11. Network Security The tale of SSL/TLS and SET

Computer Security Courses @ POLIMI

Issues of Communications Security

- Problems of remoteness
  - Trust factor between parties
  - Use of sensitive data
  - Atomicity of transaction
- Internet protocol problems
  - Authentication
  - Confidentiality
- Transparence and critical mass problem

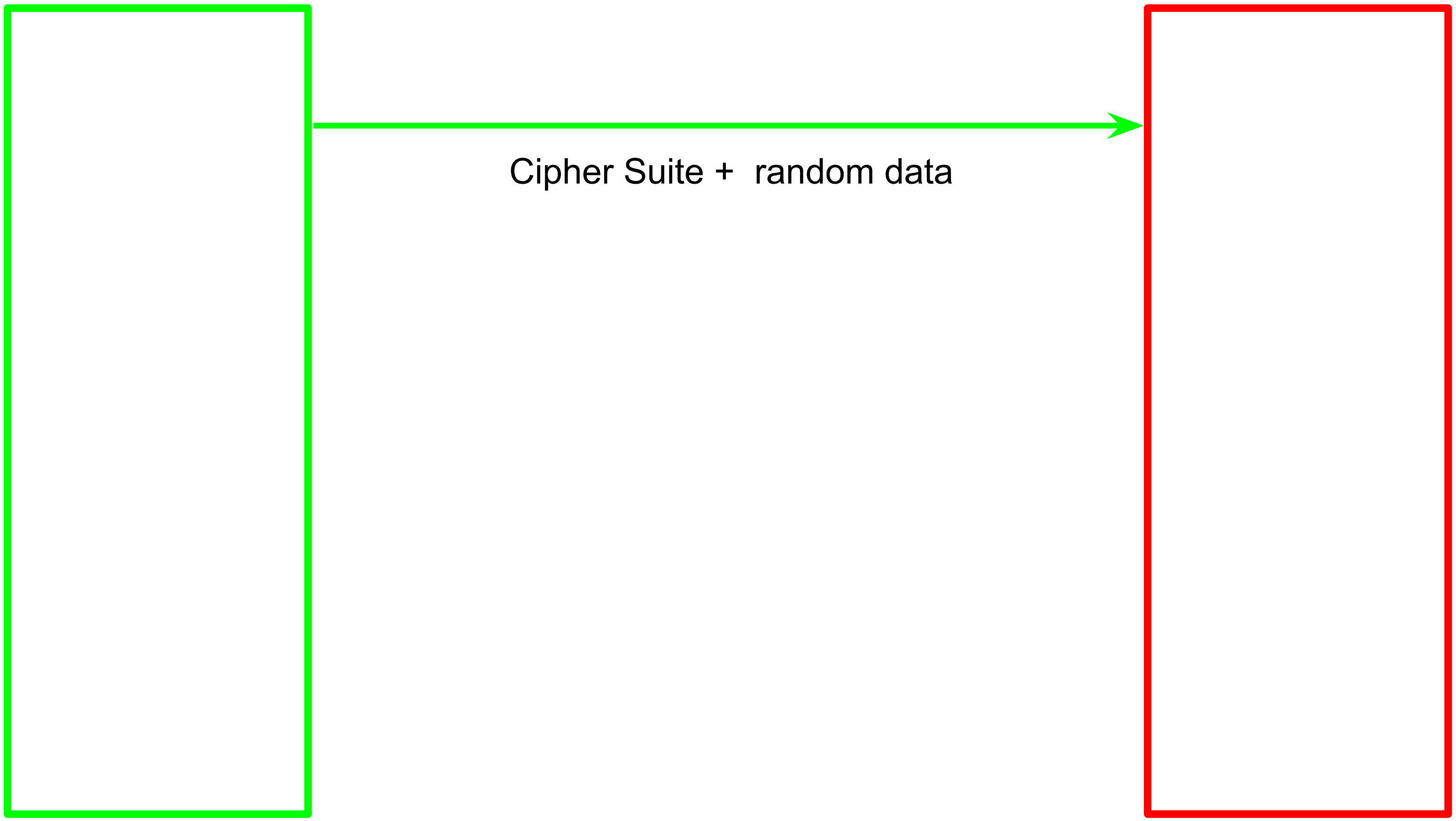
A Tale of Two Protocols

- Two valiant protocols fought against the darkness
- HTTP over SSL (Secure Socket Layer), or HTTPS
  - Communication confidentiality and integrity
  - Mutual authentication
  - No guarantees on data usage
  - No strict authentication of client (in practice)
- SET (Secure Electronic Transaction)
  - Guarantees on data usage and transaction security enforcement
  - Missing critical mass support

SSL -> TLS

- Originally designed by Netscape for securing web communication
  - de facto standard also for other protocols
  - IETF standardized TLS, which comes after version SSL v3, and is now at version 1.3.
  - All versions up to TLS 1.1 (included) are insecure
- TLS enforces:
  - Confidentiality and integrity of the communications
  - Server authentication
  - Client authentication (optionally)
- Uses both symmetric and asymmetric cryptography for performance reasons

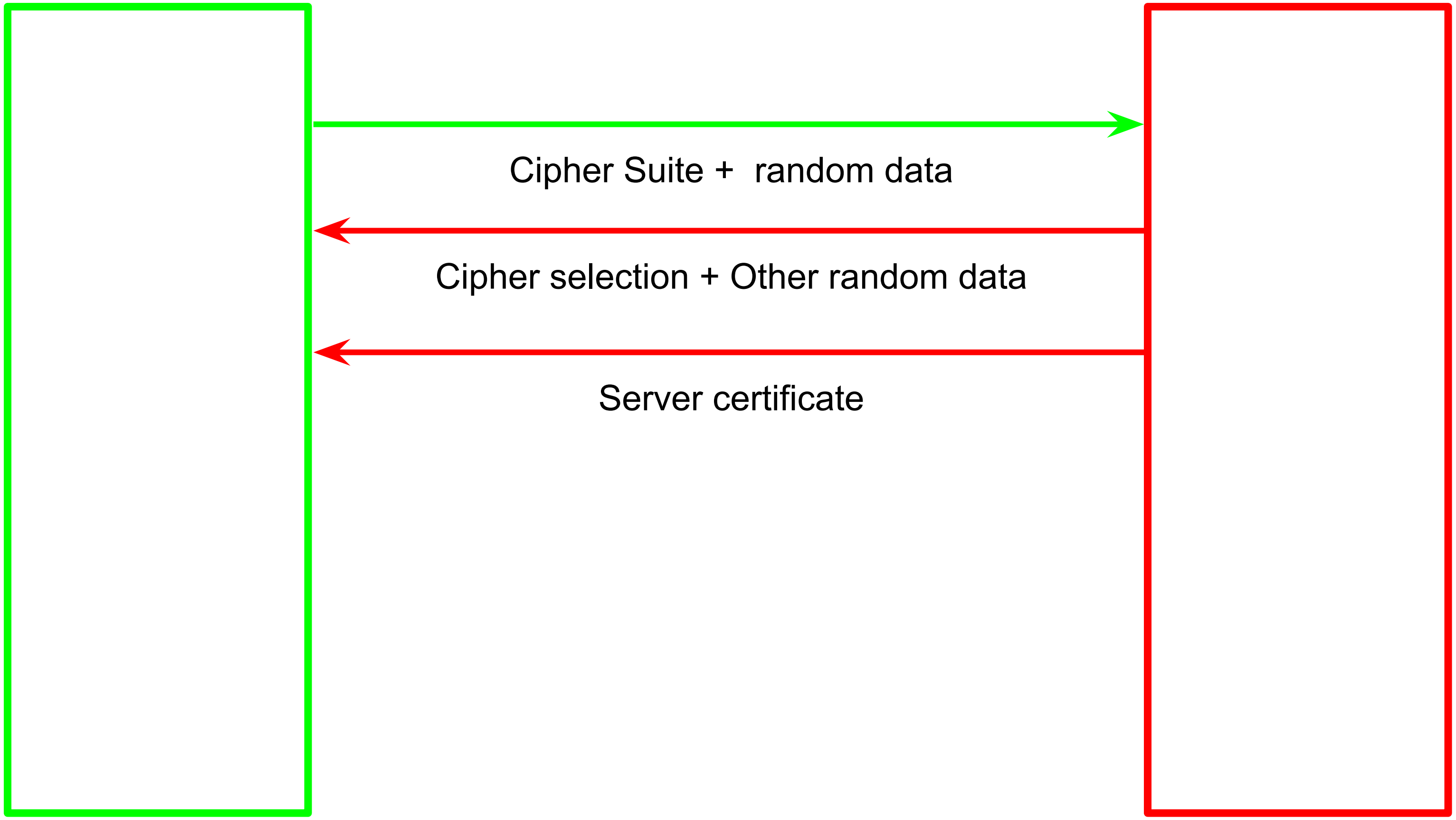
TLS Handshake Phases



Cipher Suite

- TLS designed to be flexible wrt to technical evolution
- Clients and servers may use different *suites* of algorithms for different functions
  - a key exchange/key encapsulation algorithm
  - a symmetric encryption algorithm
  - a digital signature algorithm
  - a hash function (for symm. key derivation)
- During handshake, cipher suites are compared to agree on shared algorithms in order of preference
- The standard mandates the implementation of a minimal cipher set

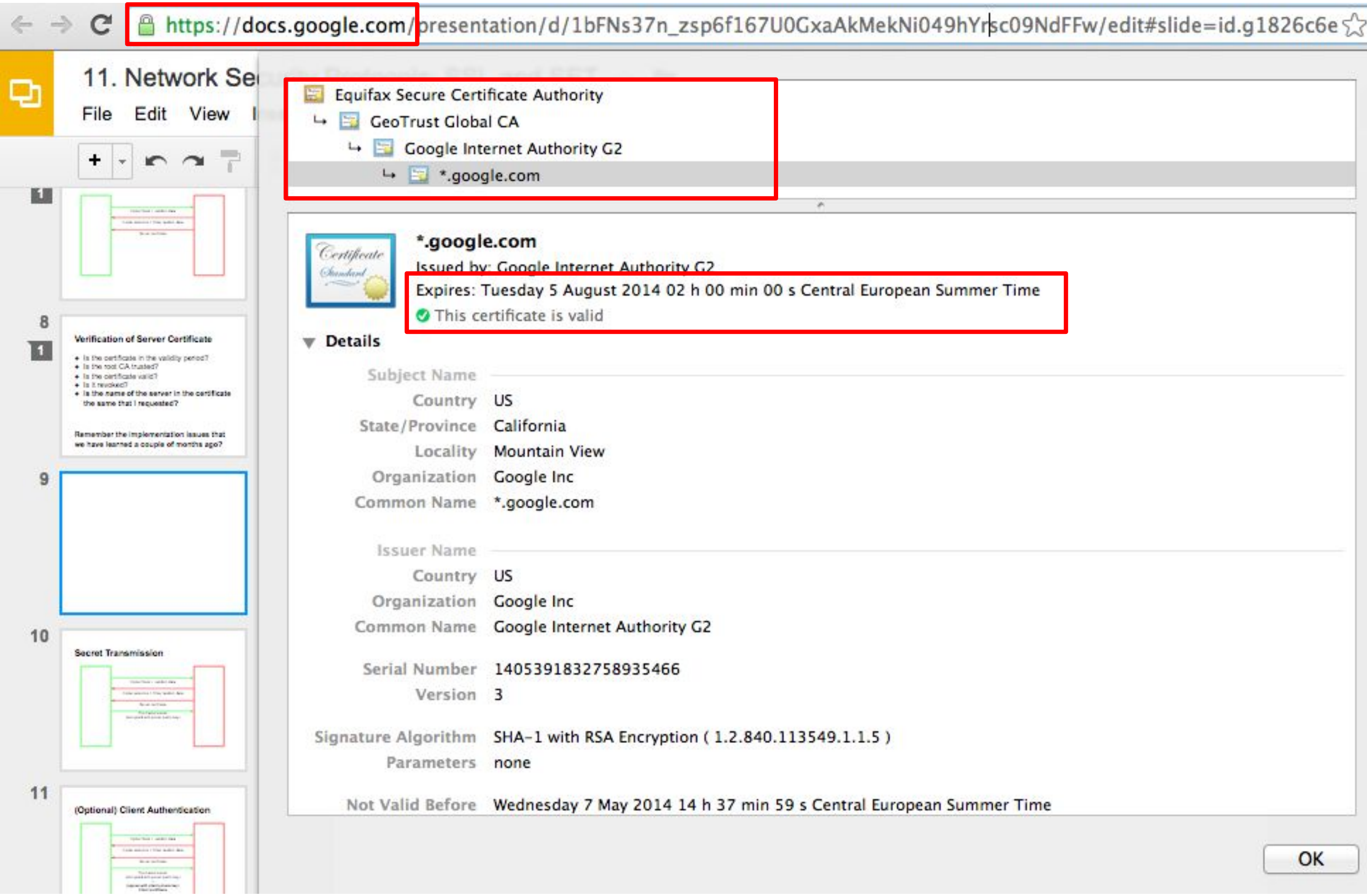
Server Authentication



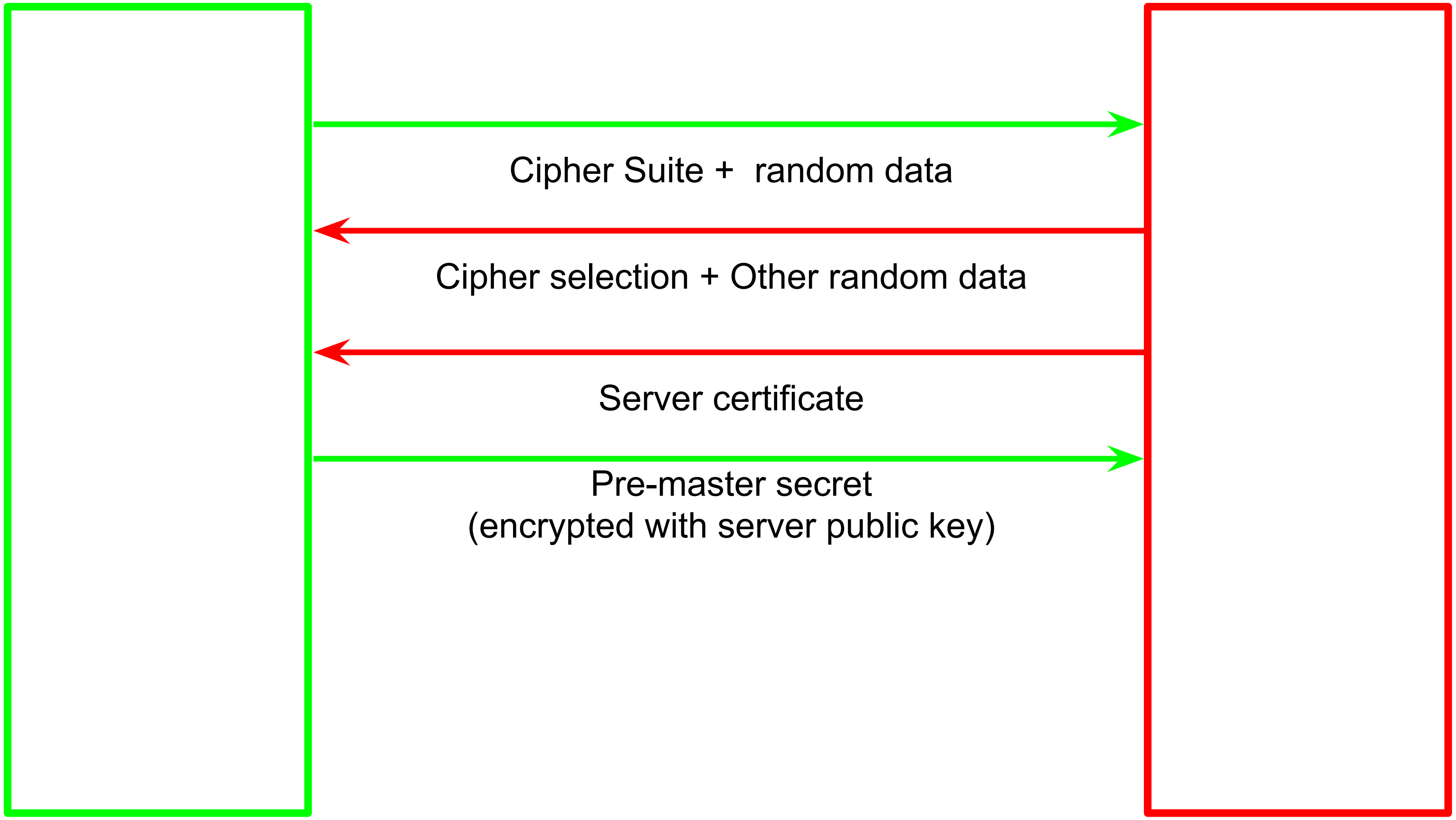
Verification of Server Certificate

- Is the certificate in the validity period?
- Is the root CA trusted?
- Is the certificate valid?
- Is it revoked?
- **Is the *name* of the server in the certificate the same that I requested?**

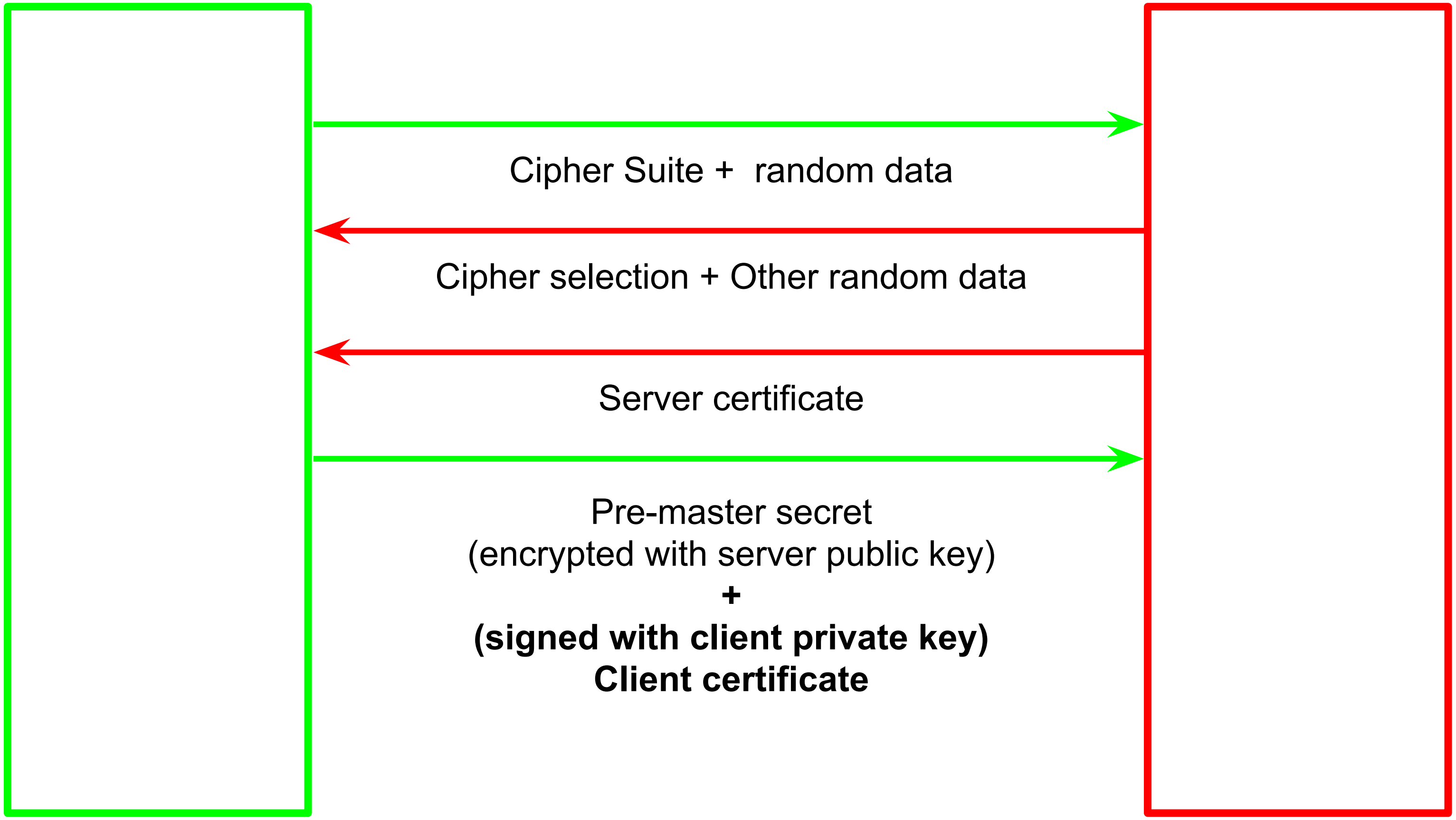
Remember the implementation issues that we have learned a couple of months ago?


https://docs.google.com/presentation/d/1bFNs37n_zsp6f167U0GxaAkMekNi049hYrsc09NdFFw/edit#slide=id.g1826c6e
11. Network Se
File Edit View
Equifax Secure Certificate Authority
GeoTrust Global CA
Google Internet Authority G2
*.google.com
Verification of Server Certificate
Secret Transmission
(Optional) Client Authentication
*.google.com
Issued by: Google Internet Authority G2
Expires: Tuesday 5 August 2014 02 h 00 min 00 s Central European Summer 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 1405391832758935466
Version 3
Signature Algorithm SHA-1 with RSA Encryption (1.2.840.113549.1.1.5)
Parameters none
Not Valid Before Wednesday 7 May 2014 14 h 37 min 59 s Central European Summer Time
OK

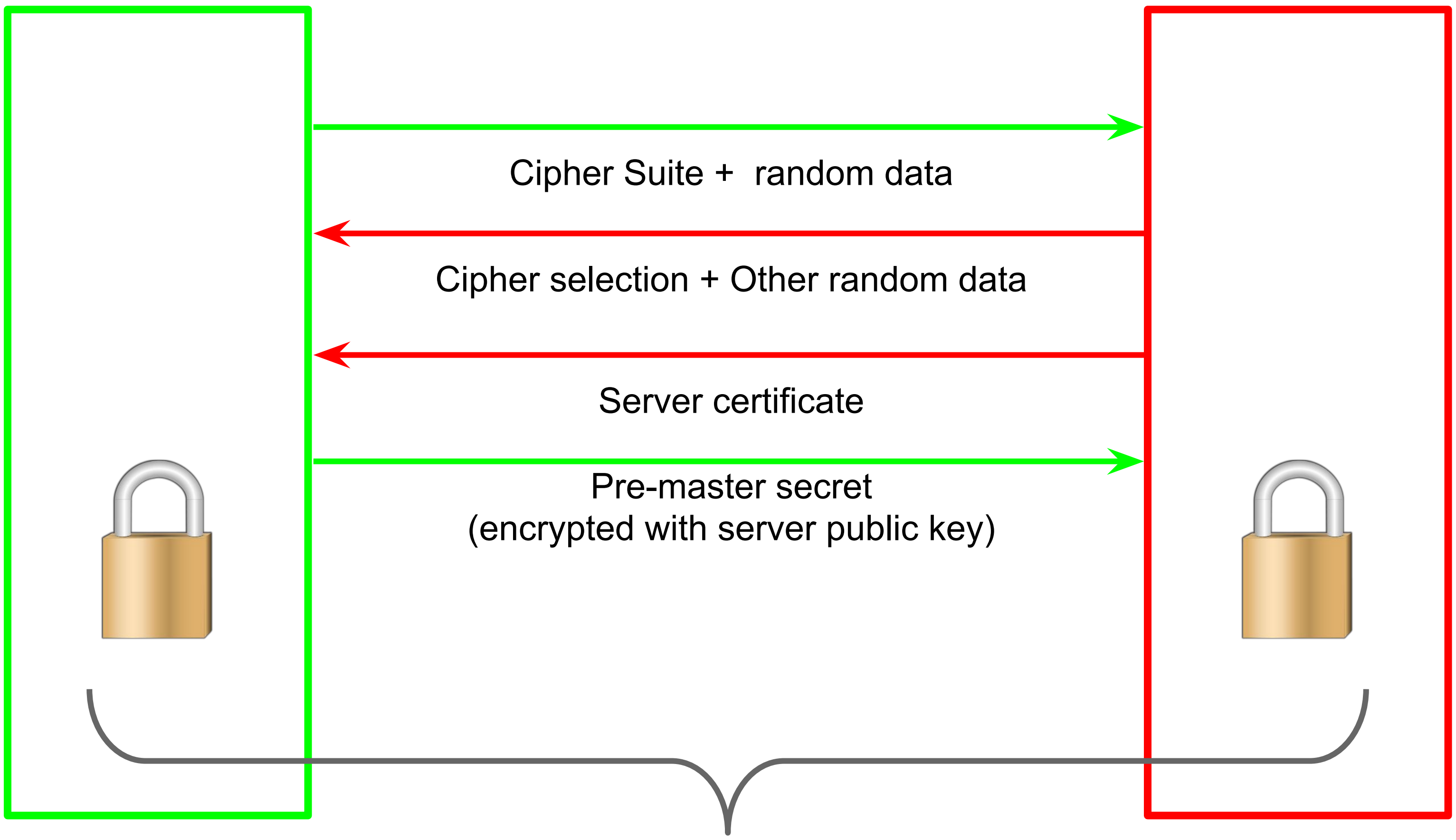
Secret Transmission



(Optional) Client Authentication

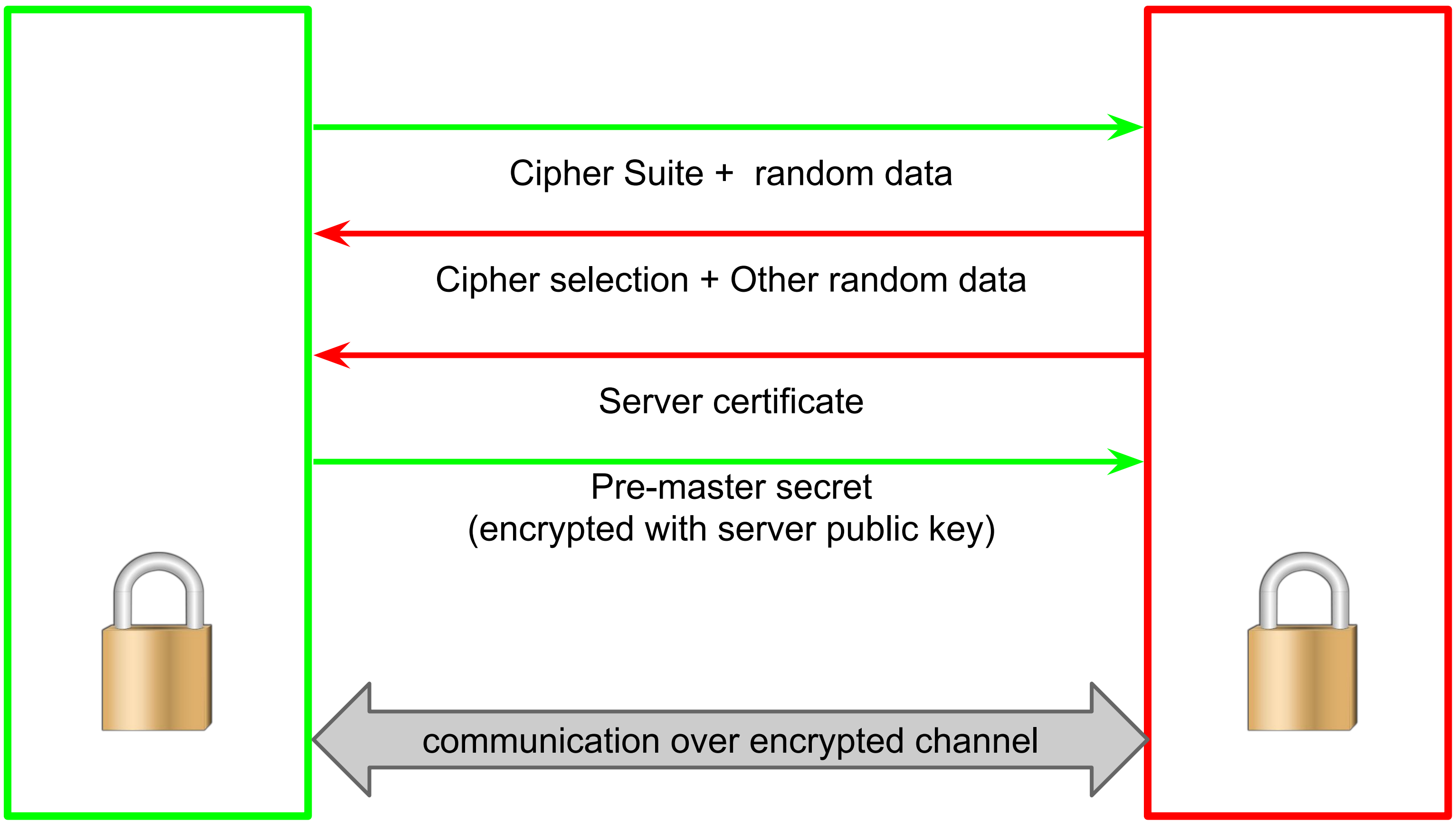


Secret Computation



Compute shared secret from pre-master secret, client random data and server random data

Encrypted Communication Phase

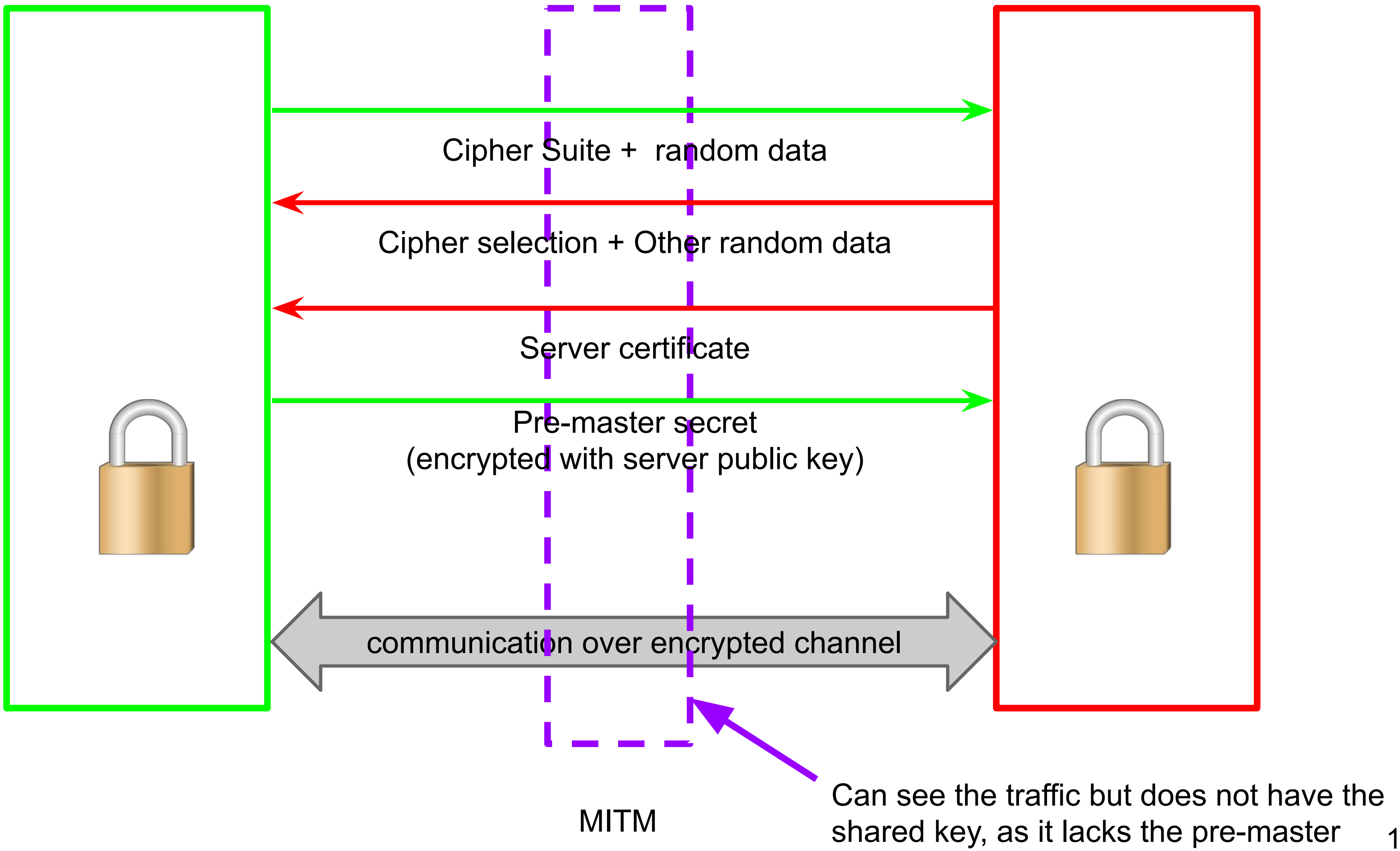


Is TLS Resistant to MITM?

What could the MITM do?

- Let the original certificate through

Cut out!



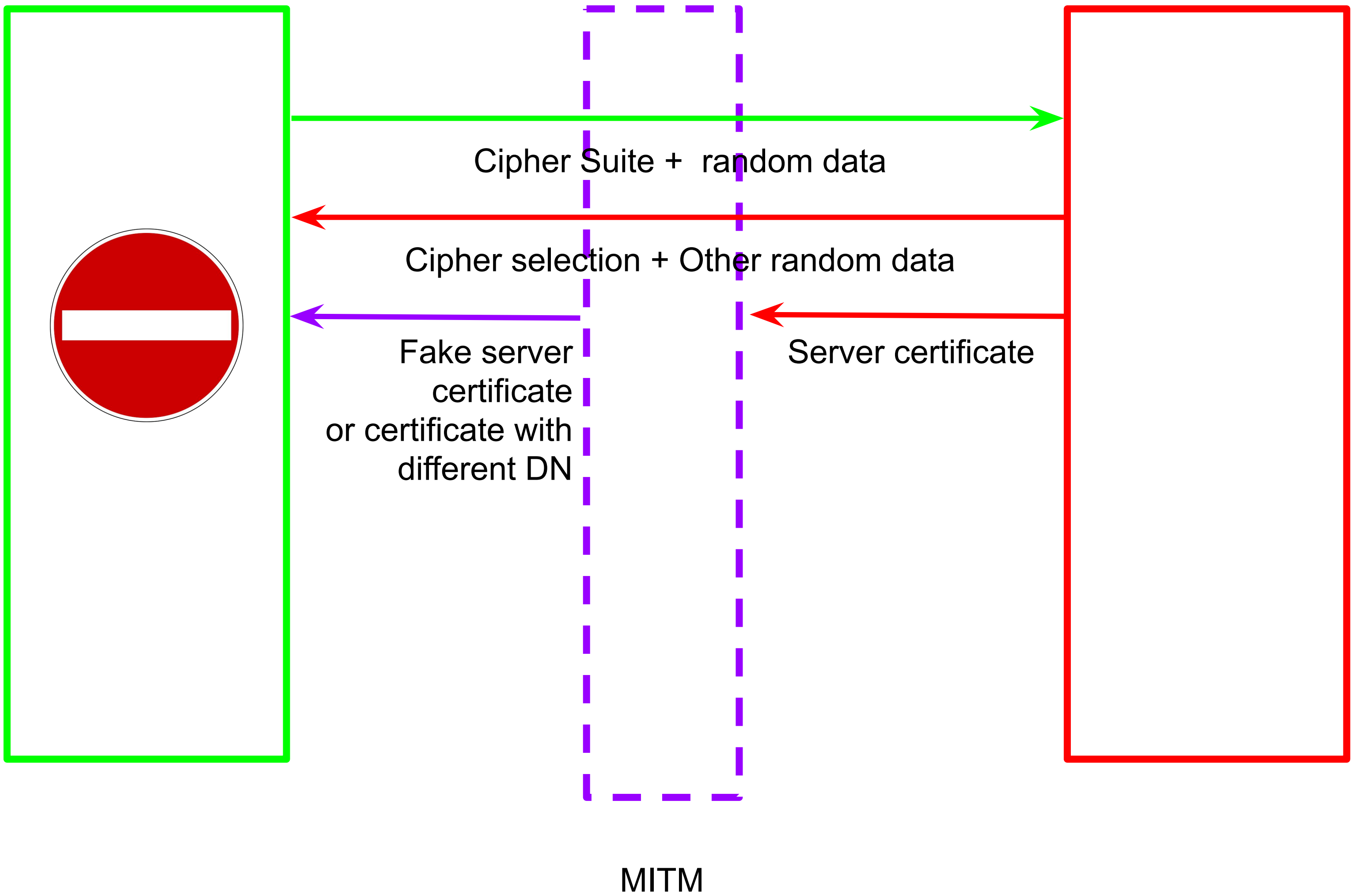
Cipher Suite + random data
Cipher selection + Other random data
Server certificate
Pre-master secret
(encrypted with server public key)
communication over encrypted channel
MITM
Can see the traffic but does not have the shared key, as it lacks the pre-master

Is TLS Resistant to MITM?

What could the MITM do?

- ~~Let the original certificate through~~
  - Needs to actually have the key on that cert!
- Send a fake certificate (i.e., signed by a non-trusted CA)
- Send a good certificate with a fake name

Rejected!



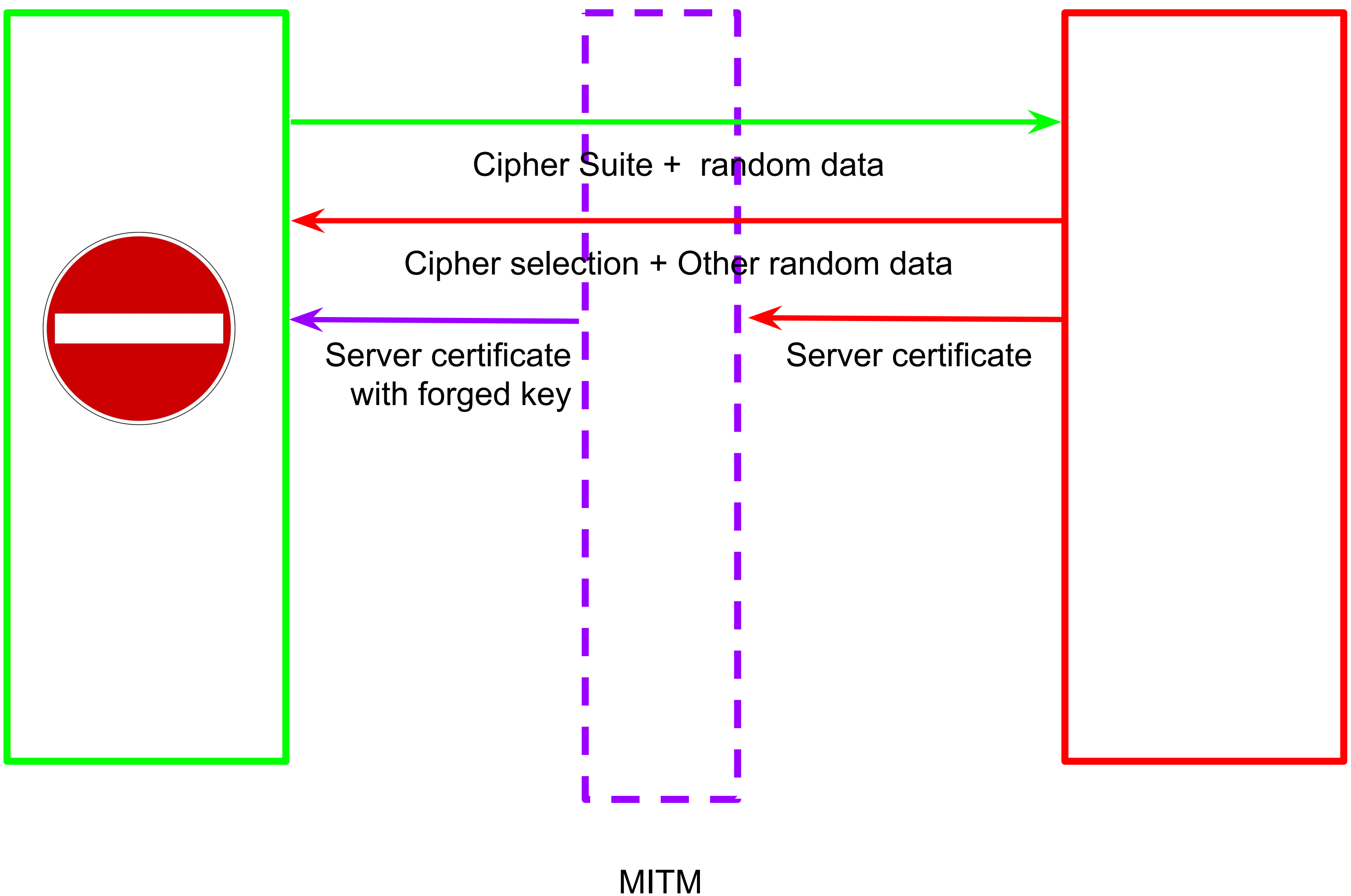
Cipher Suite + random data
Cipher selection + Other random data
Fake server certificate or certificate with different DN
Server certificate
MITM

Is TLS resistant to MITM?

What could the MITM do?

- ~~Let the original certificate through~~
- ~~Send a fake certificate (i.e. signed by a non-trusted CA)~~
- ~~Send a good certificate with a fake name~~
- Send a good certificate but substitute the public key (invalidating the signature)

Rejected!


Cipher Suite + random data
Cipher selection + Other random data
Server certificate
with forged key
Server certificate
MITM

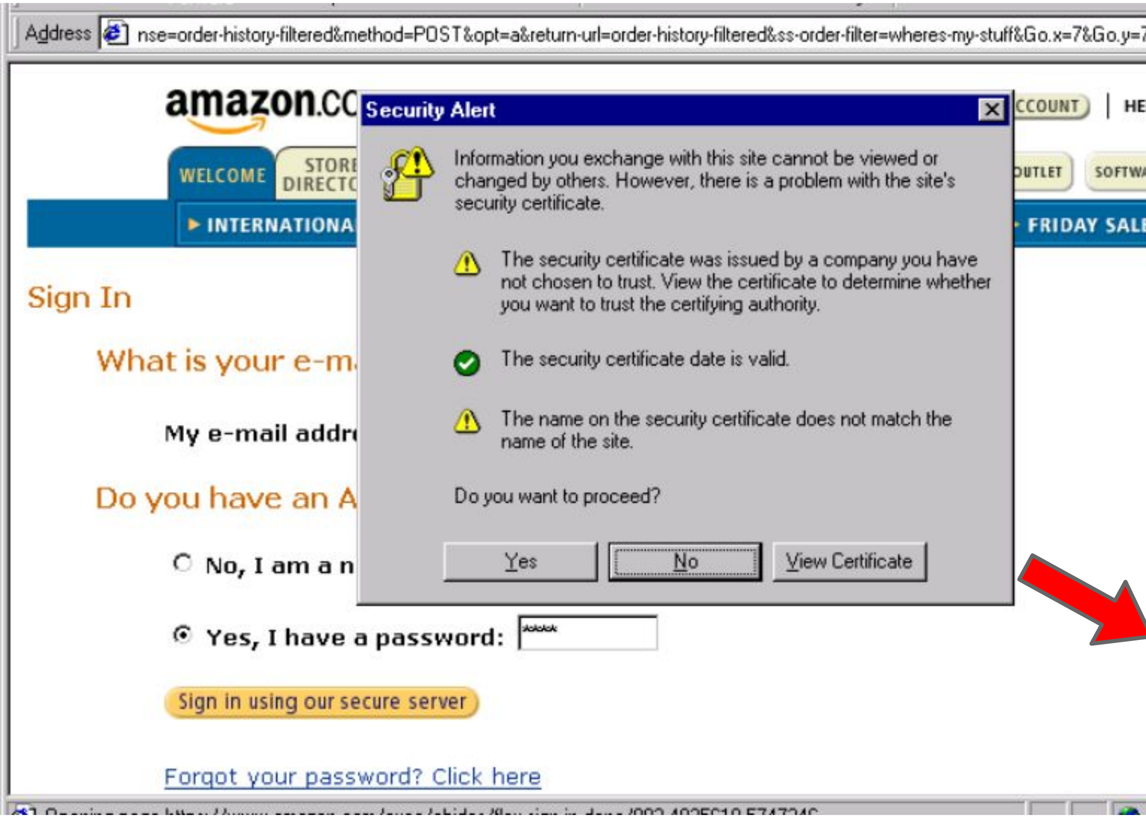
Is TLS resistant to MITM?

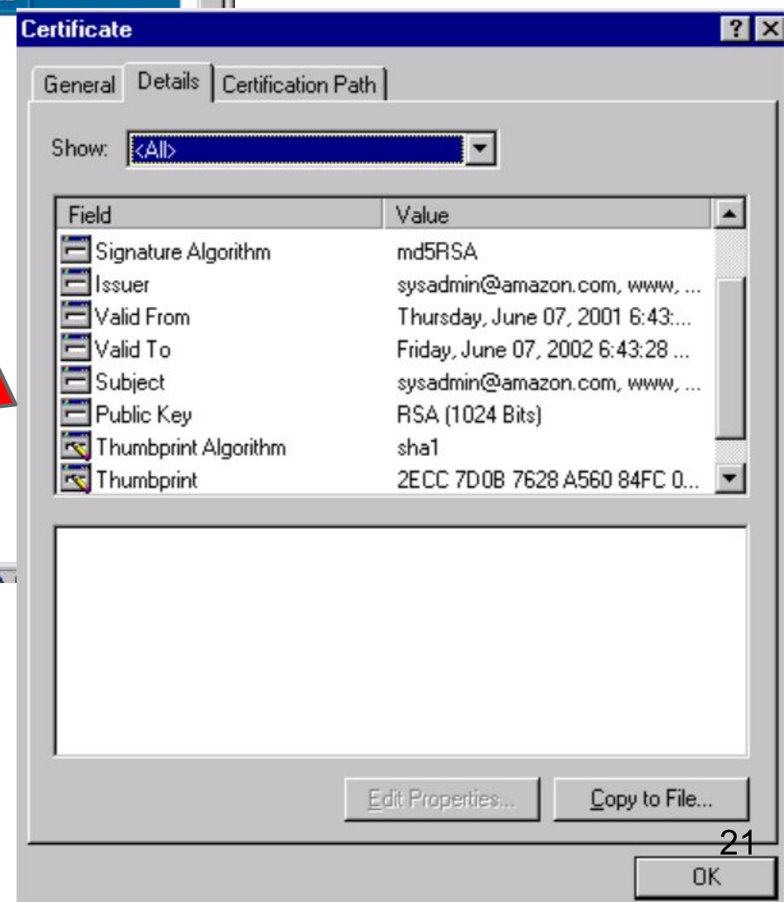
What could the MITM do?

- ~~Let the original certificate through~~
- ~~Send a fake certificate (i.e. signed by a non-trusted CA)~~
- ~~Send a good certificate with a fake name~~
- ~~Send a good certificate but substitute the public key (making it invalid)~~

Nothing: TLS is resistant to MITM by design!

Social Engineering = Fail



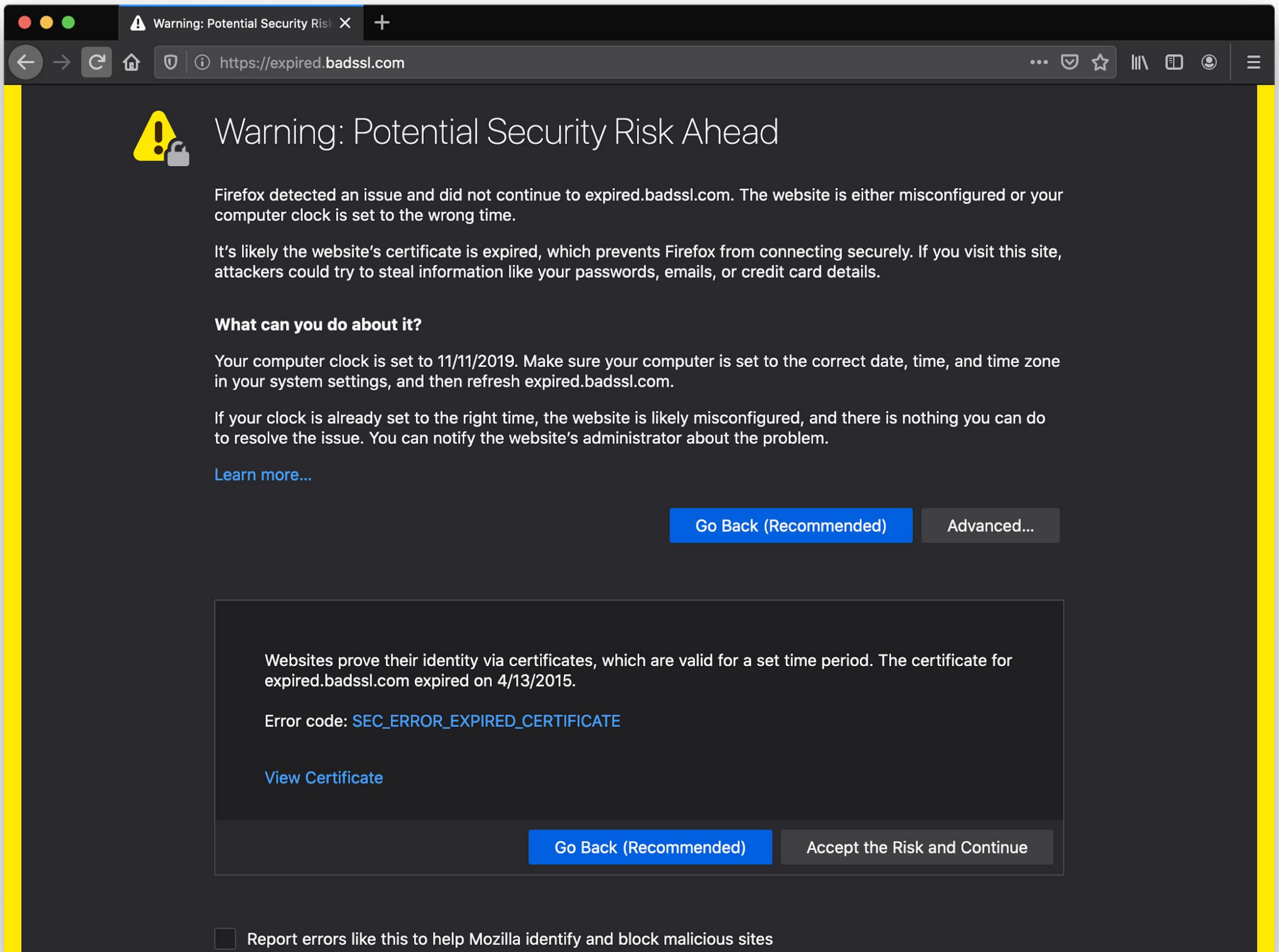


If the user clicks "yes" the assumptions of TLS are violated and attack is successful.

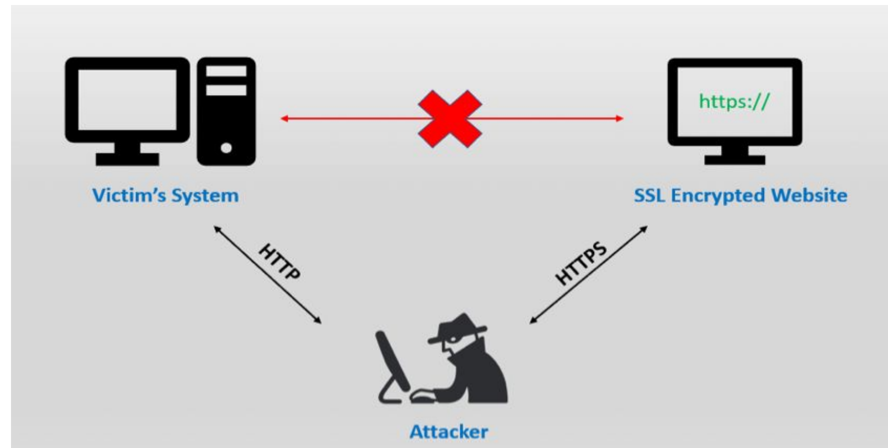
If he clicks no, he cannot buy his book.

Guess what's going to happen...

Security UI: Evolution



Security UI Pitfalls & SSL strip



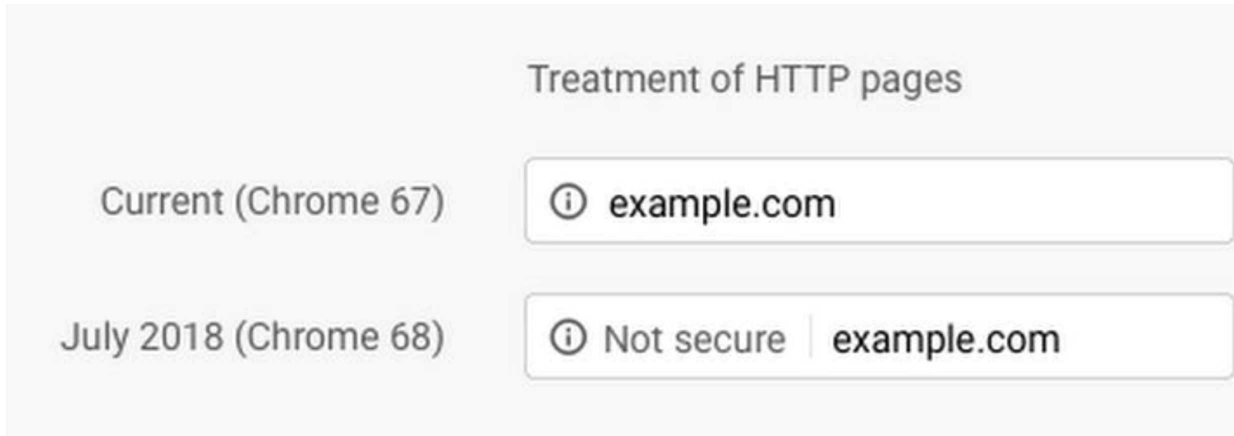
View source:

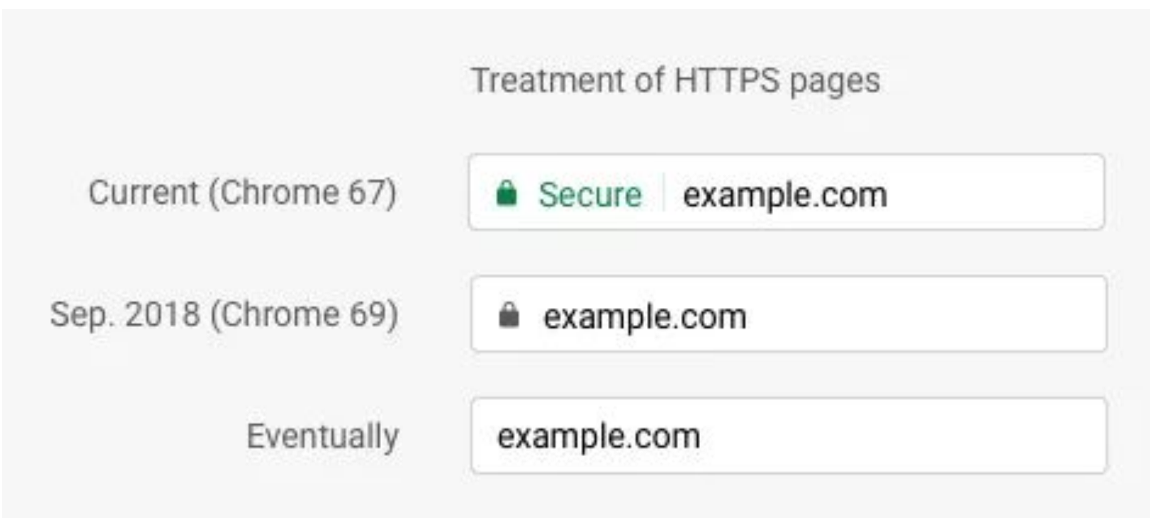
<form method="post"

action="**https**://onlineservices.wachovia.com/..."

Source: https://cs155.stanford.edu/

Security UI: Evolution





TLS: Pros and Cons

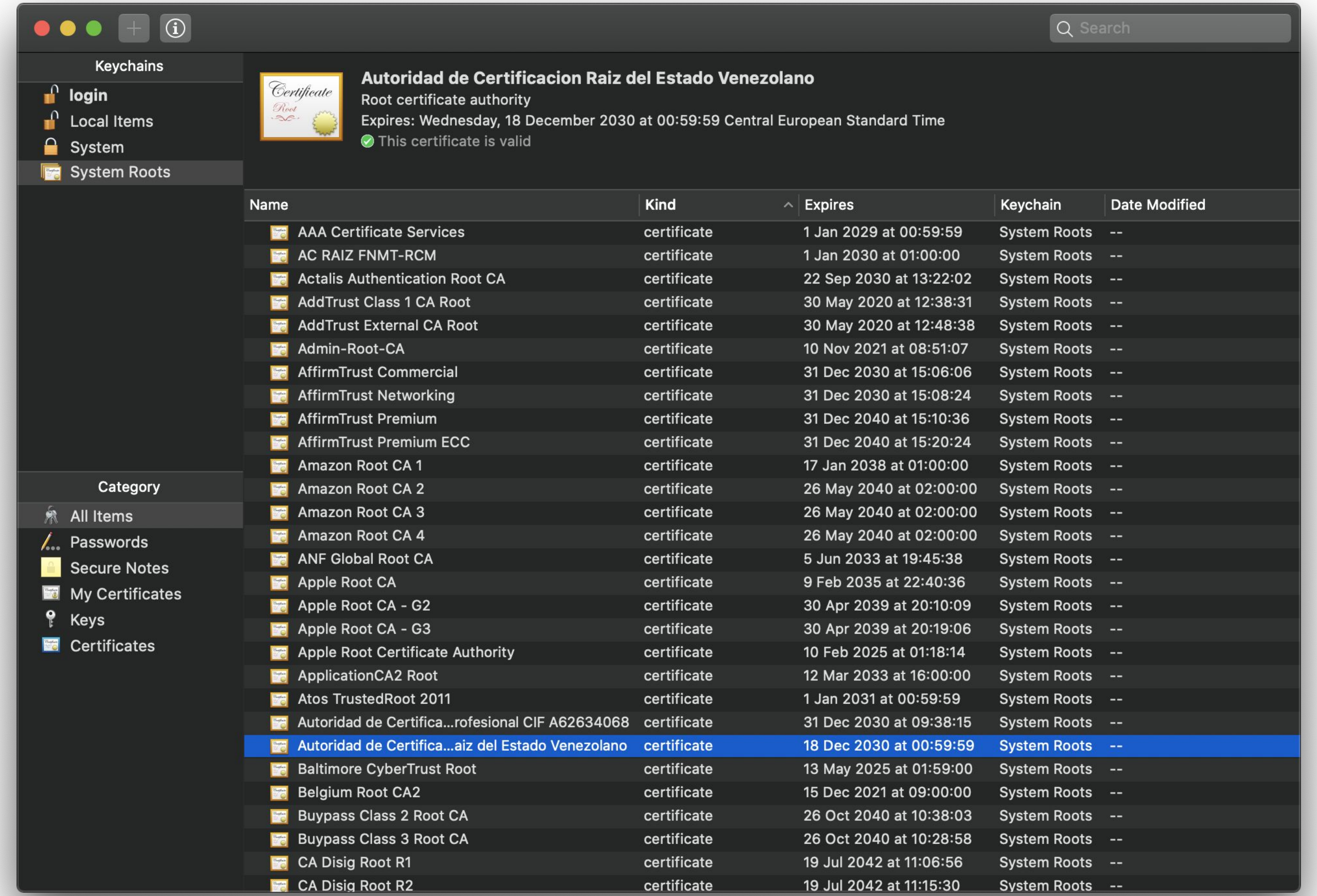
- Protects transmissions
  - Confidentiality
  - Integrity
- Ensures authentication
  - Of server
  - Of client (optionally)

- No protection before or after transmission
  - On server
  - On client (e.g., trojan)
  - By abuser (e.g., non-honest merchant)
- Relies on PKI
- Not foolproof

TLS cons: reliance on PKI

- Security guarantees of TLS depend on the security and trust of the root and intermediate CAs
- CAs can generate certs for any domain
    - They are responsible for domain\org validation
- In order to be included in browsers and OS root programs, CAs must abide to a set of requirements (CA/Browser Forum baseline requirements)
    - Dropping a non-compliant CA is a very difficult decision as it breaks websites

Reminder: CAs your OS trusts



Corollary: you need to trust the list of CA pre-installed in your computer.
It is not always so: see the 2015 Lenovo Superfish incident…

Pitfalls: A few CA Incidents

- **2011**: Diginotar as well as some Comodo resellers are compromised → rogue certs (at least 500 for Diginotar)
  - Diginotar is distrusted on all major platforms
- **2009 - 2015**: Symantec → test certificates for existing domains (e.g., Google)
  - Caught through CT logs
  - Outcome: CA gradually distrusted (2016-2018)
- **2012**: Trustwave issues a MITM certificate for a data loss prevention appliance
- **2012**: TurkTrust mistakenly gives two CA certificates to users
- **2016**: WoSign / StartSSL → various issues, including cert mis-issuance due to vulnerability in the domain verification.
  - Outcome: CA distrusted

Overcoming TLS/PKI limitations

HSTS (HTTP Strict Transport Security)

- HTTP header to tell the browser to always connect to that domain using HTTPS
- Browsers (e.g., Chrome) implement a HSTS preload list: some websites are simply never loaded over plain HTTP
- Defends against SSL stripping

Overcoming TLS/PKI limitations

HPKP (HTTP Public Key Pinning)

- HTTP header to tell the browser to “pin” a specific certificate or a specific CA
- Browser will refuse certificates from different CAs for that origin
- Defends against trust cert mis-issuance
- **Deprecated!** Can you think about why?

Overcoming TLS/PKI limitations

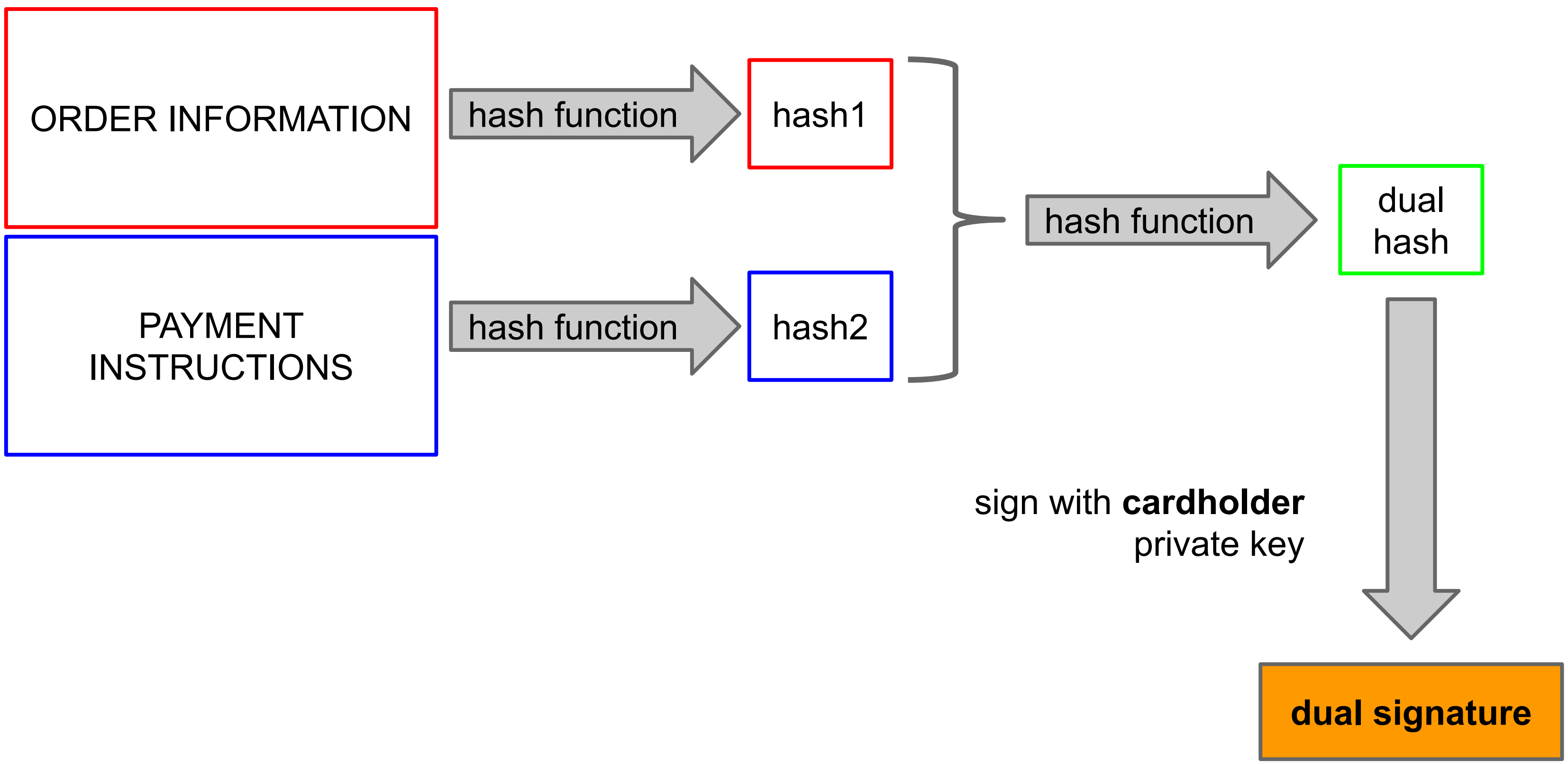
Certificate Transparency

- CA submit the metadata of every issued certificate to a (independent, replicated) log
- Can be enforced by browsers
  - browsers refuse certs not logged in CA logs
- Defends against certificate mis-issuance: site owner can check \ be notified of certificates issued for the properties they manage
- You can look at the CT logs: https://crt.sh

Introducing SET

- Joint effort VISA+MasterCard consortium
- Protect *transactions*, not connections
- Approach
  - **Cardholder** sends
    - the order of goods to the **merchant** only
    - the payment data to the **payment gateway** only
  - Empower gateway to verify correspondence
- Uses the concept of a dual signature
  - A signature that joins together the two pieces of a message, directed to two distinct recipients

Dual Signature Generation



Data Transmission

ORDER INFORMATION

hash2

dual sign.

encrypt with public key of **merchant**

PAYMENT INSTRUCTIONS

hash1

dual sign.

encrypt with public key of **payment gateway**

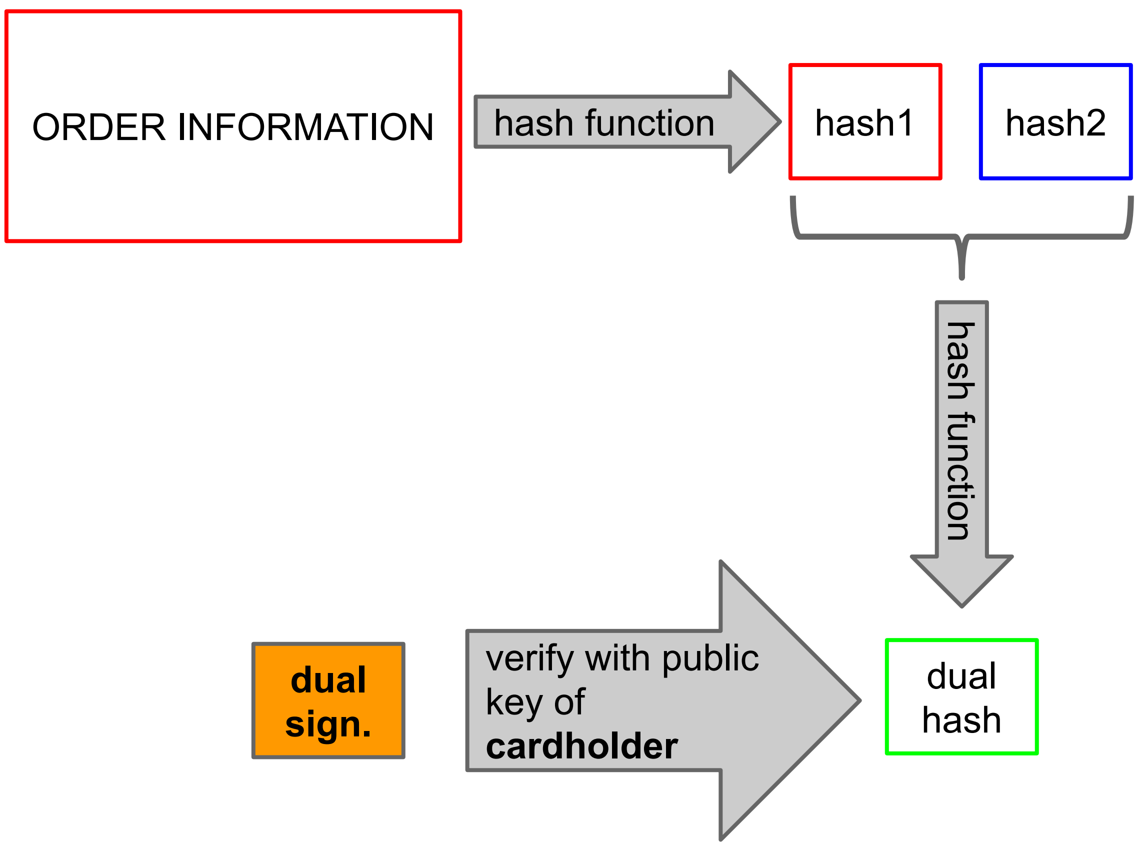
PAYMENT INSTRUCTIONS

hash1

dual sign.

(still encrypted)

Verification (merchant side)



(the payment gateway side verification is the perfect dual)

Why did SET Fail?

- SET requires a **digital certificate** from:
  - Merchant: OK, reasonable and feasible
  - Payment Gateway: OK, reasonable and feasible
  - **Cardholder: KO, does not scale!**
- Therefore, a pre-registration of the cardholder is needed! (won't buy that book)

- Non-transparent = less critical mass = failure
- Nowadays a simple redirect with a token to the website of the bank is commonly used
  - **Exercise:** think how this is implemented securely ;-)