Lecture -10 – SSL/TLS

Ryan Cunningham
University of Illinois
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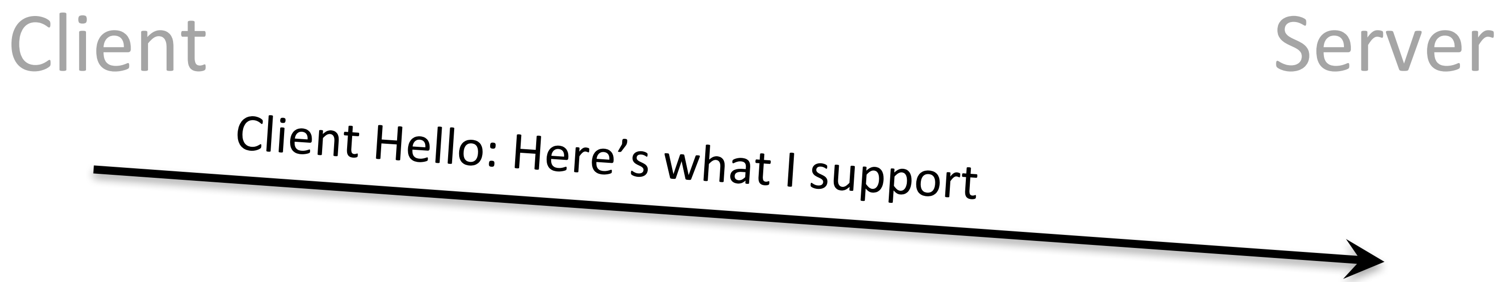
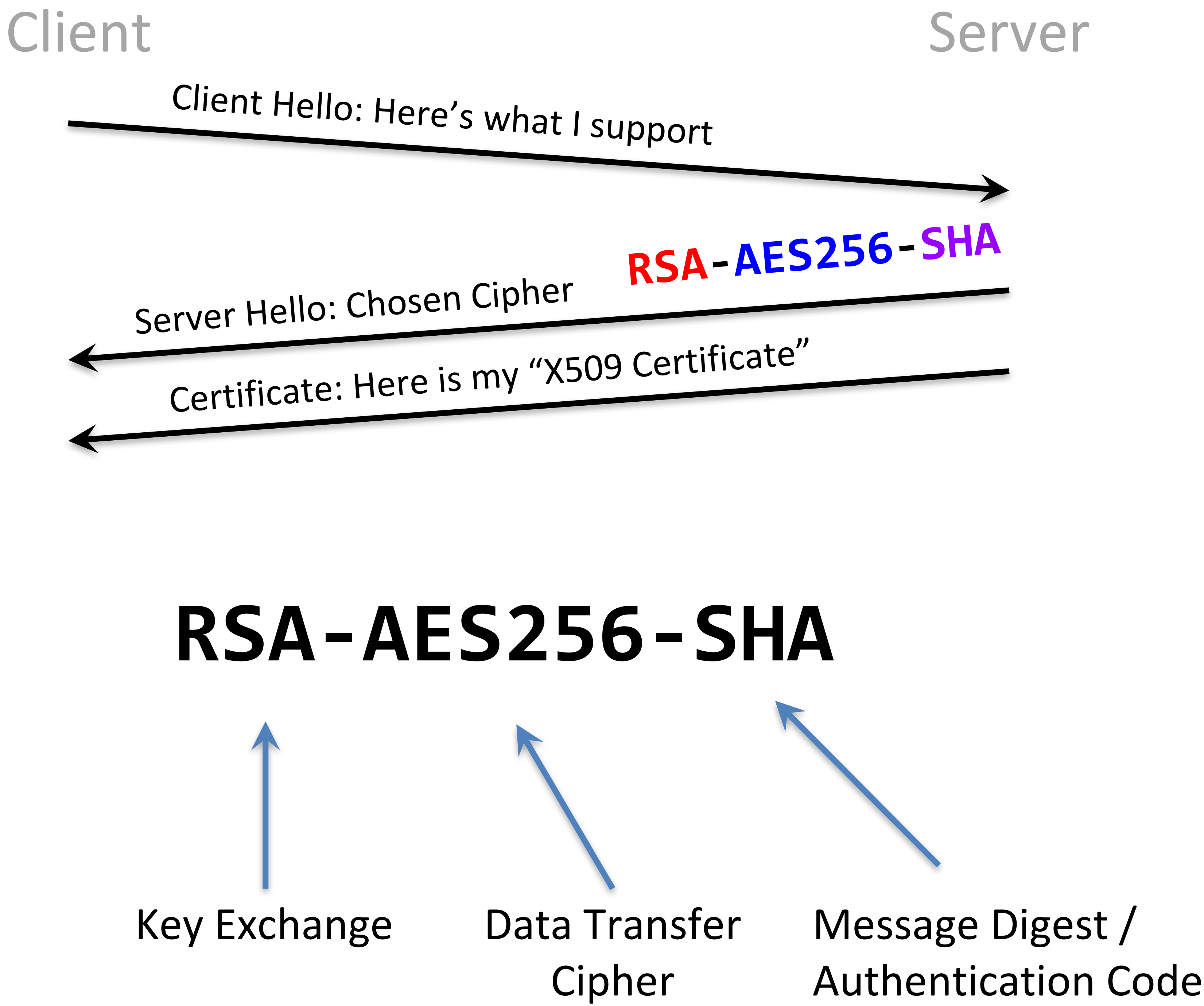
Security News

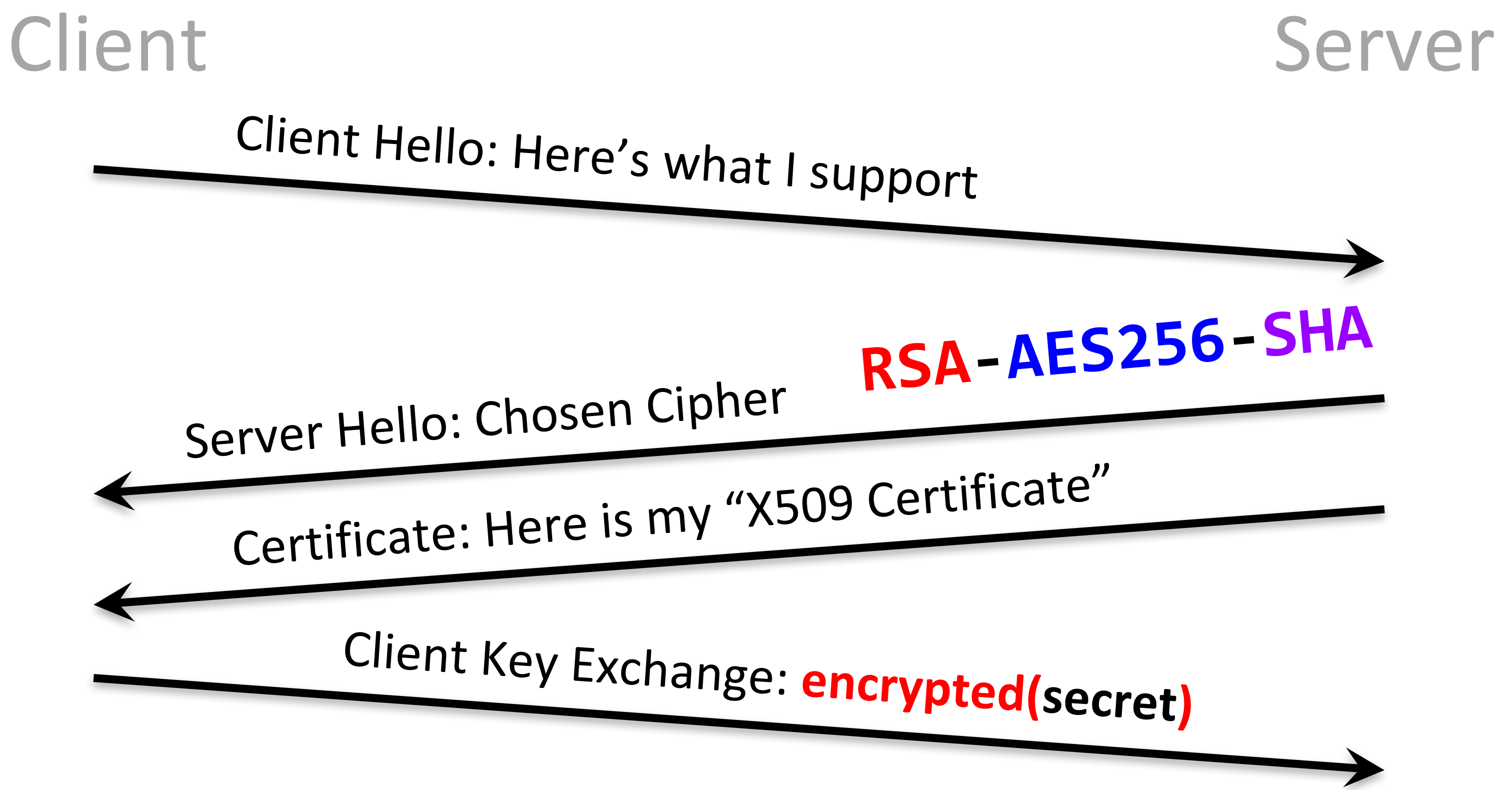
- EFF resigns from W3C over EME
- Avast breached and CCleaner compromised

Client Server

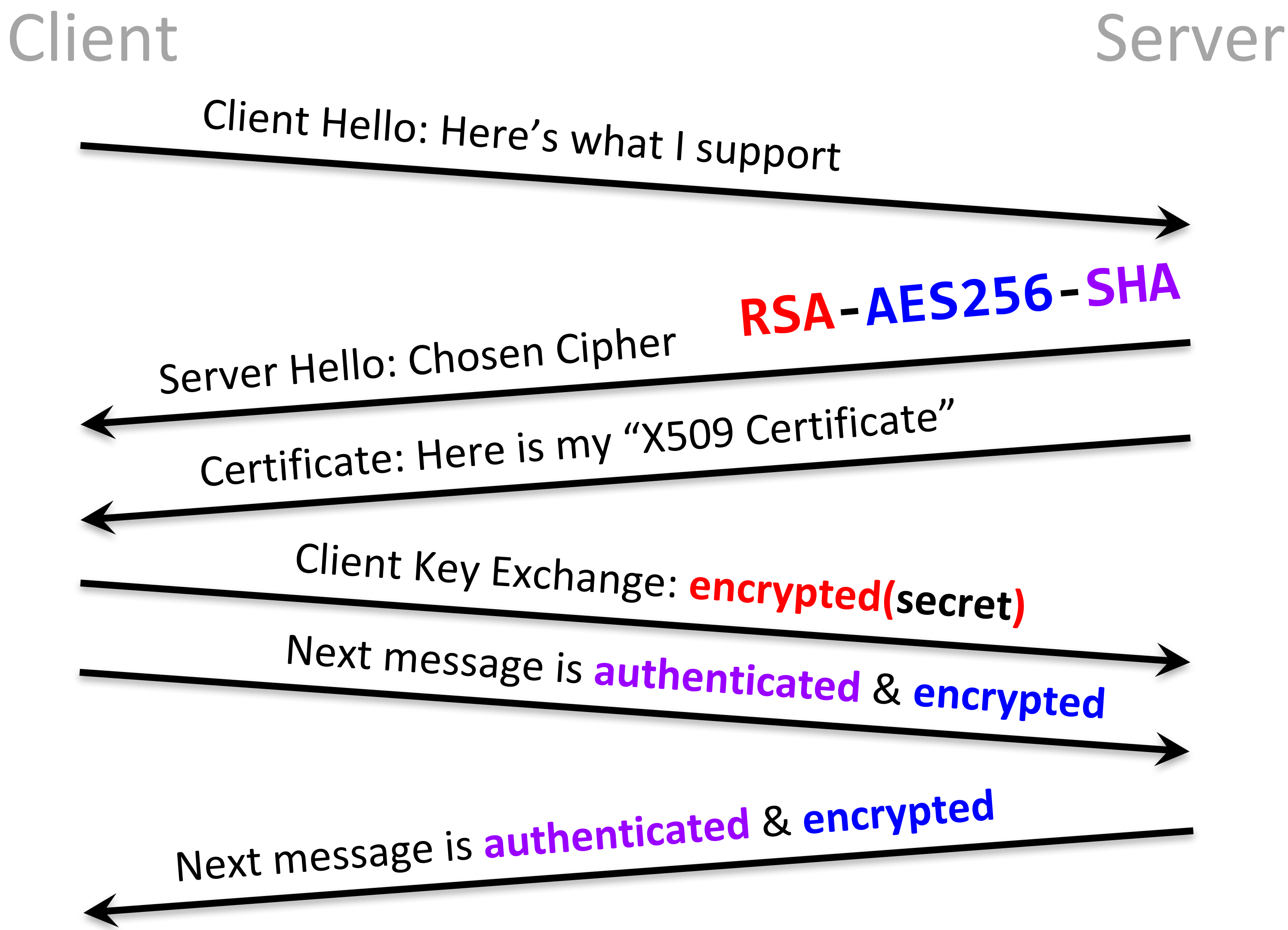
“the handshake”


Client
Server
Client Hello: Here's what I support


Client
Server
Client Hello: Here's what I support
RSA-AES256-SHA
Server Hello: Chosen Cipher
Certificate: Here is my "X509 Certificate"
RSA-AES256-SHA
Key Exchange
Data Transfer Cipher
Message Digest / Authentication Code



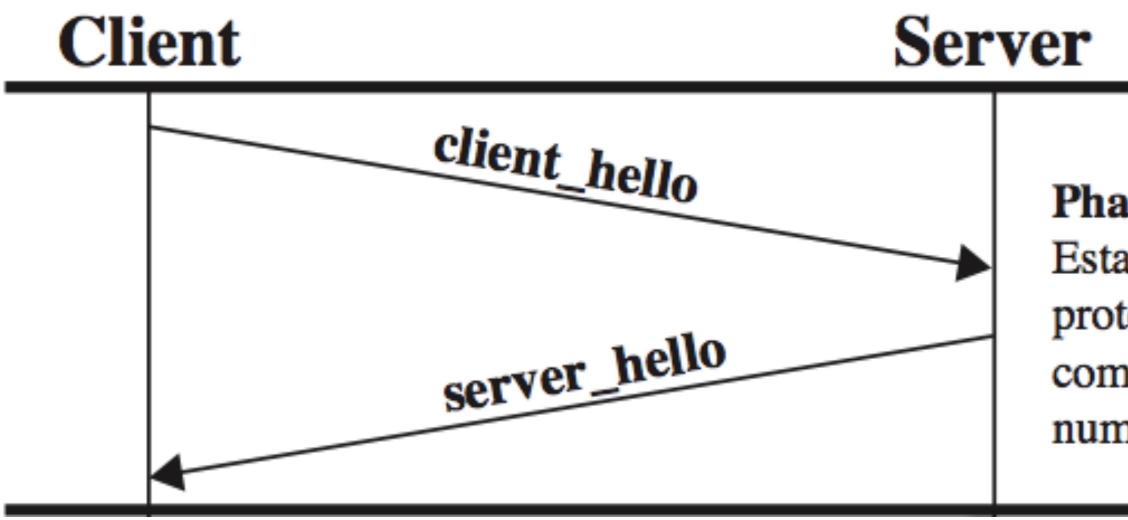
Encrypted using Server's public key
(The same public key included in the Cert)
This means: only the server can decrypt the secret! (Avoids MitM)



Shared **secret** is encrypted using Server's RSA public key
(The same RSA public key included in the Cert)
This means: only the server can decrypt the secret! (Avoids MitM)

TLS Handshake

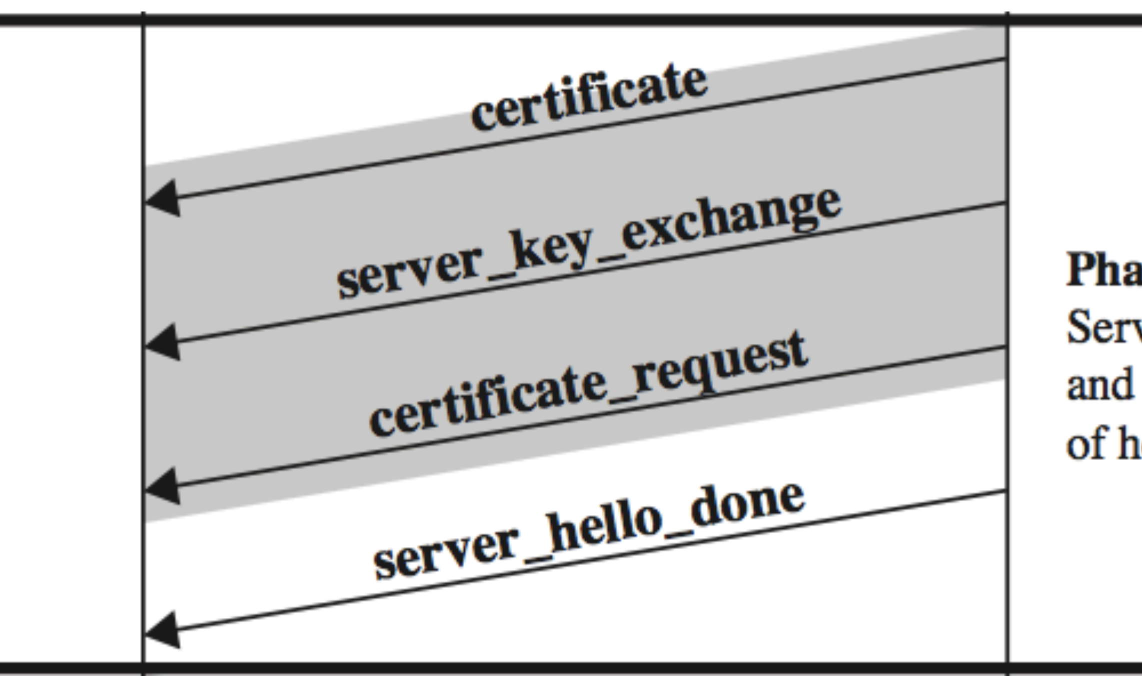
- Phase 1: establish capabilities
  - Which version of TLS?
  - What our session ID?
  - What is our cipher suite?
  - Are we compressing data?



Phase 1
Establish security capabilities, including protocol version, session ID, cipher suite, compression method, and initial random numbers.

TLS Handshake

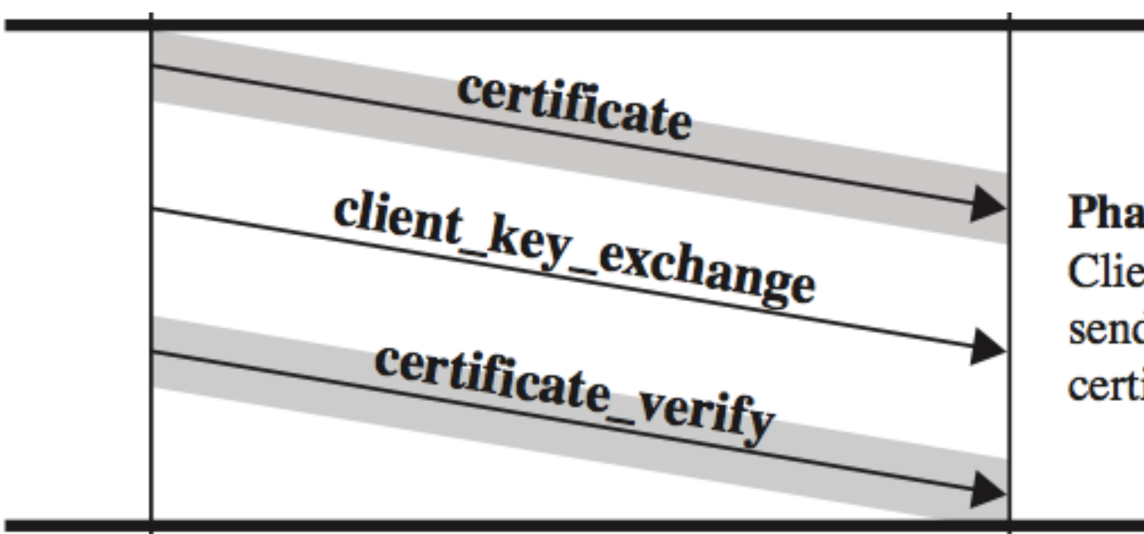
- Phase 2: Server Authentication
  - Server sends certificate



Phase 2
Server may send certificate, key exchange, and request certificate. Server signals end of hello message phase.

TLS Handshake

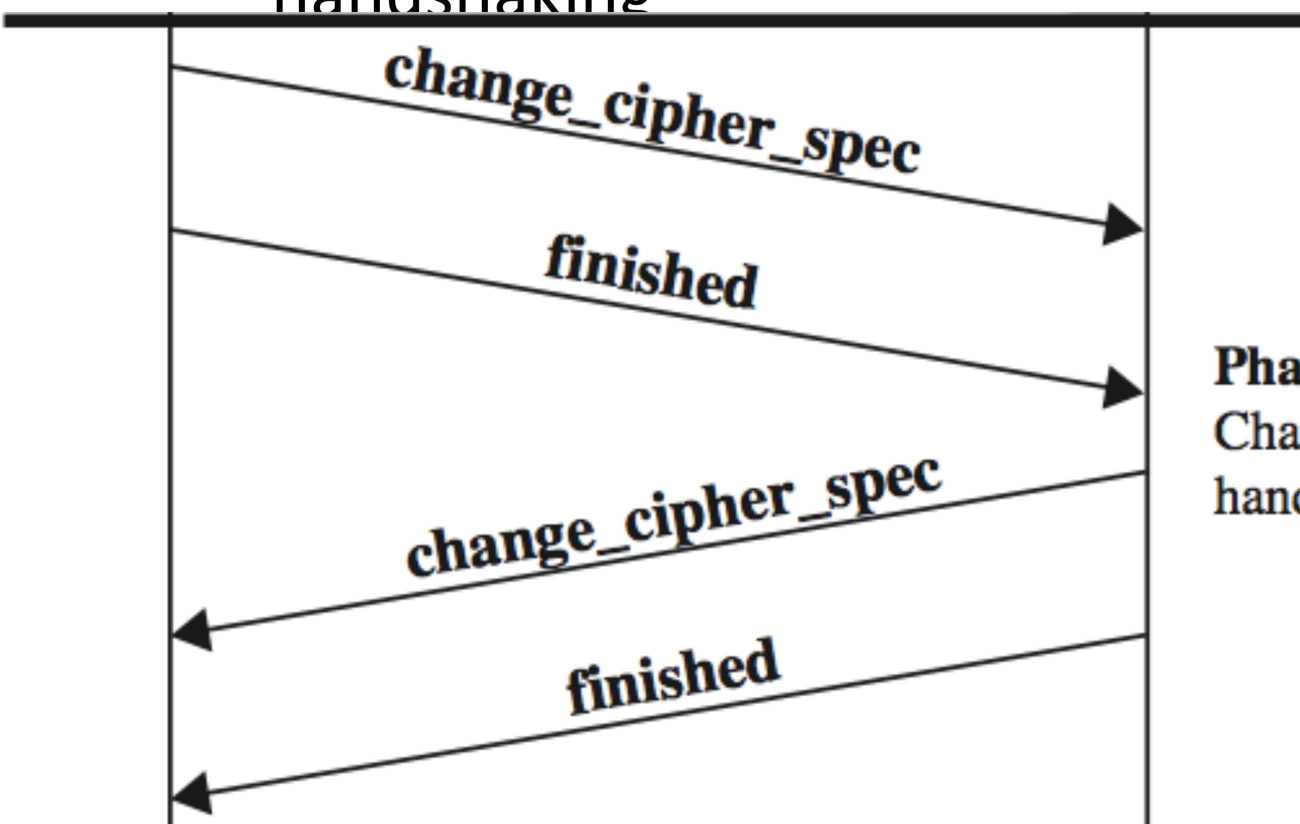
- Phase 3: Client Authentication
  - –Client sends certificate (maybe)
  - –Client exchanges key
  - –Client sends verification of server cert



Phase 3
Client sends certificate if requested. Client sends key exchange. Client may send certificate verification.

TLS Handshake

- Phase 4: Switch to Secure Connection
  - Change to agreed upon cipher suite and stop handshaking



Phase 4
Change cipher suite and finish handshake protocol.

Cipher Suites

DHE-RSA-AES256-SHA

Ephemeral Key Exchange

Key Exchange

Data Transfer Cipher

Message Digest

DH and DHE

Dierks & Rescorla Standards Track [Page 75]

RFC 5246 TLS August 2008

```
CipherSuite TLS_DH_DSS_WITH_3DES_EDE_CBC_SHA       = { 0x00,0x0D };
CipherSuite TLS_DH_RSA_WITH_3DES_EDE_CBC_SHA       = { 0x00,0x10 };
CipherSuite TLS_DHE_DSS_WITH_3DES_EDE_CBC_SHA      = { 0x00,0x13 };
CipherSuite TLS_DHE_RSA_WITH_3DES_EDE_CBC_SHA      = { 0x00,0x16 };
CipherSuite TLS_DH_DSS_WITH_AES_128_CBC_SHA        = { 0x00,0x30 };
CipherSuite TLS_DH_RSA_WITH_AES_128_CBC_SHA        = { 0x00,0x31 };
CipherSuite TLS_DHE_DSS_WITH_AES_128_CBC_SHA       = { 0x00,0x32 };
CipherSuite TLS_DHE_RSA_WITH_AES_128_CBC_SHA       = { 0x00,0x33 };
CipherSuite TLS_DH_DSS_WITH_AES_256_CBC_SHA        = { 0x00,0x36 };
CipherSuite TLS_DH_RSA_WITH_AES_256_CBC_SHA        = { 0x00,0x37 };
CipherSuite TLS_DHE_DSS_WITH_AES_256_CBC_SHA       = { 0x00,0x38 };
CipherSuite TLS_DHE_RSA_WITH_AES_256_CBC_SHA       = { 0x00,0x39 };
CipherSuite TLS_DH_DSS_WITH_AES_128_CBC_SHA256     = { 0x00,0x3E };
CipherSuite TLS_DH_RSA_WITH_AES_128_CBC_SHA256     = { 0x00,0x3F };
CipherSuite TLS_DHE_DSS_WITH_AES_128_CBC_SHA256    = { 0x00,0x40 };
CipherSuite TLS_DHE_RSA_WITH_AES_128_CBC_SHA256    = { 0x00,0x67 };
CipherSuite TLS_DH_DSS_WITH_AES_256_CBC_SHA256     = { 0x00,0x68 };
CipherSuite TLS_DH_RSA_WITH_AES_256_CBC_SHA256     = { 0x00,0x69 };
CipherSuite TLS_DHE_DSS_WITH_AES_256_CBC_SHA256    = { 0x00,0x6A };
CipherSuite TLS_DHE_RSA_WITH_AES_256_CBC_SHA256    = { 0x00,0x6B };
```

HTTPS key exchange

At the end of the exchange, a secret is used to generate 4 keys (2 for MAC, 2 for encryption)

1. RSA key exchange
   - Use RSA for encryption to achieve confidentiality
   - Use RSA for signature to achieve authentication
2. Ephemeral Diffie Hellman (EDH)
   - For *forward secrecy* guarantees
3. Fixed Diffie Hellman
   - For packet inspection within the server's network

SSL Certificates

- A trusted authority vouches that a certain public key belongs to a particular site
- Format called x.509 (complicated)
- Browsers ship with CA public keys for large number of trusted CAs [accreditation process]
- Important fields:
    - Common Name (CN) [e.g., *.google.com]
      Expiration Date [e.g. 2 years from now]
      Subject's Public Key
      Issuer -- e.g., Verisign
      Issuer's signature
- Common Name field
    - Explicit name, e.g. ece.illinois.edu
    - Or wildcard, e.g. *.illinois.edu

X509 Certificates

Subject: C=US/O=Google Inc/CN=www.google.com
Issuer: C=US/O=Google Inc/CN=Google Internet Authority
Serial Number: 01:b1:04:17:be:22:48:b4:8e:1e:8b:a0:73:c9:ac:83
Expiration Period: Jul 12 2010 - Jul 19 2012
Public Key Algorithm: rsaEncryption
Public Key: 43:1d:53:2e:09:ef:dc:50:54:0a:fb:9a:f0:fa:14:58:ad:a0:81:b0:3d
7c:be:b1:82:19:b9:7c3:8:04:e9:1e5d:b5:80:af:d4:a0:81:b0:b0:68:5b:a4:a4
:ff:b5:8a:3a:a2:29:e2:6c:7c3:8:04:e9:1e5d:b5:7c3:8:04:e9:39:23:46

Signature Algorithm: sha1WithRSAEncryption

Signature: 39:10:83:2e:09:ef:ac:50:04:0a:fb:9a:f0:fa:14:58:ad:a0:81:b0:3d
7c:be:b1:82:19:b9:7c3:8:04:e9:1e5d:b5:80:af:d4:a0:81:b0:b0:68:5b:a4:a4
:ff:b5:8a:3a:a2:29:e2:6c:7c3:8:04:e9:1e5d:b5:7c3:8:04:e9:1e:5d:b5

Certificate Chains

- CA can delegate ability to generate certificates for certain names: Intermediate CAs
- Root CA signs "certificate issuing certificate" for delegated authority
- Delegated authority signs cert for ”ece.illinios.edu”
  - Delegated CA certificate: "pubkey=.... is allowed to sign certs for *.illinois.edu"
- Browser that trusts root can examine certs to establish validity -- "Chain of trust”
- How to find out about all the CAs?
- More than 1000 trusted parties today, can sign for any domain – huge problem!

Certificate Chains

Mozilla Firefox Browser

Trust everything signed by this "root" certificate

Subject: C=US/…/OU=Equifax Secure Certificate Authority
Issuer: C=US/…/OU=Equifax Secure Certificate Authority
Public Key:
Signature: 39:10:83:2e:09:ef:ac:50:04:0a:fb:9a:38:c9:d1

I authorize and trust this certificate; here is my signature

Subject: C=US/…/CN=Google Internet Authority
Issuer: C=US/…/OU=Equifax Secure Certificate Authority
Public Key:
Signature: be:b1:82:19:b9:7c:5d:28:04:e9:1e:5d:39:cd

I authorize and trust this certificate; here is my signature

Subject: C=US/…/O=Google Inc/CN=*.google.com
Issuer: C=US/…/CN=Google Internet Authority
Public Key:
Signature: bf:dd:e8:46:b5:a8:5d:28:04:38:4f:ea:5d:49:ca

Certificate Authority Ecosystem

- Each browser trusts a set of CAs
  - CAs can sign certificates for new CAs
  - CAs can sign certificates for any web site
- If a single CA is compromised, then the entire system is compromised
- We ultimately place our complete trust of the Internet in the weakest CA

Immediate Concerns

- Nobody has any idea who all these CAs are…
- 1,733 *umich*-known browser trusted CAs
- History of CAs being hacked (e.g. Diginotar)
- Oooops, Korea gave every elementary school, library, and agency a CA certificate (1,324)
  - Luckily invalid due to a higher-up constraint

Getting a Certificate

- Certificates are free (from LetsEncrypt!)
  - Identity validated by challenge to website
- Certificates are cheap elsewhere too
  - Identity is validated via e-mail to the default e-mail addresses
- Setting up SSL is hard. People are terrible at it.
  - Certificate Signing Requests, eugh
  - Integrating in a web server

SSL in the browser

- Lock icon
  - HTTPS cert must be issued by a CA trusted by browser
  - HTTPS cert is valid (e.g., not expired or revoked)
  - CommonName in cert matches domain in URL
- Extended Validation (EV) certificates
  - CA does extra work to verify identity -- expensive, but more secure
- Invalid certificate warnings

Attack Vectors

- Attack the weakest Certificate Authority
- Attack browser implementations
- Notice a bug in a key generation library that leads you to discovering all the private keys on the Internet
- Attack the cryptographic primitives
  - Math is hard

"-----BEGIN RSA PRIVATE KEY-----" -openssl

Search

About 274,000 results (0.24 seconds)

Everything

Images

Maps

Videos

News

Shopping

More

All results

Related searches

More search tools

-----**BEGIN RSA PRIVATE KEY** - Pastebin.com - #1 paste tool since ...

pastebin.com/TbaeU93m

19 Apr 2010 – ... the difference. Copied. -----**BEGIN RSA PRIVATE KEY**-----.
MIICXwIBAAKBpenis1ePqHkVN9IKaGBESjV6zBrIsZc+XQYTtSIVa9R/4SAXoYpI ...

-----**BEGIN RSA PRIVATE KEY** - Pastebin.com - #1 paste tool since ...

pastebin.com/sC7bGw30

18 Apr 2010 – ... difference. Copied. -----**BEGIN RSA PRIVATE KEY**-----.
MIIEogIBAAKCAQEAvxBalhzKMewLvmIr1ptID1gO7EWGFyudzOAHLqm3+0+gpPbk ...

site:pastebin.com "-----**BEGIN RSA PRIVATE KEY**-----" - Posterous

cdevers.posterous.com/sitepastebincom-**begin-rsa-private-key**-google

20 Apr 2010 – Apr 19, 2010 ... -----**BEGIN RSA PRIVATE KEY**-----
MIICXwIBAAKBpenis1ePqHkVN9IKaGBESjV6zBrIsZc+ XQYTtSIVa9R/4SAXoYpI .

help/en/howto/sftp – Cyberduck

trac.cyberduck.ch/wiki/help/en/howto/sftp

Private keys containing a DSA or RSA private key in PEM format are supported (look for -----BEGIN DSA PRIVATE KEY----- or -----**BEGIN RSA PRIVATE KEY**----- ...

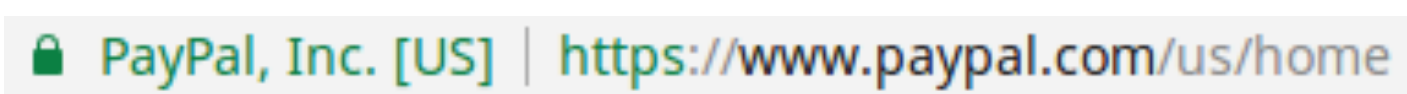
SSH access with a private RSA key [Archive] - VanDyke Software For...

forums.vandyke.com/archive/index.php/t-2185.html

2 Sep 2011 – -----**BEGIN RSA PRIVATE KEY**-----
MIIEogIBAAKCAQBujdbtxyIX4KaQPeTf5F/
aOSBwSpZN4MjTixU2Yq8JkipjMYpYwpNj1TODzRJf ...

Attacking site design

- SSLstrip attack
  - Proxy through the content w/o HTTPS
- Defense
  - Default HTTPS for all web sites?
  - HSTS (hypertext strict transport security): header says: always expect HTTPS, enforced by browsers.
  - HTTPS Everywhere: browser extension
  - EV: Extended Validation (compared to DV: Domain Validation)



Attacking site design

- Mixed Content attack -- Page loads over HTTPS but contains content over HTTP
  - e.g. JavaScript, Flash
  - Active attacker can tamper with HTTP content to hijack session
- Defense: Browser warnings: ["This page contains insecure content"],
  - but inconsistent and often ignored

UI based attacks

- Invalid certs
  - Expired, Common Name != URL, unknown CA (e.g., self-signed)
- Defense: browser warnings, anti-usability to bypass…
- Picture-in-picture attack: spoof the user interface
  - Attacker page draws fake browser window with lock icon
- Defense: individualized image

Attacking the PKI: CA compromise
Example: DigiNotar

Attacking the PKI: CA compromise Example: DigiNotar

- DigiNotar ***was*** a Dutch Certificate Authority
- On June 10, 2011, **`*.google.com`** cert was issued to an attacker and subsequently used to orchestrate MITM attacks in Iran
- Nobody noticed the attack until someone found the certificate in the wild… and posted to *pastebin*

DigiNotar Contd.

- DigiNotar later admitted that dozens of fraudulent certificates were created
- Google, Microsoft, Apple and Mozilla all revoked the root Diginotar certificate
- Dutch Government took over Diginotar
- Diginotar went bankrupt and died

Attacking the PKI: Hash collisions

- MD5/SHA1 is known to be broken -- Can generate collisions
- In 2008, researchers showed that they could create a rogue CA certificate using an MD5 collision
- Attack: Make colliding messages A, B, with same MD5 hash:
  – A: Site certificate: "cn=attack.com, pubkey=....”
  – B: Delegated CA certificate: "pubkey=.... is allowed to sign certs for *”
  – Get CA to sign A -- Signature is Sign(MD5(message))
  – Signature also valid for B (same hash)
  – Attacker is now a CA!
  – Make a cert for any site, browsers will accept it

MD5 considered harmful

- MD5 CA certificates still exist, but CAs have stopped signing certificates with them
  - 879,705 certificates still have MD5 signatures

- SHA-1 should not be used either
  - 46,969,095 out of 146,442,087 certs ever seen by Censys use SHA1WithRSA (32%)

Attacking implementations: Null Termination Attack

- ASN.1 utilizes Pascal-style strings
- Web browsers utilize use C-style strings
- Announced by Moxie Marlinspike in 2009

`gmail.com\0.badguy.com`

Null Termination Attack

- www.attacker.com
  - [CAs verify cert by looking up who owns the last part of the domain via DNS record]
  - emails "webmaster@attack.com" --> "Click here to validate cert request"
- x.509 certs encode CN field as a Pascal string (length+data)
- Browsers copy it into a C string (data+\0)
- What if CA contains "\0"?
  - www.paypal.com\0.attacker.com?
  - CA contacts "attacker.com" to verify (last part of domain name)
  - Browsers copy to C string, terminates at "\0" -- see only paypal.com
  - Attacker now has a cert that works for Paypal!

Other implementation-based attacks

- Goto fail, Feb. 2014 (Apple SSL bug; skipped certificate check for almost a year!)
- Heartbleed, April 2014 (OpenSSL bug; leaked data, possibly including private key!)
- Mozilla BERserk vulnerability, Oct 2014 (Bug in verifying cert signatures, allowed spoofing certs, probably since the beginning….!)
- Logjam, Oct 2016 (TLS vulnerable to Man-in-the middle “Downgrade” attack)

Who controls the TLS endpoint?

Cloudbleed

- one of the most popular “content delivery networks”
- acts as the SSL endpoint for many servers
- a **buffer overflow** attack caused it to leak HTTPS data

Clientside HTTP Interception -

- Most antivirus software intercepts your HTTPS [How?]
- Introduces new vulnerabilities by implementing poorly
- Tavis Ormandy (again)

Takeaways

- Use HTTPS! It’s so much better than nothing

- SSL keeps breaking. Use it, but don't rely on it exclusively.