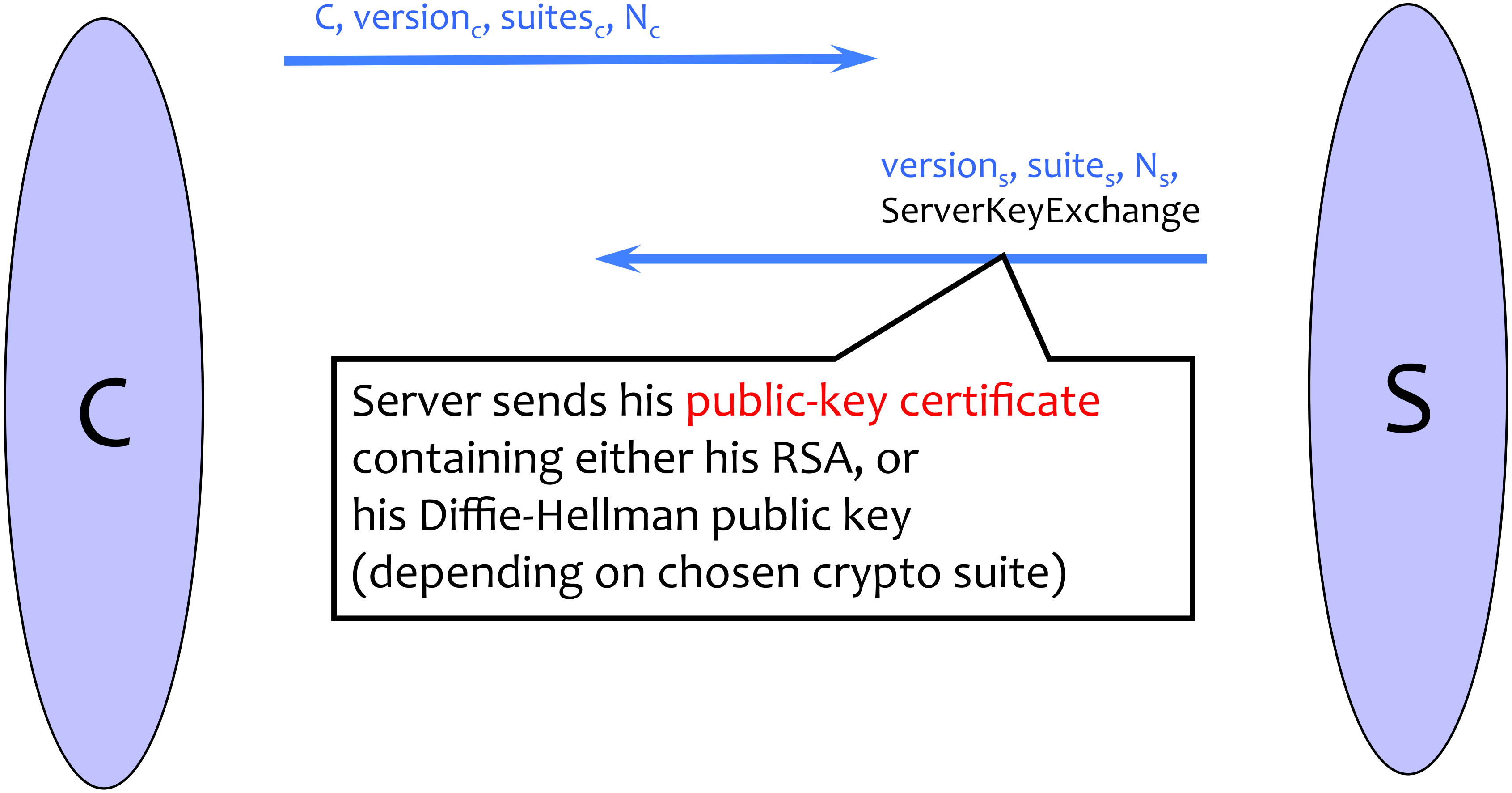
Basic Handshake Protocol



Server responds (in plaintext) with:

- Highest protocol version supported by both the client and the server
- Strongest cryptographic suite selected from those offered by the client
- Fresh, random number

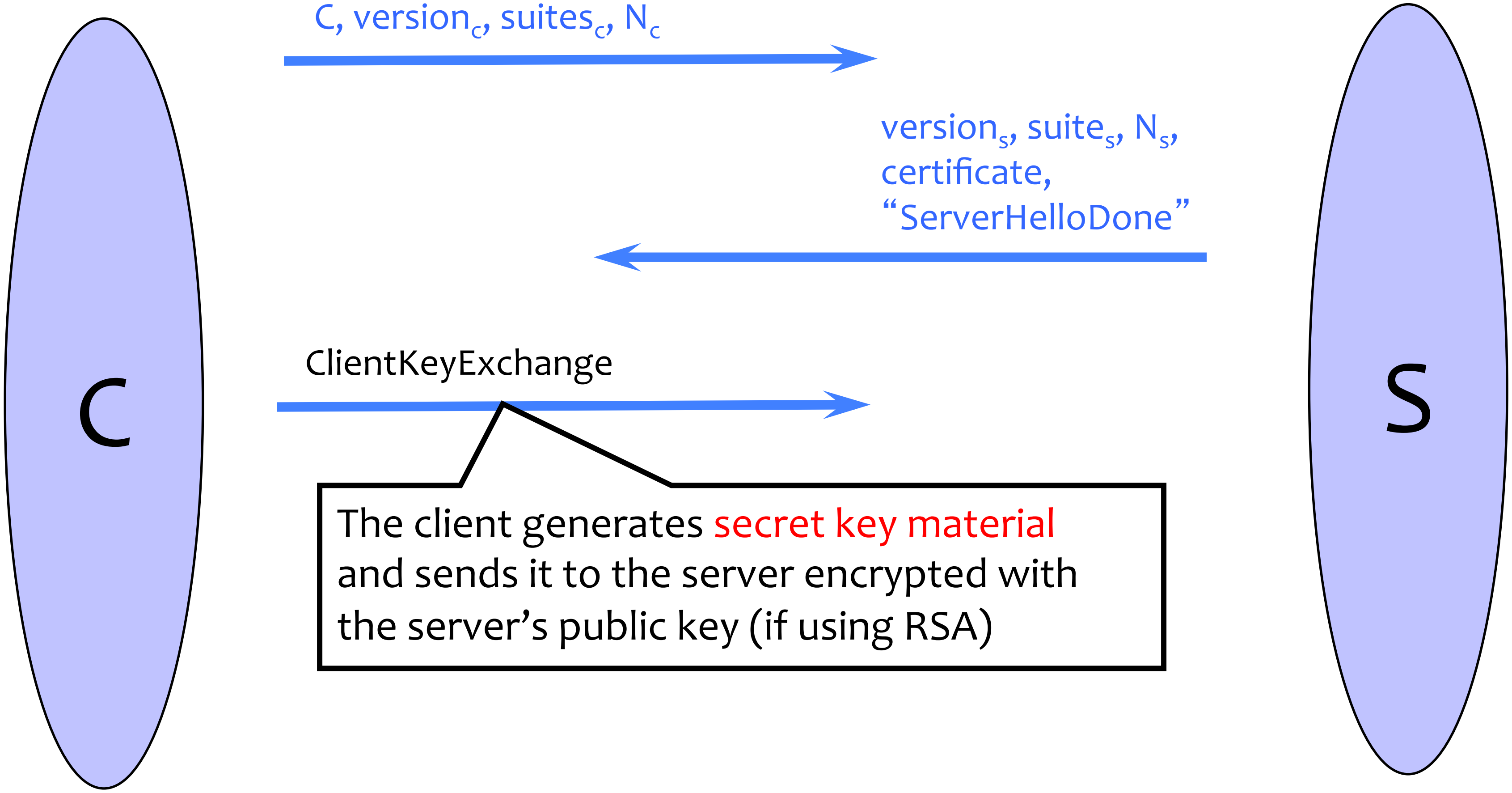
Basic Handshake Protocol



C, version$_c$, suites$_c$, N$_c$
version$_s$, suite$_s$, N$_s$,
ServerKeyExchange
C
S

Server sends his public-key certificate containing either his RSA, or his Diffie-Hellman public key (depending on chosen crypto suite)

Basic Handshake Protocol



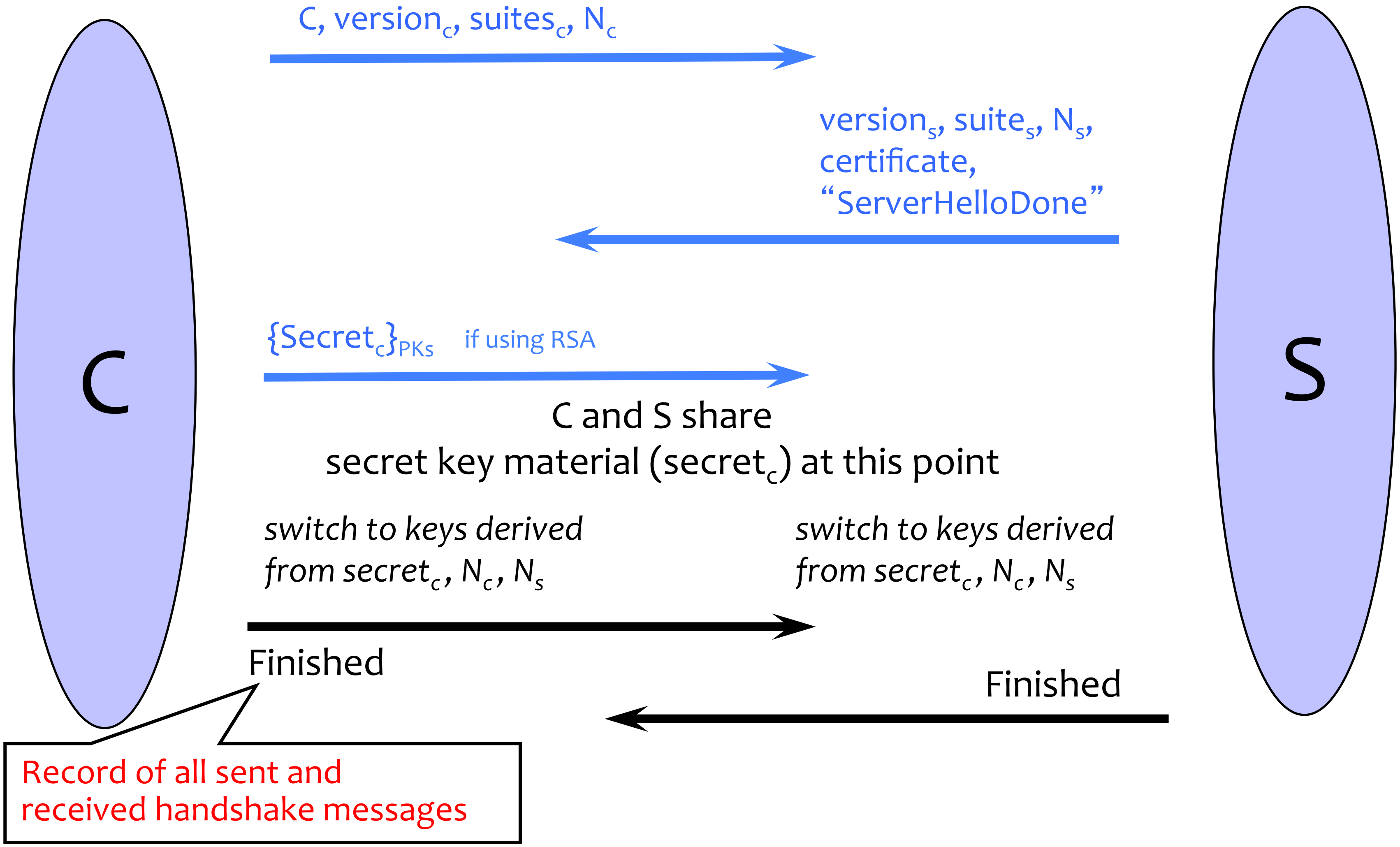
C, version_c, suites_c, N_c

version_s, suite_s, N_s,
certificate,
"ServerHelloDone"

ClientKeyExchange

The client generates secret key material and sends it to the server encrypted with the server's public key (if using RSA)

Basic Handshake Protocol



C, version_c, suites_c, N_c

version_s, suite_s, N_s,
certificate,
"ServerHelloDone"

$\{\text{Secret}_c\}_{PKs}$ if using RSA

C and S share
secret key material (secret_c) at this point

switch to keys derived
from $secret_c$, N_c, N_s

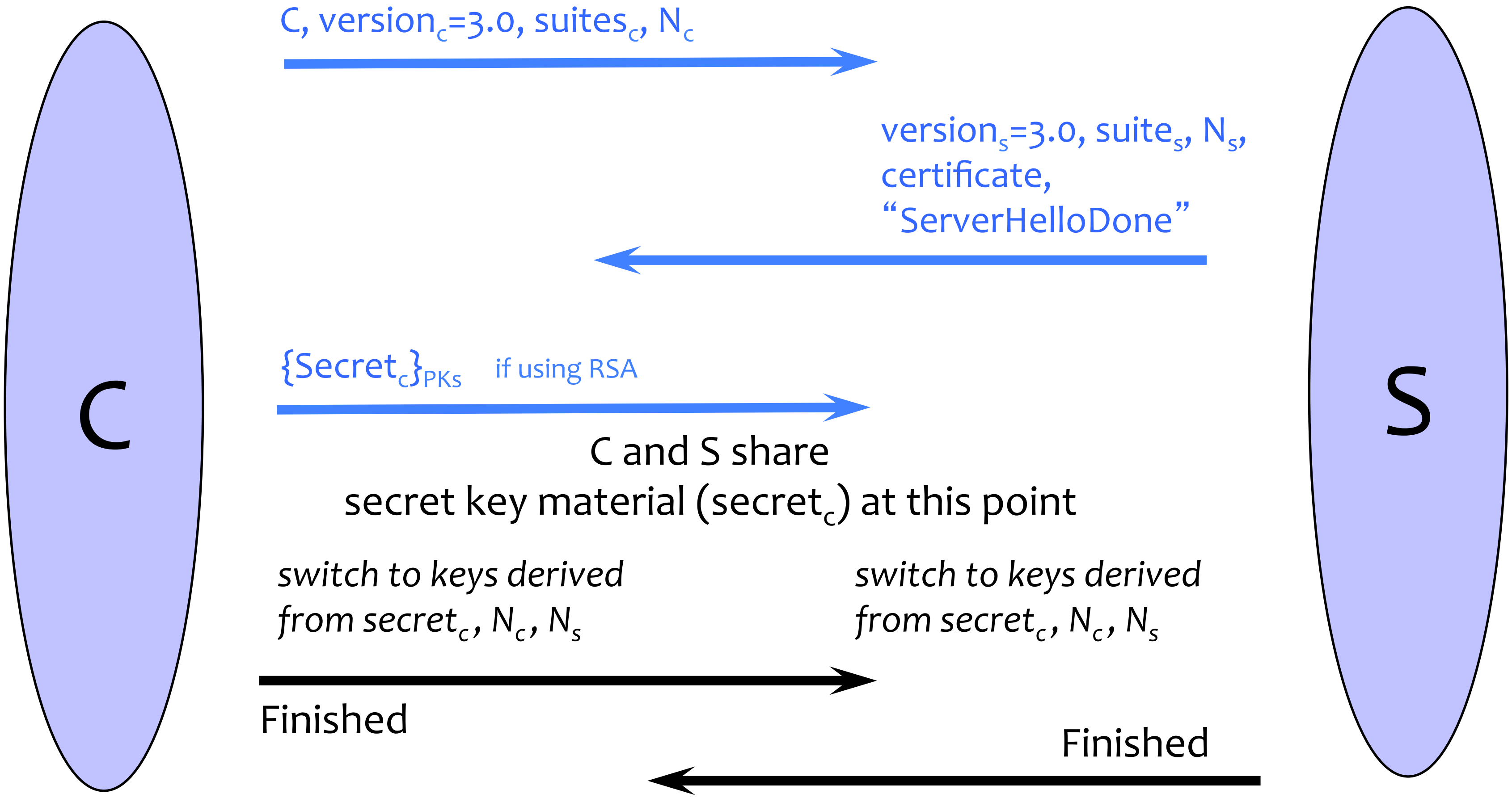
switch to keys derived
from $secret_c$, N_c, N_s

Finished

Finished

Record of all sent and
received handshake messages

"Core" SSL 3.0 Handshake (Not TLS)



C

C, version$_c$=3.0, suites$_c$, N_c

version$_s$=3.0, suite$_s$, N_s,
certificate,
"ServerHelloDone"

$\{\text{Secret}_c\}_{PKs}$ if using RSA

C and S share
secret key material (secret$_c$) at this point

*switch to keys derived
from secret$_c$, N_c, N_s*

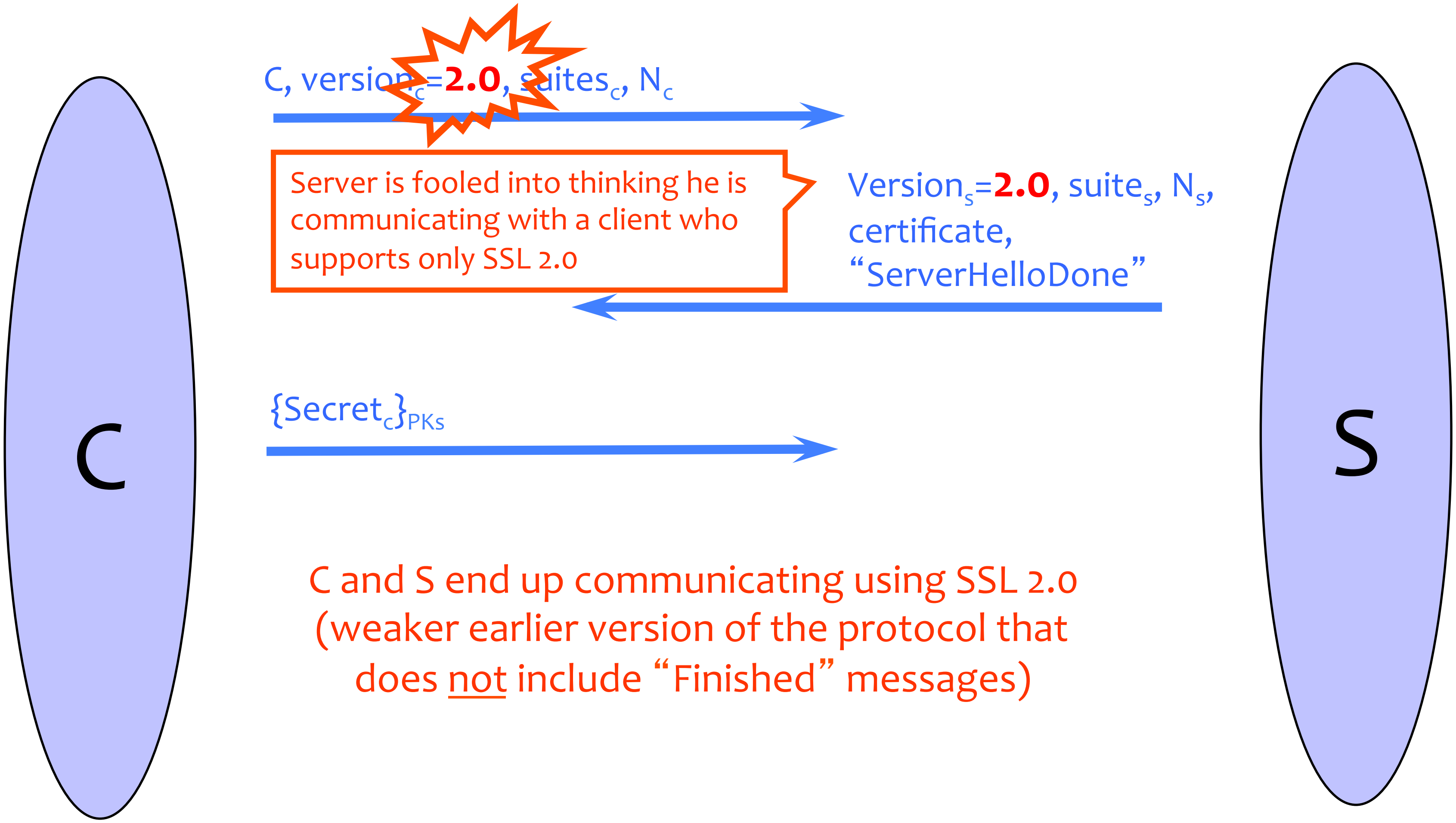
*switch to keys derived
from secret$_c$, N_c, N_s*

Finished

Finished

S

Version Rollback Attack



C, version$_c$=**2.0**, suites$_c$, N$_c$

Server is fooled into thinking he is communicating with a client who supports only SSL 2.0

Version$_s$=**2.0**, suite$_s$, N$_s$, certificate, "ServerHelloDone"

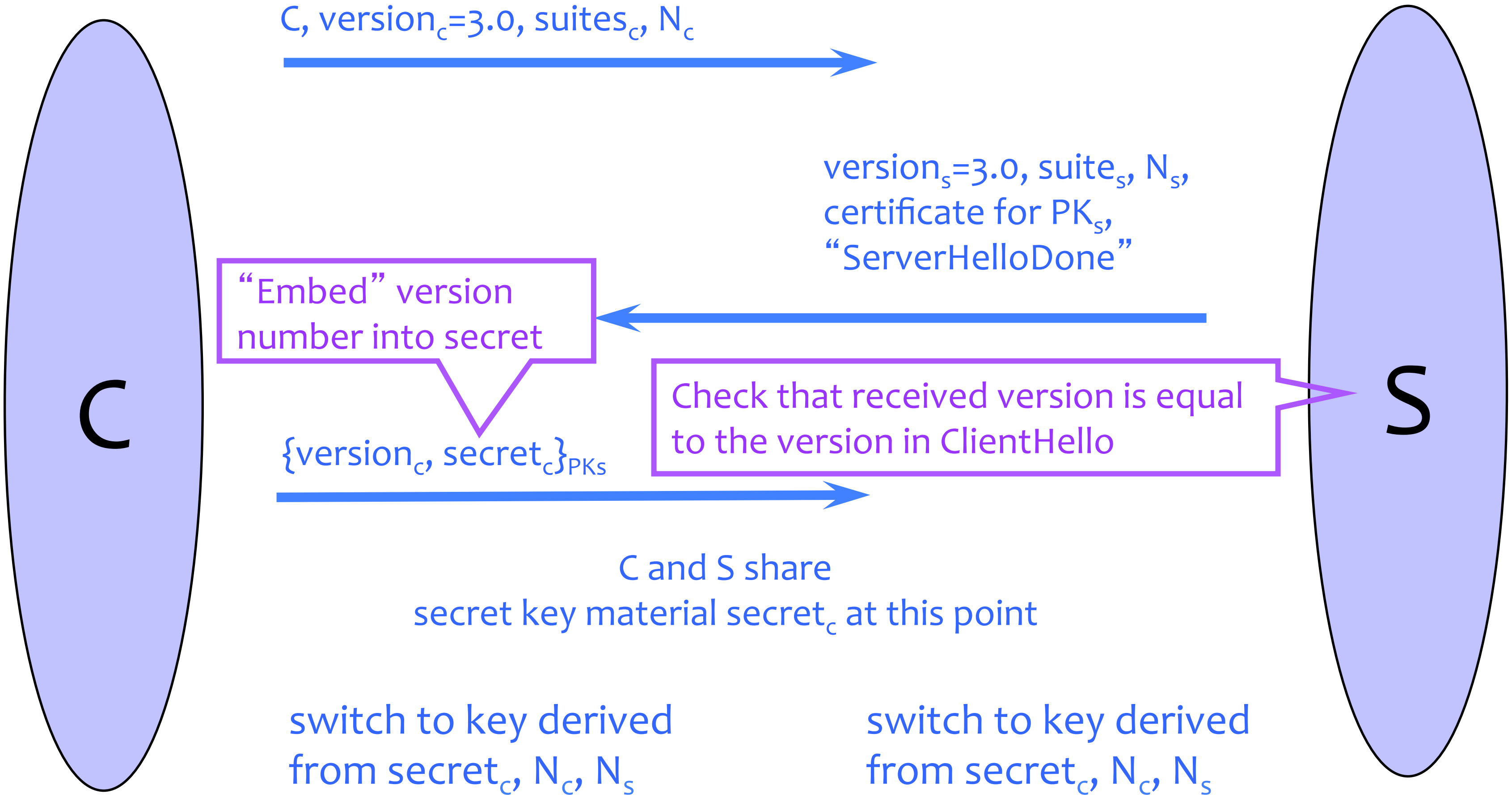
{Secret$_c$}$_{PKs}$

C and S end up communicating using SSL 2.0 (weaker earlier version of the protocol that does <ins>not</ins> include "Finished" messages)

“Chosen-Protocol” Attacks

- Why do people release new versions of security protocols? Because the old version got broken!
- New version must be backward-compatible
  - Not everybody upgrades right away
- Attacker can fool someone into using the old, broken version and exploit known vulnerability
  - Similar: fool victim into using weak crypto algorithms
- Defense is hard: must authenticate version in early designs
- Many protocols had “version rollback” attacks
  - SSL, SSH, GSM (cell phones)

Version Check in SSL 3.0



C, version$_c$=3.0, suites$_c$, N$_c$

version$_s$=3.0, suite$_s$, N$_s$,
certificate for PK$_s$,
"ServerHelloDone"

"Embed" version number into secret

{version$_c$, secret$_c$}$_{PKs}$

Check that received version is equal to the version in ClientHello

C and S share
secret key material secret$_c$ at this point

switch to key derived
from secret$_c$, N$_c$, N$_s$

switch to key derived
from secret$_c$, N$_c$, N$_s$