CSCI-1680
TLS

Nick DeMarinis

Based partly on lecture notes by Rodrigo Fonseca, Scott Shenker and John Jannotti

Administrivia

- Thanksgiving break!
  - No hours/Ed support Wed-Fri
- TCP grading: after break, signups on Mon, Dec 2
  - You can work on your readme, fix small bugs before meeting without using late days

Administrivia

TCP was due Friday, Nov 22

- Like with IP: you can continue to make *small* bugfixes after the deadline
  - OK: Fixing *small* bugs, README, capture files, code cleanup
  - Not OK: eg. implementing sendfile/recvfile, teardown, submitting untested code

- Grading meetings: after break

After break: HW5, small SRC component, final project

Administrivia

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The final project

Out after break, handout online after class

- …maybe skim it before break?

The final project

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<u>What it is</u>

- Open-ended: build something new related to class topics
- List of ideas in document… or propose your own!

Project examples

- Make your own iterative DNS resolver
- Make your own web API / responsive website
- Implement something (eg. Snowcast), etc. using RPCs (more next week)
- Build your own traffic analyzer
- Extend your IP/TCP in some way…

Project examples

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These are only a few ideas!

Final project Logistics

Out after break, document online after class

…maybe skim it before break?

Deadlines

- Team assignment form: Due Monday, 12/2
  - Keep your current groups, or form new ones, or work solo
- Project proposal: Due Friday, 12/6
- Final submission: Due Thursday, 12/16

Version 1

```
func VWrite(toSend) {
    snd.add(toSend)

}

func SendThread()  {
  for {

    if canSend() && snd.hasBytes() {
       doSend()
    }
  }
}
```

Version 1

```
func VWrite(toSend) {
    snd.add(toSend)

}

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       doSend()
    }
  }
}
```

```
func VWrite(toSend) {
    snd.add(toSend)
    sendChan <- true
}

func SendThread()  {
  for {
    <- sendChan
    if canSend() && snd.hasBytes() {
       doSend()
    }
  }
}
```

Warmup: what's the functional difference between these?
(And why did we prefer version 2?)

Version 1

```
func VWrite(toSend) {
    snd.add(toSend)

}

func SendThread()  {
  for {

    if canSend() && snd.hasBytes() {
       doSend()
    }
  }
}
```

Version 2: signal channel when writing

```
func VWrite(toSend) {
    snd.add(toSend)
    sendChan <- true
}

func SendThread()  {
  for {
    <- sendChan
    if canSend() && snd.hasBytes() {
       doSend()
    }
  }
}
```

The good

```
func VWrite(toSend) {
    snd.add(toSend)
    sendChan <- true
}

func SendThread()  {
  for {
    <- sendChan
    if canSend() && snd.hasBytes() {
       doSend()
    }
  }
}
```

The bad

```
func VWrite(toSend) {
    snd.add(toSend)
    sendChan <- true
}

func SendThread()  {
  for {
    <- sendChan
    if canSend() && snd.hasBytes() {
       doSend()
    }
  }
}
```

"I thought using threads was good?!" 😱

Up to the kernel to decide how to schedule threads

How long before next thread wakes up????

=> Depends on how long the kernel takes to get around to it!

```
func VWrite(toSend) {
    snd.add(toSend)
    sendChan <- true
}

func SendThread()  {
  for {
    <- sendChan
    if canSend() && snd.hasBytes() {
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  }
}
```
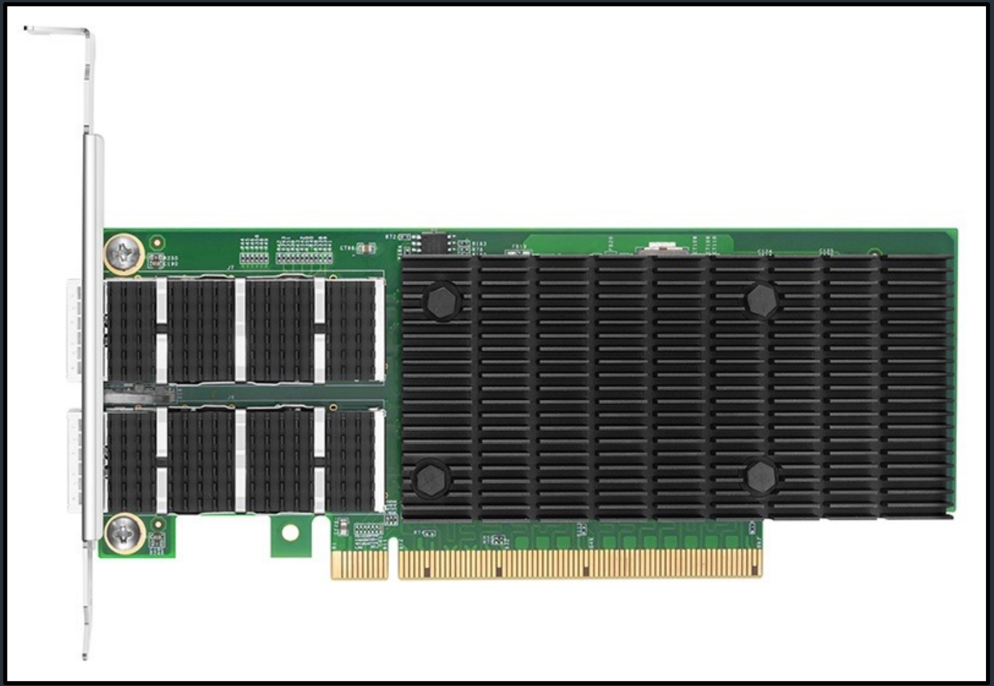



vs.

Modern enterprise network cards
40-100+ Gbps

Linux kernel

Lot of ongoing work in this area

- Work to improve kernel performance

- Kernel bypass: circumvent kernel entirely

- Help from hardware: offload things like checksum, batching of segments, even more…

I am *absolutely not* an expert on this…

Example: kernel bypass

Data Plane Development Kit

文A 5 languages

Article Talk Read Edit View history Tools

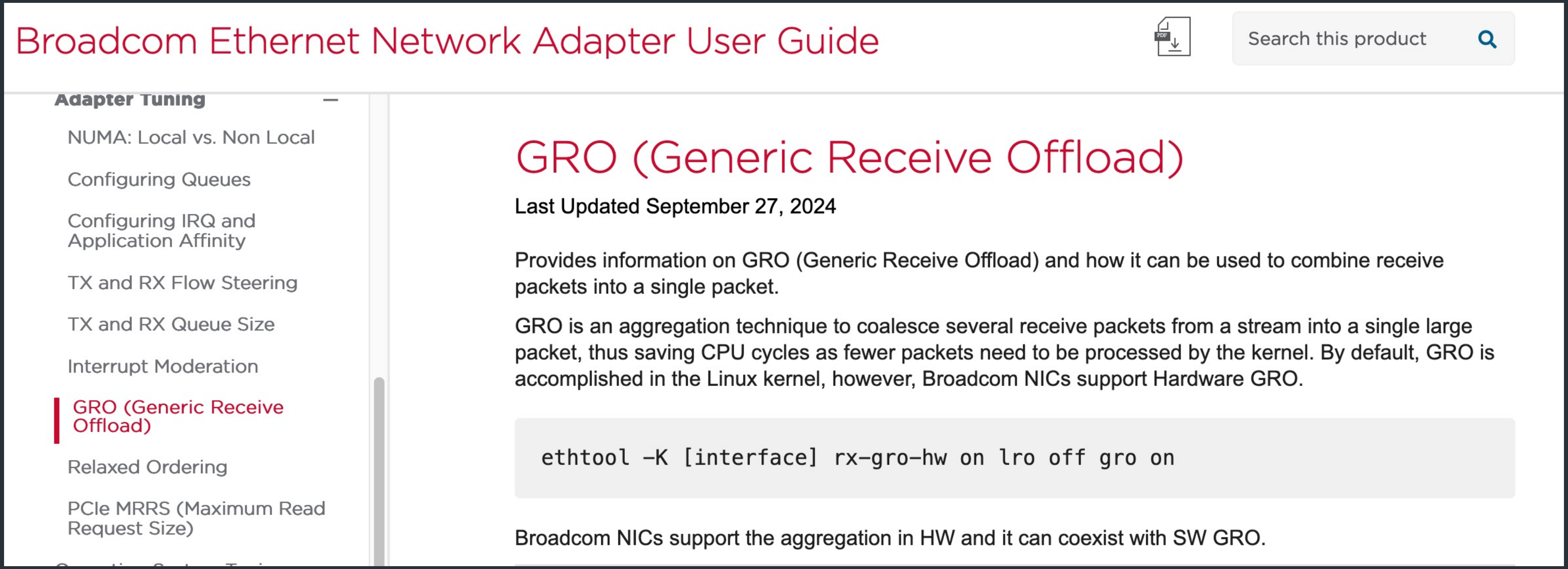
From Wikipedia, the free encyclopedia

(Redirected from DPDK)

The **Data Plane Development Kit** (**DPDK**) is an open source software project managed by the Linux Foundation. It provides a set of data plane libraries and network interface controller polling-mode drivers for offloading TCP packet processing from the operating system kernel to processes running in user space. This offloading achieves higher computing efficiency and higher packet throughput than is possible using the interrupt-driven processing provided in the kernel.

DPDK	
DPDK DATA PLANE DEVELOPMENT KIT	
Stable release	24.07 / 31 July 2024[1]
Repository	git.dpdk.org

Example: help from hardware



Broadcom Ethernet Network Adapter User Guide

Search this product

Adapter Tuning

- NUMA: Local vs. Non Local
- Configuring Queues
- Configuring IRQ and Application Affinity
- TX and RX Flow Steering
- TX and RX Queue Size
- Interrupt Moderation
- GRO (Generic Receive Offload)
- Relaxed Ordering
- PCIe MRRS (Maximum Read Request Size)

GRO (Generic Receive Offload)

Last Updated September 27, 2024

Provides information on GRO (Generic Receive Offload) and how it can be used to combine receive packets into a single packet.

GRO is an aggregation technique to coalesce several receive packets from a stream into a single large packet, thus saving CPU cycles as fewer packets need to be processed by the kernel. By default, GRO is accomplished in the Linux kernel, however, Broadcom NICs support Hardware GRO.

```
ethtool -K [interface] rx-gro-hw on lro off gro on
```

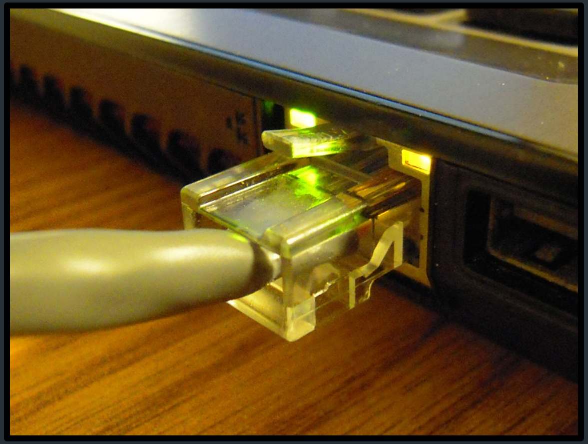
Broadcom NICs support the aggregation in HW and it can coexist with SW GRO.

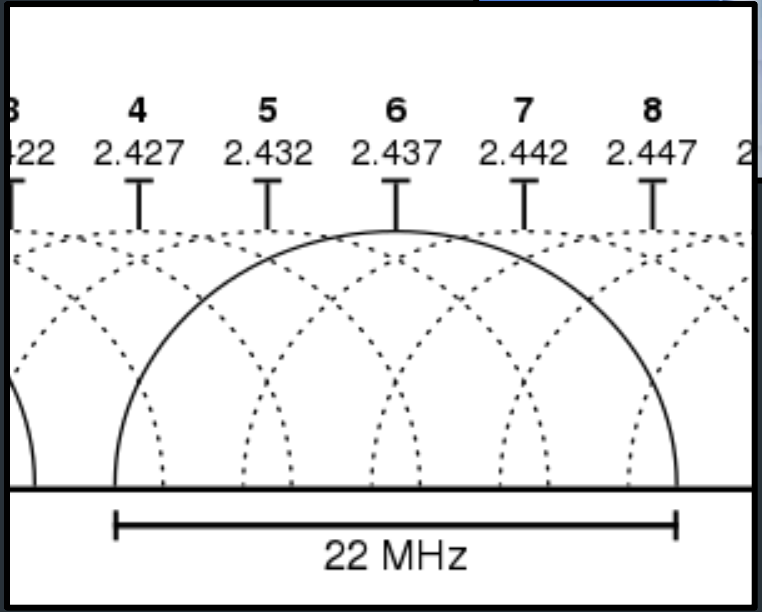
IPoAC

How can we improve the physical layer?

Traditional links have fixed bandwidth

- Media limits what frequencies can be used for signal
- Places upper bound on channel capacity





What if we weren’t constrained by the EM spectrum?

How else can we transmit data?

Network Working Group
Request for Comments: 1149

D. Waitzman
BBN STC

1 April 1990

A Standard for the Transmission of IP Datagrams on Avian Carriers

Status of this Memo

This memo describes an experimental method for the encapsulation of IP datagrams in avian carriers. This specification is primarily useful in Metropolitan Area Networks. This is an experimental, not recommended standard. Distribution of this memo is unlimited.

Overview and Rational

Avian carriers can provide high delay, low throughput, and low altitude service. The connection topology is limited to a single point-to-point path for each carrier, used with standard carriers, but many carriers can be used without significant interference with each other, outside of early spring. This is because of the 3D ether space available to the carriers, in contrast to the 1D ether used by

RFC1149: IPoAC

IP over Avian Carriers (1 April 1990)

- High delay, low throughput, low altitude datagram service
- Nearly unlimited movement in 3D etherspace
- Intrinsic collision avoidance
- Typical MTU: 256 milligrams

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IPoAC: Design

IPoAC: Implementation

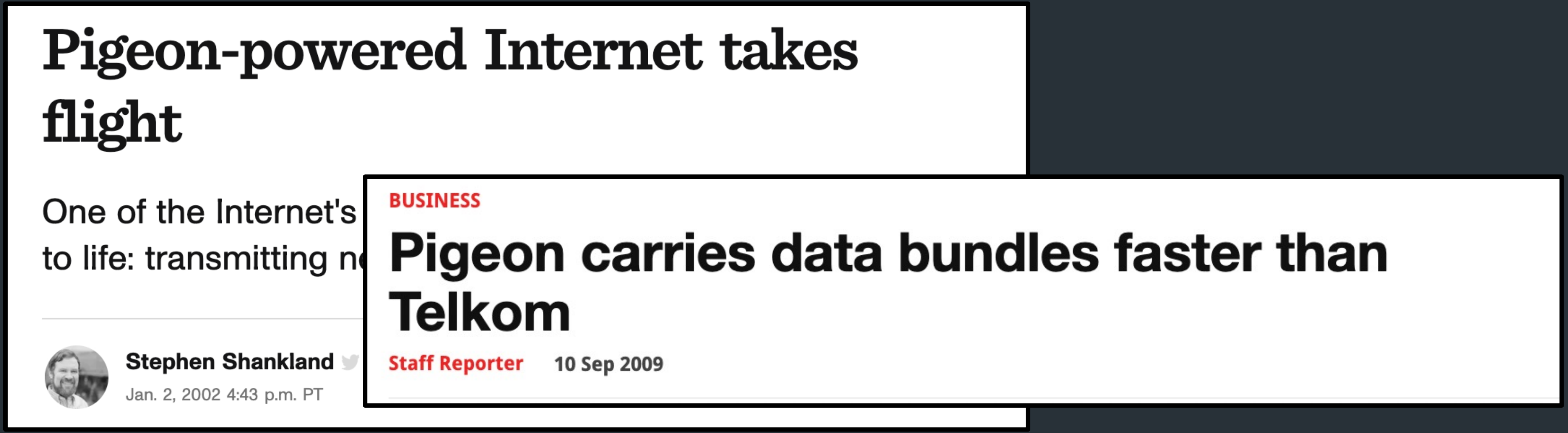
Proof of concept: 28 April 2001
Bergen, Norway
https://web.archive.org/web/20140215072548/http://www.blug.linux.no/rfc1149/

IPoAC in practice

```
$ ping -c 9 -i 900 10.0.3.1
PING 10.0.3.1 (10.0.3.1): 56 data bytes
64 bytes from 10.0.3.1: icmp_seq=0 ttl=255 time=6165731.1 ms
64 bytes from 10.0.3.1: icmp_seq=4 ttl=255 time=3211900.8 ms
64 bytes from 10.0.3.1: icmp_seq=2 ttl=255 time=5124922.8 ms
64 bytes from 10.0.3.1: icmp_seq=1 ttl=255 time=6388671.9 ms

--- 10.0.3.1 ping statistics ---
9 packets transmitted, 4 packets received, 55% packet loss round-trip
min/avg/max = 3211900.8/5222806.6/6388671.9 ms
```

IPoAC: (more) Modern implementations



Pigeon-powered Internet takes flight

One of the Internet's
to life: transmitting n

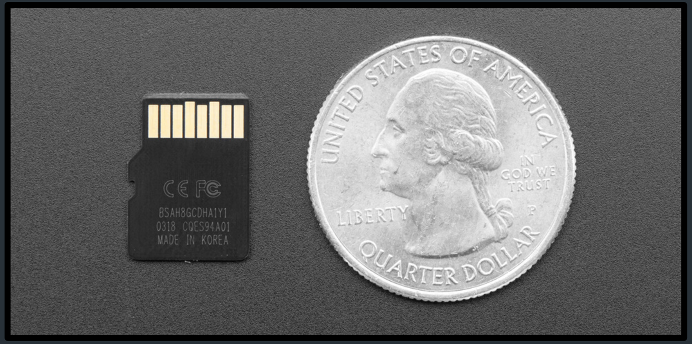
Stephen Shankland
Jan. 2, 2002 4:43 p.m. PT

BUSINESS

Pigeon carries data bundles faster than Telkom

Staff Reporter 10 Sep 2009

<u>Today</u>: microSD card: ~250mg, 1TB



+

= ???

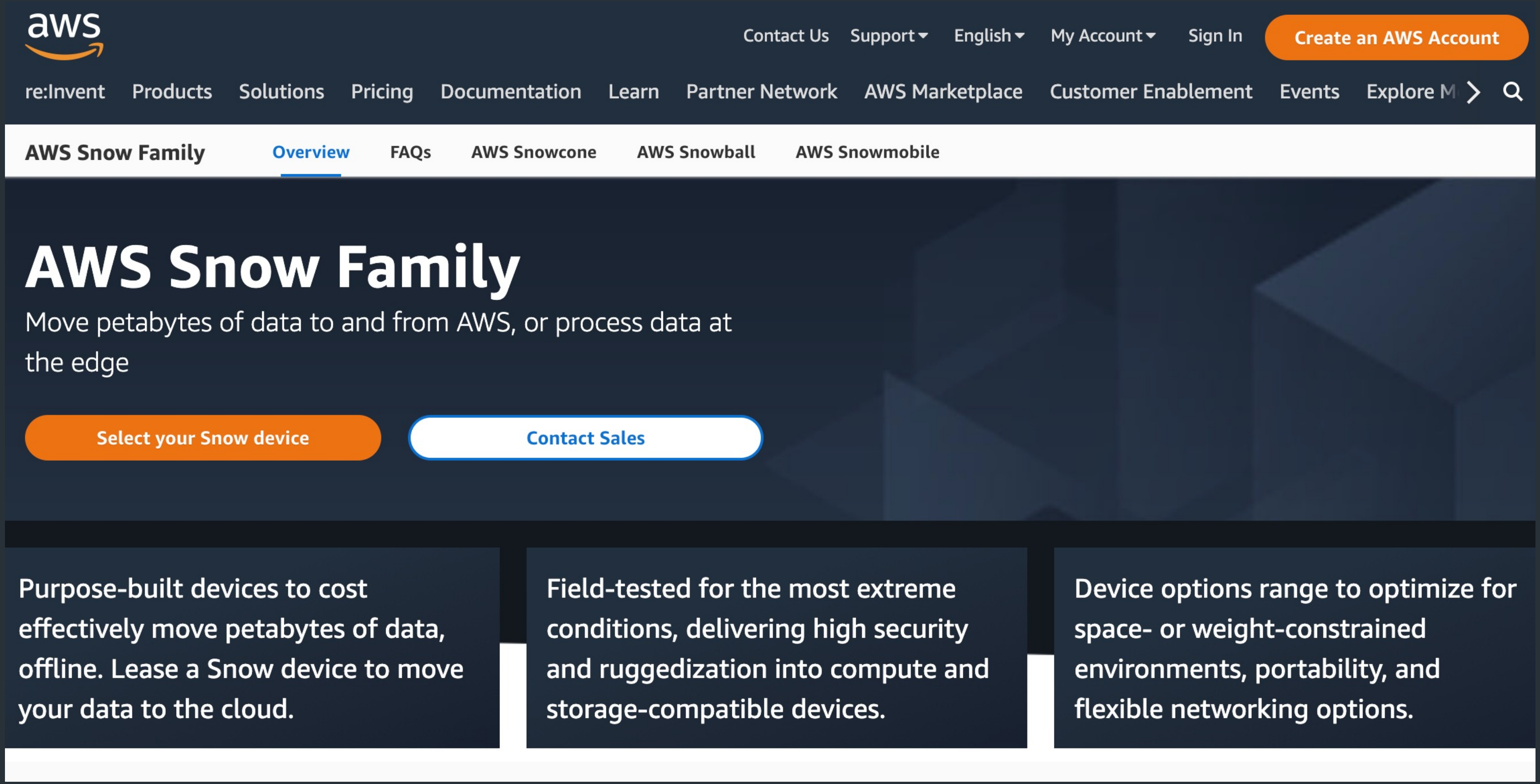
But actually

What happens if you have a LOT of data to move into the cloud?

But actually

What happens if you have a LOT of data to move into the cloud?

Example: AWS



Feature comparison matrix

	AWS SNOWCONE	AWS SNOWBALL EDGE STORAGE OPTIMIZED	AWS SNOWBALL EDGE COMPUTE OPTIMIZED	AWS SNOWMOBILE
Usable HDD Storage	8 TB	80 TB	N/A	100 PB
Usable SSD Storage	14 TB	1 TB	28 TB	No
Usable vCPUs	4 vCPUs	40 vCPUs	104 vCPUs	N/A
Usable Memory	4 GB	80 GB	416 GB	N/A
Device Size	9in x 6in x 3in 227 mm x 148.6 mm x 82.65 mm	548 mm x 320 mm x 501 mm	548 mm x 320 mm x 501 mm	45 ft. shipping container
Device Weight	4.5 lbs. (2.1 kg)	49.7 lbs. (22.3 kg)	49.7 lbs. (22.3 kg)	N/A
Storage Clustering	No	Yes, 5-10 nodes	Yes, 5-10 nodes	N/A
256-bit Encryption	Yes	Yes	Yes	Yes
HIPAA Compliant	No	Yes, eligible	Yes, eligible	Yes, eligible

RFC791: IPv4 Header

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Version|  IHL  |Type of Service|          Total Length         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Identification        |Flags|      Fragment Offset    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Time to Live |    Protocol   |         Header Checksum       |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Source Address                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Destination Address                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Data                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Internet Header Format [RFC-791]

IP over Burrito Carriers

```
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Obvious|  Onion    |  Jalapenos  |    Physical Length (mm)     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Number Written on Foil      |Bean Type|  Number of Beans  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| Given Delivery Time | Guacamole |       Receipt               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                             Lettuce                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                              Rice                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                              Beef                             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+


               The Burrito Internet Header Format
```

April Fool's Day RFCs

April Fools' Day Request for Comments

From Wikipedia, the free encyclopedia
(Redirected from Peg DHCP)

A Request for Comments (RFC), in the context of Internet governance, is a type of publication from the Internet Engineering Task Force (IETF) and the Interne
behaviors, research, or innovations applicable to the working of the Internet and Internet-connected systems.

Almost every April Fools' Day (1 April) since 1989, the Internet RFC Editor has published one or more humorous Request for Comments (RFC) documents, fo
RFC 527 called ARPAWOCKY, a parody of Lewis Carroll's nonsense poem "Jabberwocky". The following list also includes humorous RFCs published on othe

Contents [hide]

List of April Fools' RFCs [edit]

1978

M. R. Crispin (1 April 1978). *TELNET RANDOMLY-LOSE option*. IETF. doi:10.17487/RFC0748. RFC 748.

A parody of the TCP/IP documentation style. For a long time it was specially marked in the RFC index with "note date of issue".

1989

https://en.wikipedia.org/wiki/April_Fools%27_Day_Request_for_Comments Enjoy!

This is not a security class
(as much as I would like it to be…)

- This isn't intended to be a lecture on all crypto
- I want you to appreciate the important principles, understand what's important for TLS (and other protocols like it)

Want to know more?

This is not a security class
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- I want you to appreciate the important principles, understand what's important for TLS (and other protocols like it)

Want to know more?

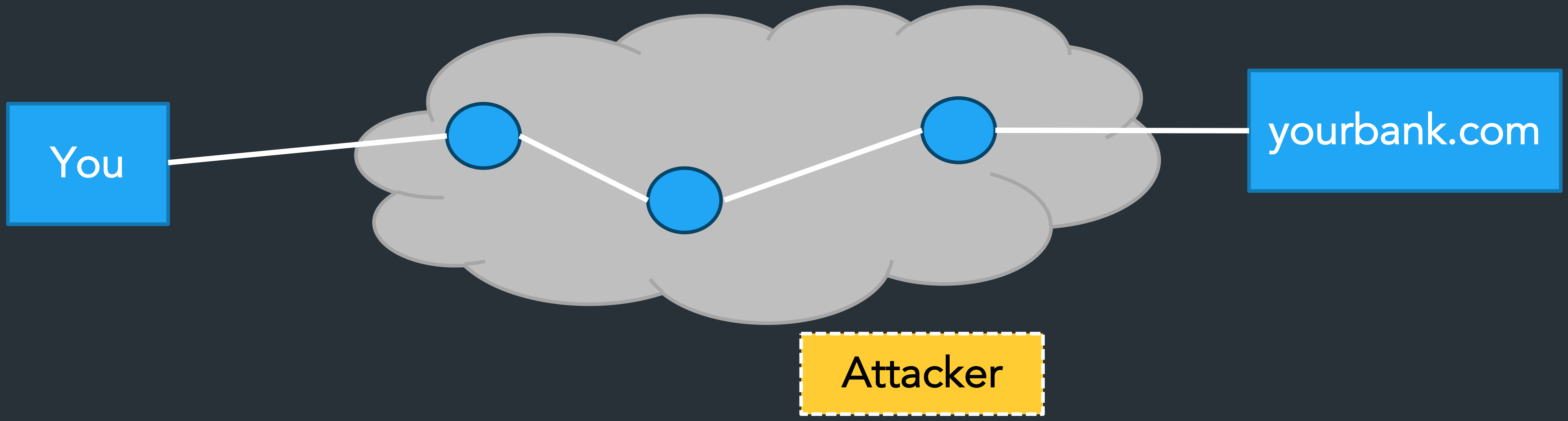
- CS1660 (Spring): Intro to Computer Systems Security
- CS1515 (Spring): Applied cryptography
- CS1510 (Fall): Intro to Cryptography and Computer Security

Internet’s Design: Insecure

- Designed for simplicity in a naïve era
- Lots of insecure systems that can be compromised

- No central administration => hard to diagnose, coordinate fixes

What can go wrong?



(some) Key security properties

- Confidentiality

- Authentication

- Integrity

(some) Key security properties

- Confidentiality: prevent adversary from reading the data
  => Protect against *eavesdropping*, *sniffing*

- Authentication: verifying the identity of a message or actor
  => Protect against *spoofing*, *impersonation*

- Integrity: make sure messages arrive in original form
  => Protect against *tampering*

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There are more security properties, but we'll stick to these => Focus of TLS

Other important security properties

- Availability: Will the network deliver data?
  - Protect against infrastructure compromise, DDoS
- Provenance: Who is responsible for this data?
  - Prevent forging responses, denying responsibility; prove who created the data

- Authorization: is actor *allowed* to do this action?
- Appropriate use: is action *consistent with policy*? (spam, copyright, …)
- Anonymity: can someone tell what packets *I* am sending?

TLS: Transport layer security

TLS 1.0 (1999) => TLS 1.3 (2018)

Bidirectional pipe between two parties providing:

- Confidentiality
- Integrity
- Authentication

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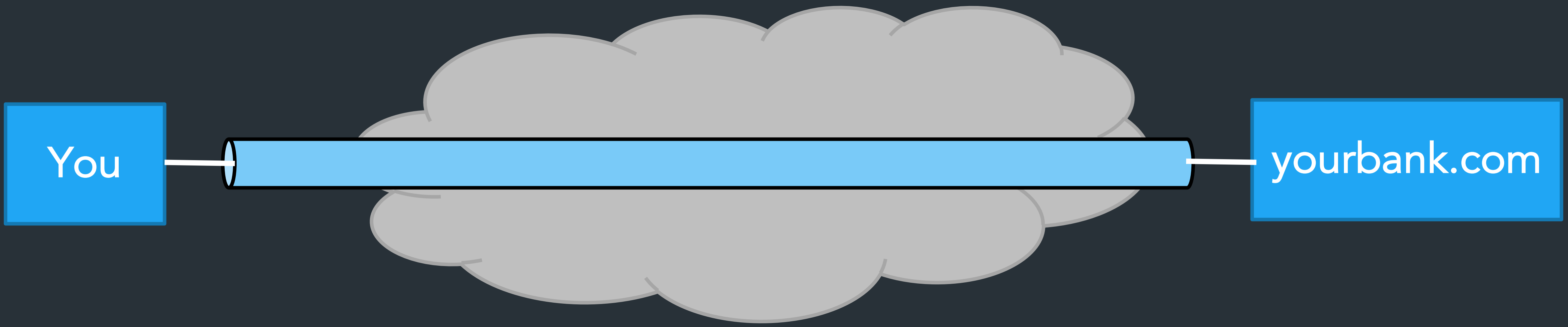
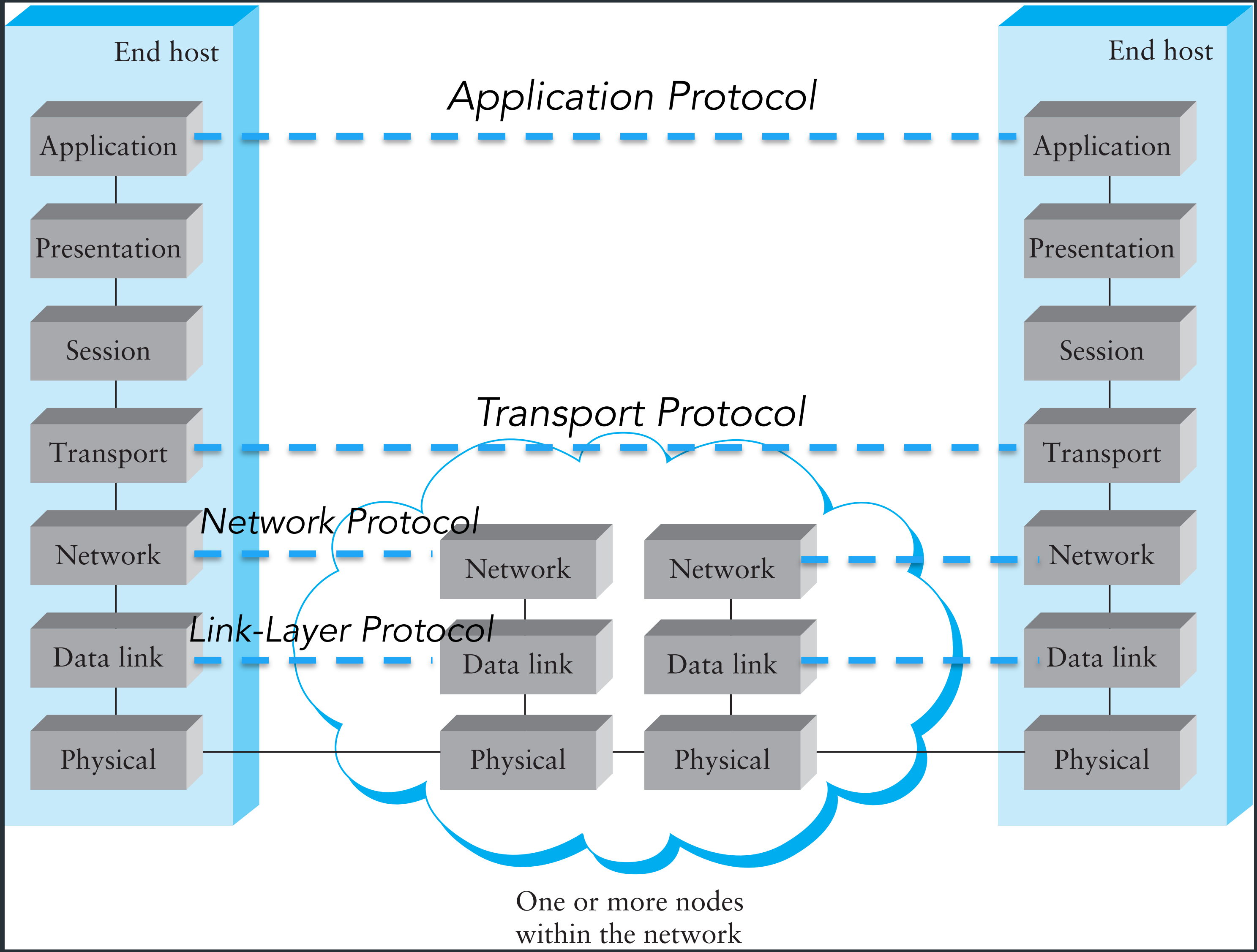


Are these all the security properties we might want? No!

Where does TLS go?

Application	Service: user-facing application. Application-defined messages
Transport	How to support multiple applications?
Network	Moving data between hosts (nodes)
Link	Move data across individual *links*
Physical	Service: move bits to other node across link

Throwback: The OSI model



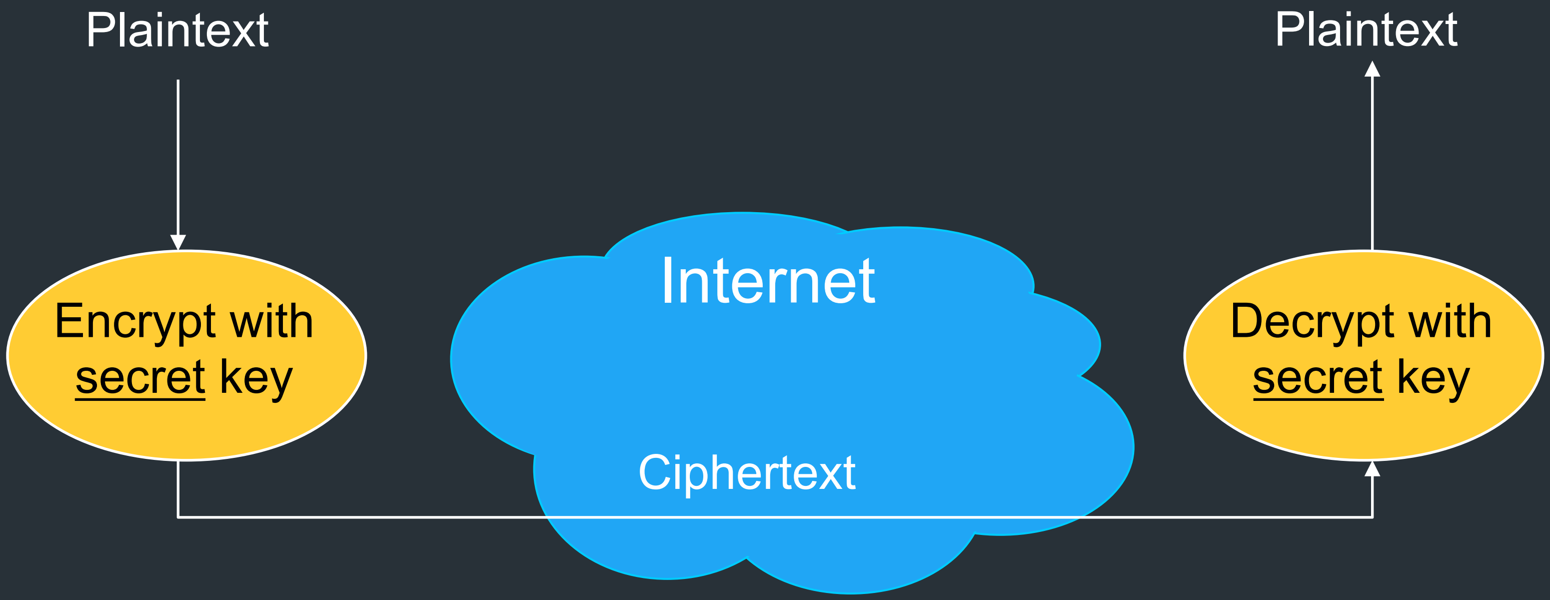
Fundamental crypto properties we need

Symmetric cryptography

- A, B share secret key k
- Examples: AES, Serpent, Whirlpool, DES (old, insecure), …
- Provides: confidentiality (encrypt/decrypt), integrity (MAC)

Symmetric crypto: strong, fast, but parties <u>need to have shared key k</u>
=> Key distribution is hard, why?

Confidentiality: Symmetric encryption



Confidentiality: Asymmetric encryption

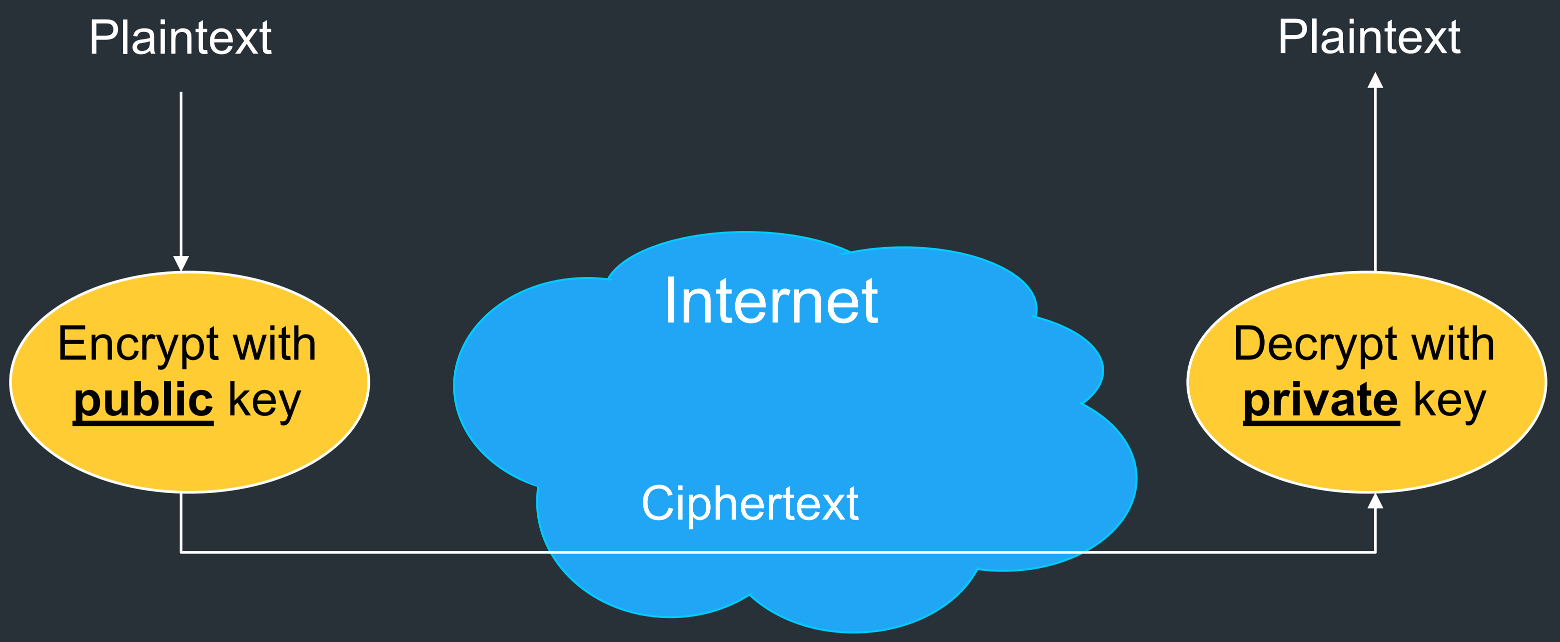
Everyone has two keys: k_pub, k_priv

Confidentiality: Asymmetric encryption

- Everyone has two keys: k_pub, k_priv
  - k_pub: Public key, widely-known
  - k_priv: Private key, kept secret
- Used for: authentication, signing (and confidentiality, integrity)

Public Key / Asymmetric Encryption

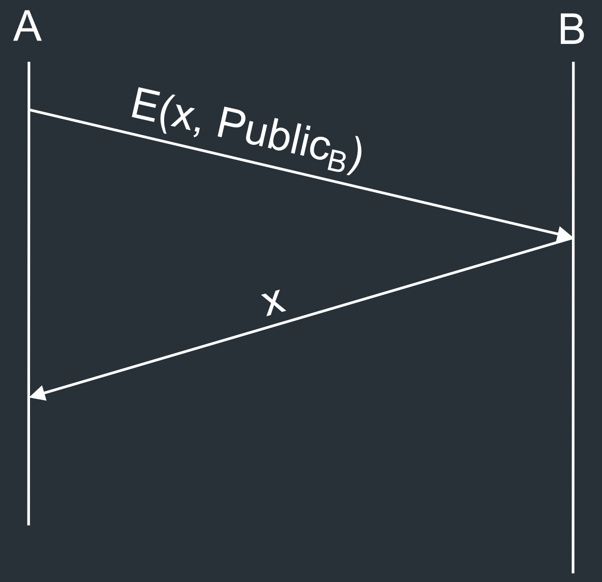
- Sender uses receiver's public key
  - Advertised to everyone
- Receiver uses complementary private key
  - Must be kept secret



What can we do with this?

Public Key Authentication

- Each side need only to know the other side's public key
  - No secret key need be shared
- A encrypts a nonce (random number) x using B's public key
- B proves it can recover x
- A can authenticate itself to B in the same way



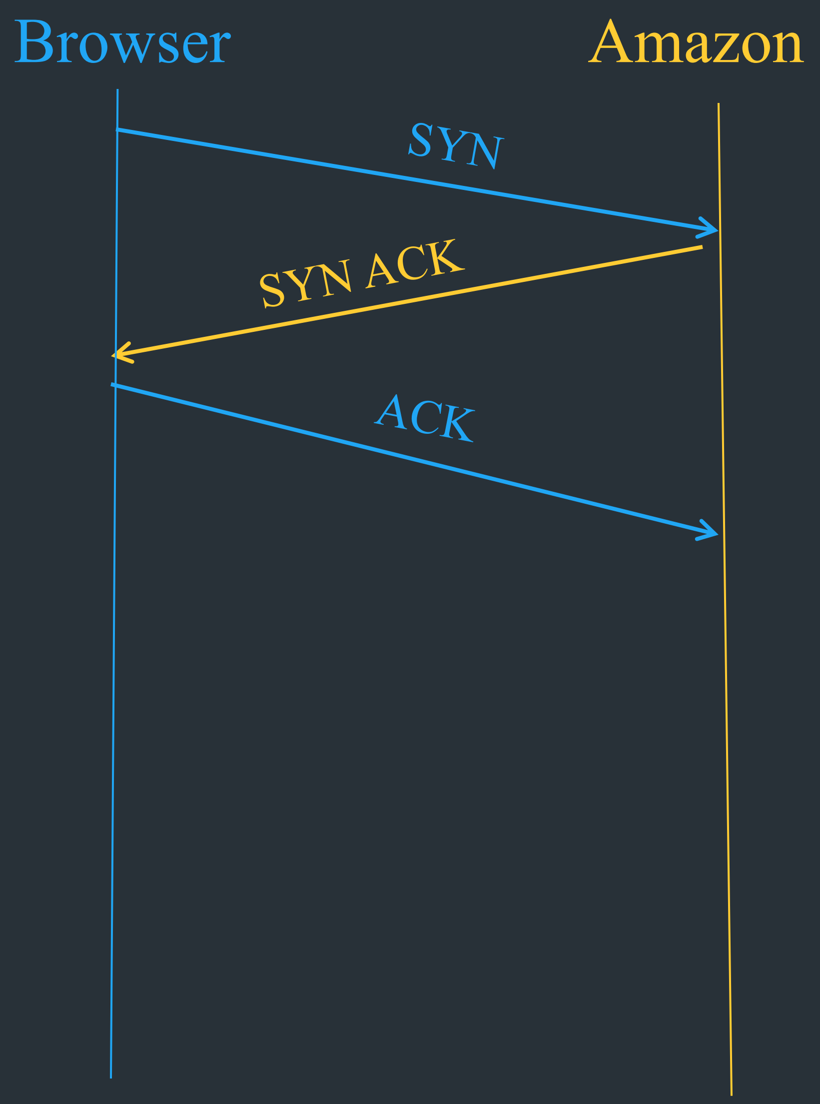
How it works in TLS

- Type in your browser: https://www.amazon.com
- https = "Use HTTP over TLS"
  - TLS = Transport Layer Security
  - SSL = Secure Socket Layer (older version)
  - RFC 4346, and many others

Goal: provide security layer (authentication, encryption) on top of transport layer
=> Fairly transparent to the app (once set up)

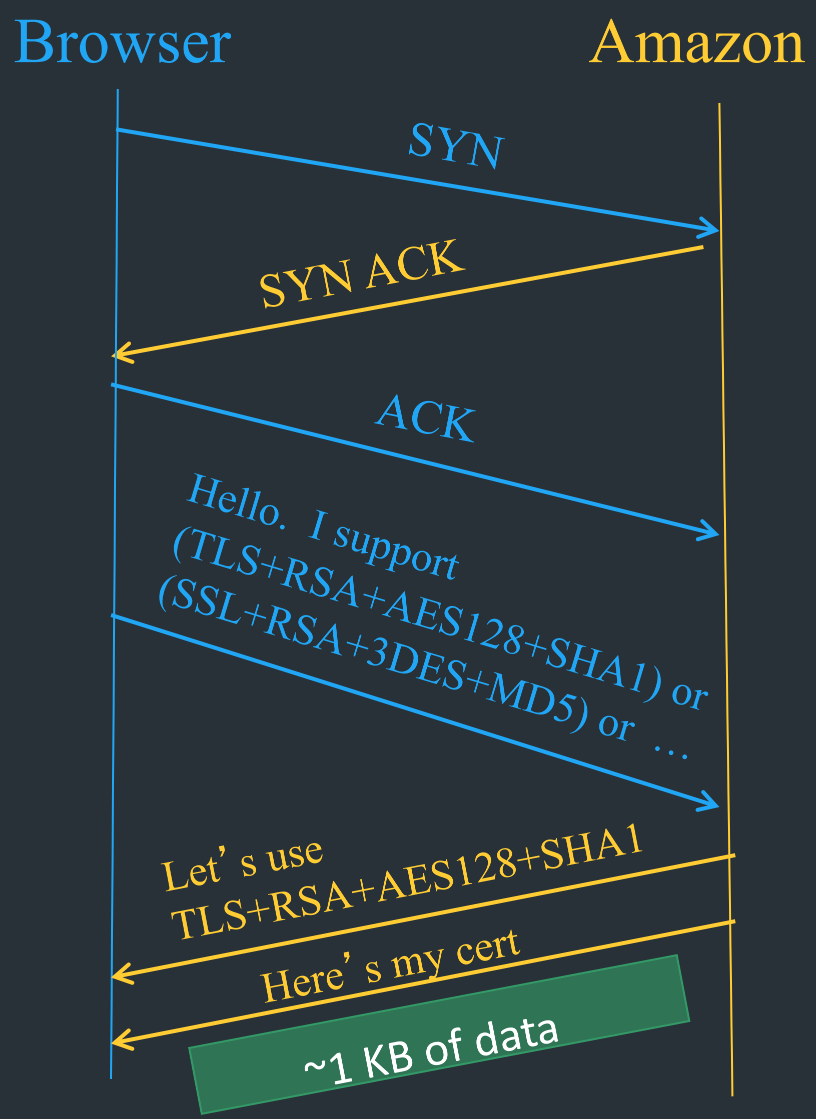
TLS: setup

- First: TCP handshake



TLS: setup

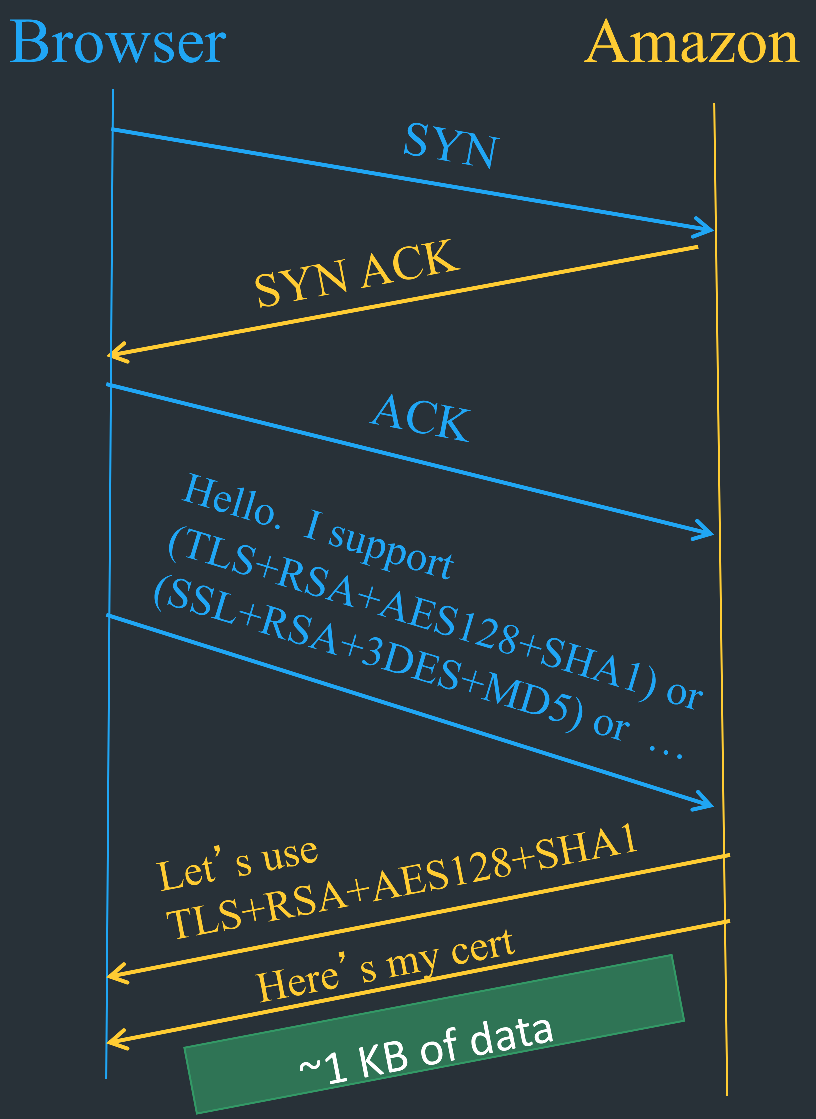
- First: TCP handshake
- Client sends over list of crypto protocols it supports
- Server picks crypto protocols to use for this session



TLS: setup

- First: TCP handshake
- Client sends over list of crypto protocols it supports
- Server picks crypto protocols to use for this session

- Use this to do two things:
  - Create shared session key
  - Verify server's identity



0x00,0xA0	TLS_DH_RSA_WITH_AES_128_GCM_SHA256	Y	N	[RFC5288]
0x00,0xA1	TLS_DH_RSA_WITH_AES_256_GCM_SHA384	Y	N	[RFC5288]
0x00,0xA2	TLS_DHE_DSS_WITH_AES_128_GCM_SHA256	Y	N	[RFC5288]
0x00,0xA3	TLS_DHE_DSS_WITH_AES_256_GCM_SHA384	Y	N	[RFC5288]
0x00,0xA4	TLS_DH_DSS_WITH_AES_128_GCM_SHA256	Y	N	[RFC5288]
0x00,0xA5	TLS_DH_DSS_WITH_AES_256_GCM_SHA384	Y	N	[RFC5288]
0x00,0xA6	TLS_DH_anon_WITH_AES_128_GCM_SHA256	Y	N	[RFC5288]
0x00,0xA7	TLS_DH_anon_WITH_AES_256_GCM_SHA384	Y	N	[RFC5288]
0x00,0xA8	TLS_PSK_WITH_AES_128_GCM_SHA256	Y	N	[RFC5487]
0x00,0xA9	TLS_PSK_WITH_AES_256_GCM_SHA384	Y	N	[RFC5487]
0x00,0xAA	TLS_DHE_PSK_WITH_AES_128_GCM_SHA256	Y	Y	[RFC5487]
0x00,0xAB	TLS_DHE_PSK_WITH_AES_256_GCM_SHA384	Y	Y	[RFC5487]
0x00,0xAC	TLS_RSA_PSK_WITH_AES_128_GCM_SHA256	Y	N	[RFC5487]
0x00,0xAD	TLS_RSA_PSK_WITH_AES_256_GCM_SHA384	Y	N	[RFC5487]
0x00,0xAE	TLS_PSK_WITH_AES_128_CBC_SHA256	Y	N	[RFC5487]
0x00,0xAF	TLS_PSK_WITH_AES_256_CBC_SHA384	Y	N	[RFC5487]

TLS + Authentication

TLS Goals

Authentication: verifying that the entity on the other end of the connection is who they claim to be

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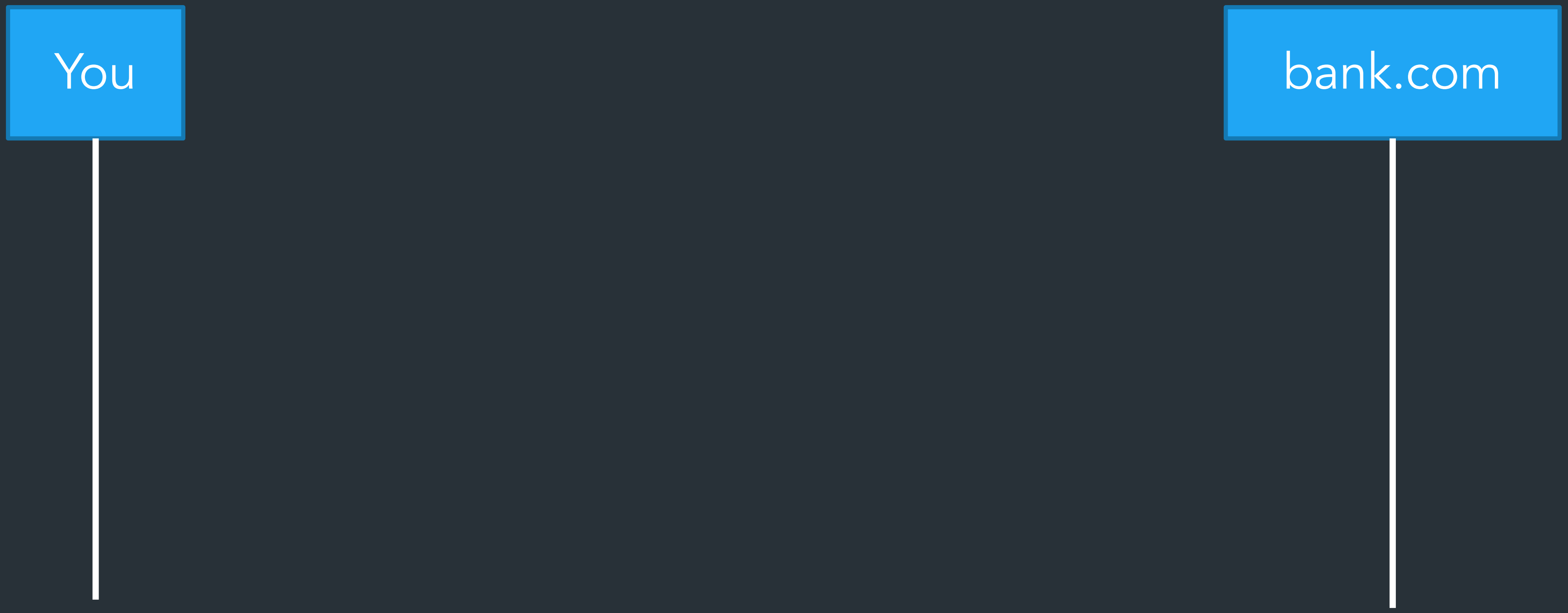
Authentication: verifying that the entity on the other end of the connection is who they claim to be

- Technical aspects: crypto
- Social aspects
  - How to distribute keys to entities
  - What to do when things go wrong

TLS: relies on Public Key Infrastructure (PKI) via certificates

The Challenge



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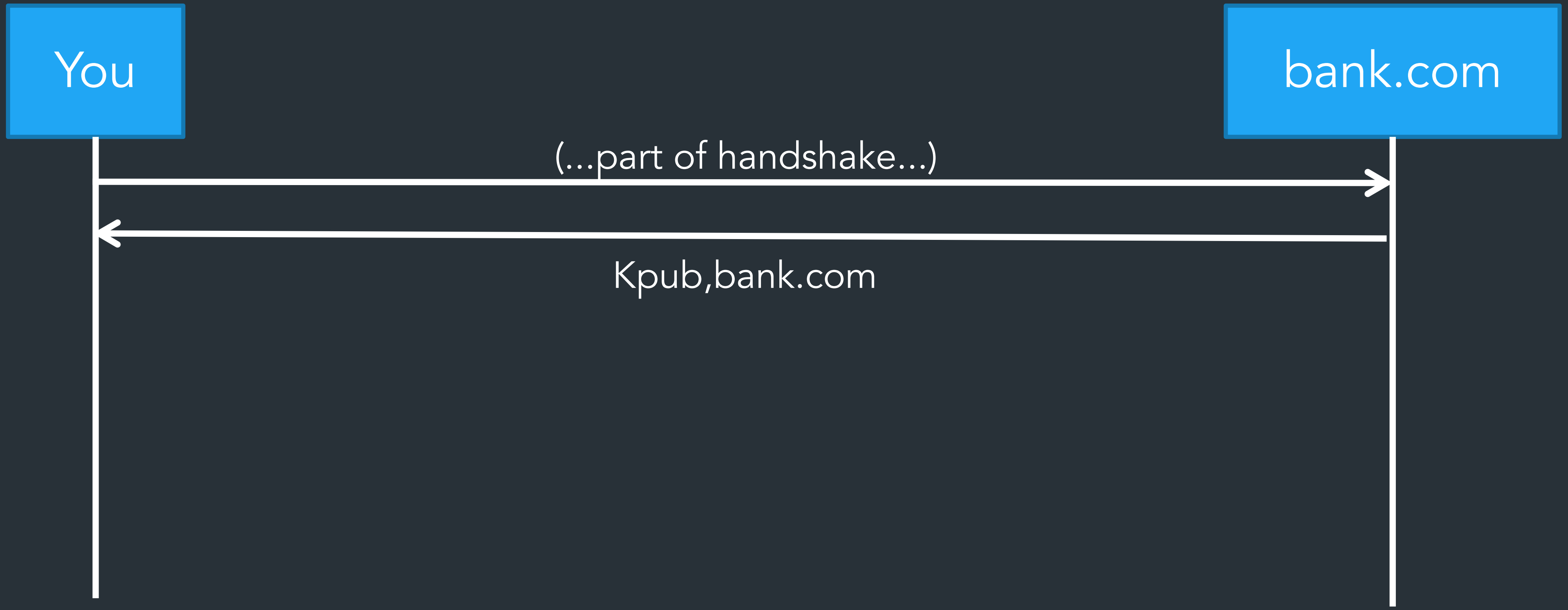
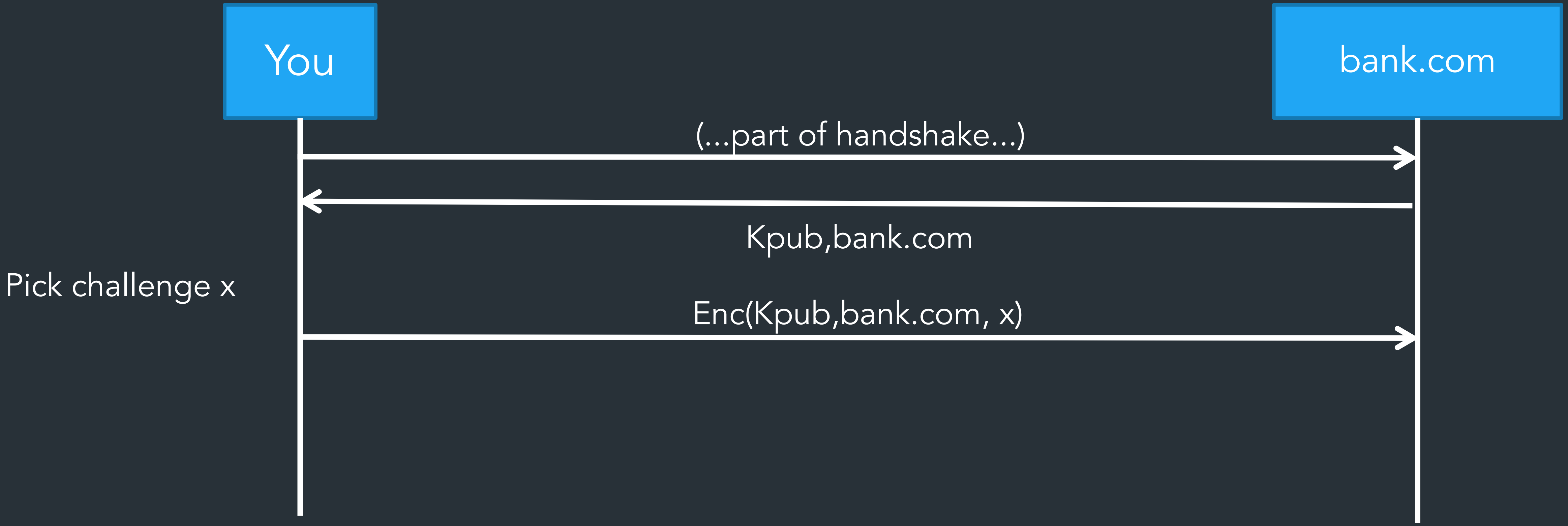


The Challenge



The Challenge

What does this prove?

Authentication challenges

- Challenge proves that the server at bank.com holds K_priv
- Does NOT prove belong to the server belongs to your bank, the real-life bank with your money

Authentication challenges

- Challenge proves that the server at yourbank.com holds K_priv
- Does NOT prove the server belongs to YourBank, the real-life bank that holds your money

"But I'm visiting yourbank.com!"

Authentication challenges

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- Does NOT prove the server belongs to YourBank, the real-life bank that holds your money

"But I'm visiting yourbank.com!"

- DNS can be spoofed
- Possible active network attacker (redirecting your IP traffic to malicious server)
- Domain names can expire and be re-registered...

Problem: How can we trust K_pub is Your Bank's public key?

Problem: distributing trust

How can we trust Kpub is Your Bank's public key?

Problem: Trust distribution

- Hard to verify real-world identities
- Hard to scale to the whole Internet

Different protocols have different mechanisms

=> TLS (and others): Public Key Infrastructure (PKI) with certificates

PKI: The main idea

Public keys managed by Certificate Authorities (CAs)

- Everyone knows public key for some <u>root CAs</u>
  - Pre-installed into browser/OS

CA

PKI: The main idea

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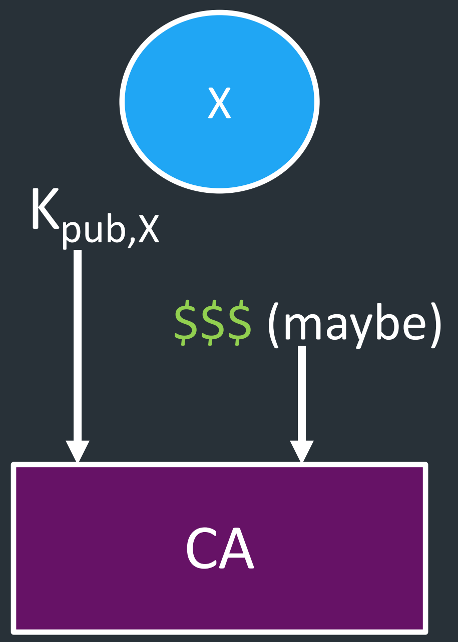

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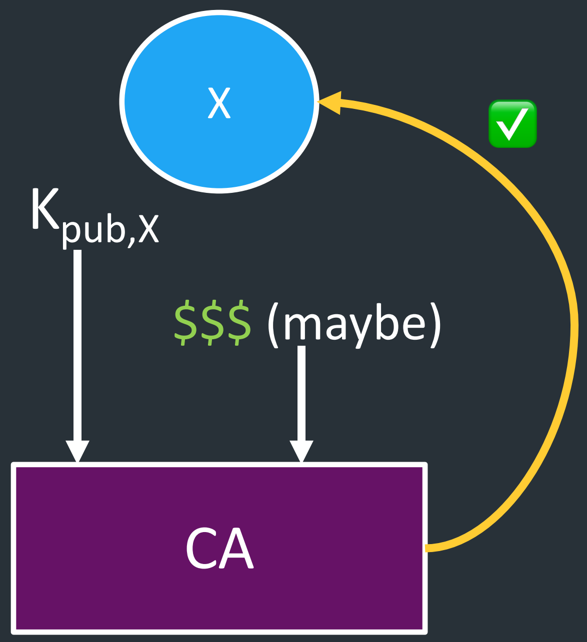

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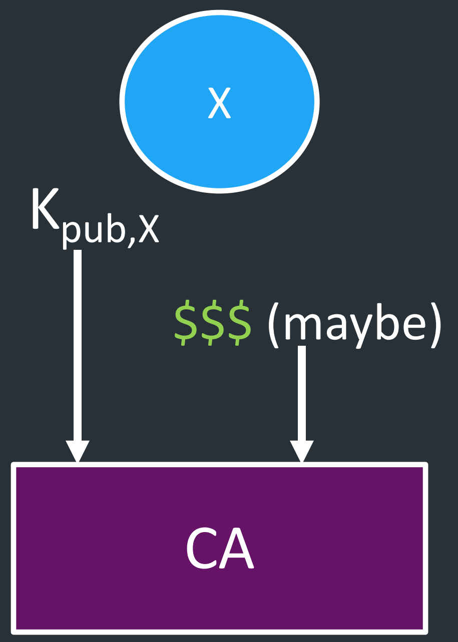

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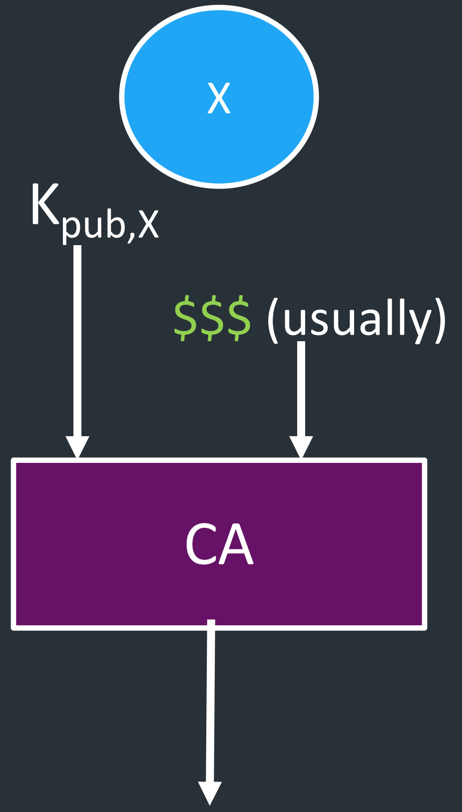

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$\text{Cert} = \{K_{pub,X}, \text{metadata}, s\}$

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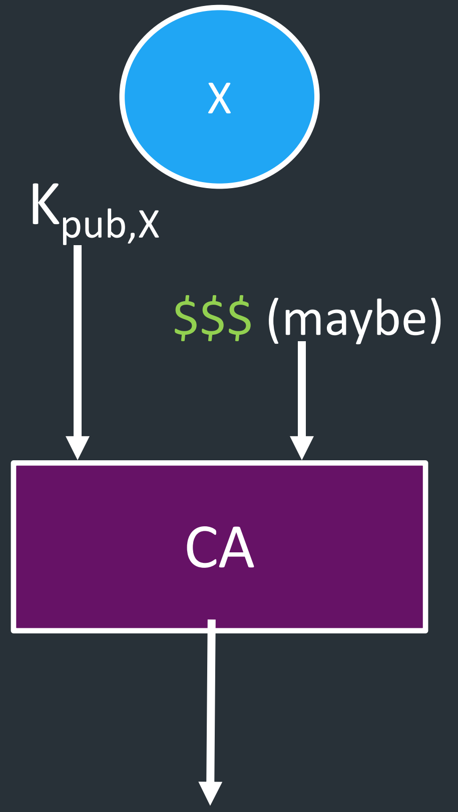

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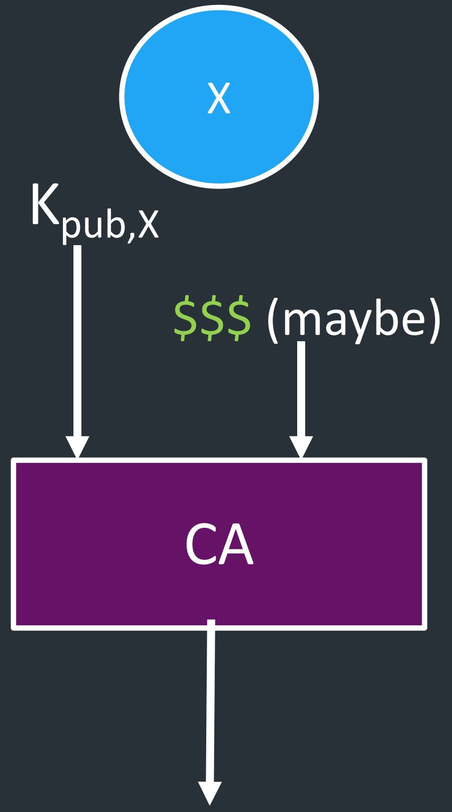

s = Sign($K_{priv,CA}$, {$K_{pub,X}$, … })

Cert = {$K_{pub,X}$, metadata, s}

=> Delegates trust for individual entity to a more trusted authority

DigiCert Assured ID Root CA

DigiCert Assured ID Root CA

Root certificate authority

Expires: Sunday, November 9, 2031 at 19:00:00 Eastern Standard Time

This certificate is valid

Trust

Details

Subject Name	
Country or Region	US
Organization	DigiCert Inc
Organizational Unit	www.digicert.com
Common Name	DigiCert Assured ID Root CA
Issuer Name	
Country or Region	US
Organization	DigiCert Inc
Organizational Unit	www.digicert.com
Common Name	DigiCert Assured ID Root CA
Serial Number	0C E7 E0 E5 17 D8 46 FE 8F E5 60 FC 1B F0 30 39
Version	3
Signature Algorithm	SHA-1 with RSA Encryption (1.2.840.113549.1.1.5)
Parameters	None
Not Valid Before	Thursday, November 9, 2006 at 19:00:00 Eastern Standard Time
Not Valid After	Sunday, November 9, 2031 at 19:00:00 Eastern Standard Time
Public Key Info	
Algorithm	RSA Encryption (1.2.840.113549.1.1.1)
Parameters	None
Public Key	256 bytes : AD 0E 15 CE E4 43 80 5C ...
Exponent	65537
Key Size	2,048 bits
Key Usage	Verify

Keychain Access

Search

All Items | Passwords | Secure Notes | My Certificates | Keys | Certificates

Amazon Root CA 1
Root certificate authority
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- Public key of entity (eg. yourbank.com)
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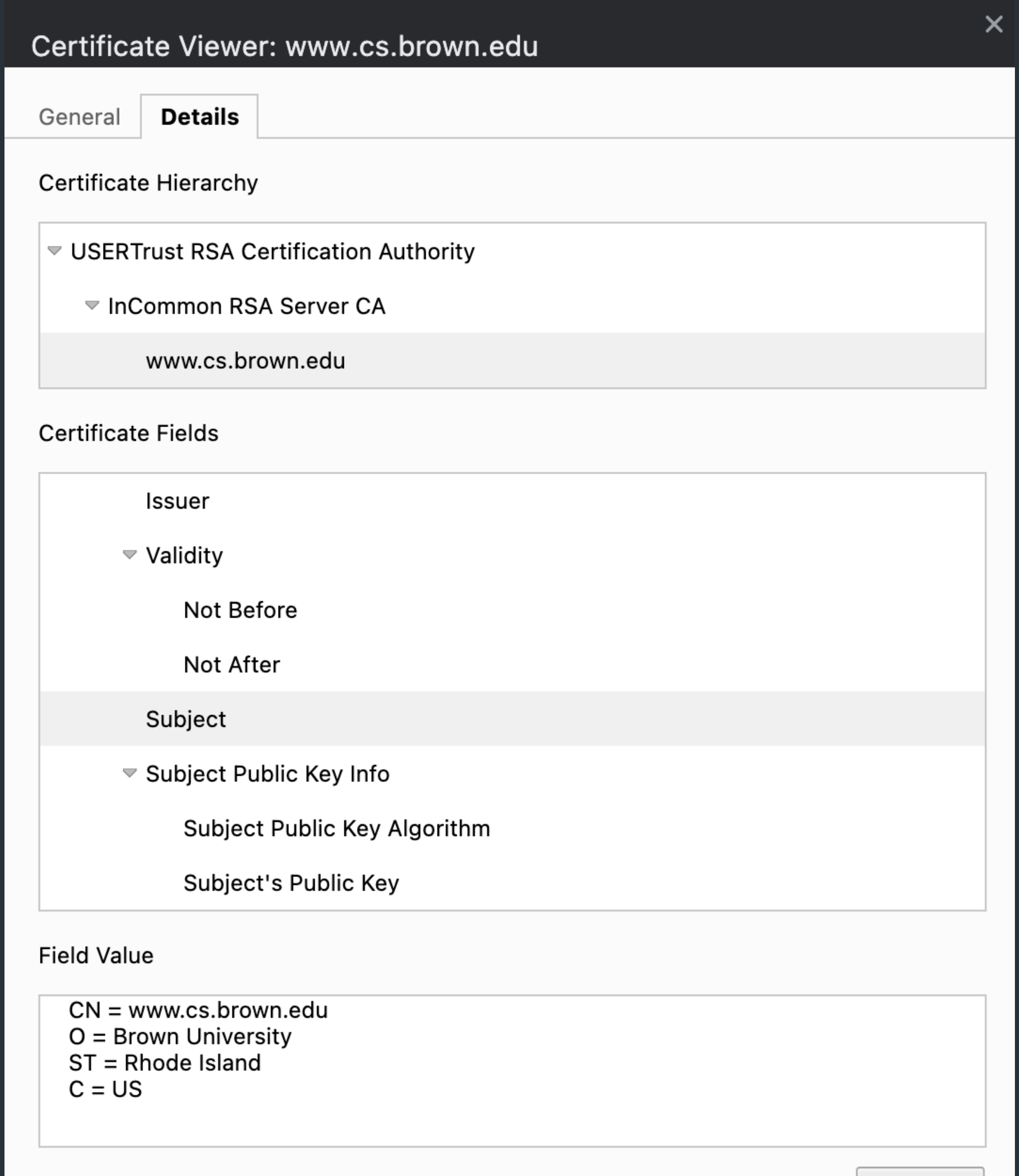
- Public key of entity (eg. yourbank.com)
- Common name: DNS name of server (yourbank.com)
- Contact info for organization
- Validity dates (start date, expire date)
- URL of *revocation center* to check if key has been revoked

All of this is part of the data signed by the CA
=> Critical to check all parts during TLS startup!


Certificate Viewer: www.cs.brown.edu
General
Details
Certificate Hierarchy
USERTrust RSA Certification Authority
InCommon RSA Server CA
www.cs.brown.edu
Certificate Fields
Issuer
Validity
Not Before
Not After
Subject
Subject Public Key Info
Subject Public Key Algorithm
Subject's Public Key
Field Value
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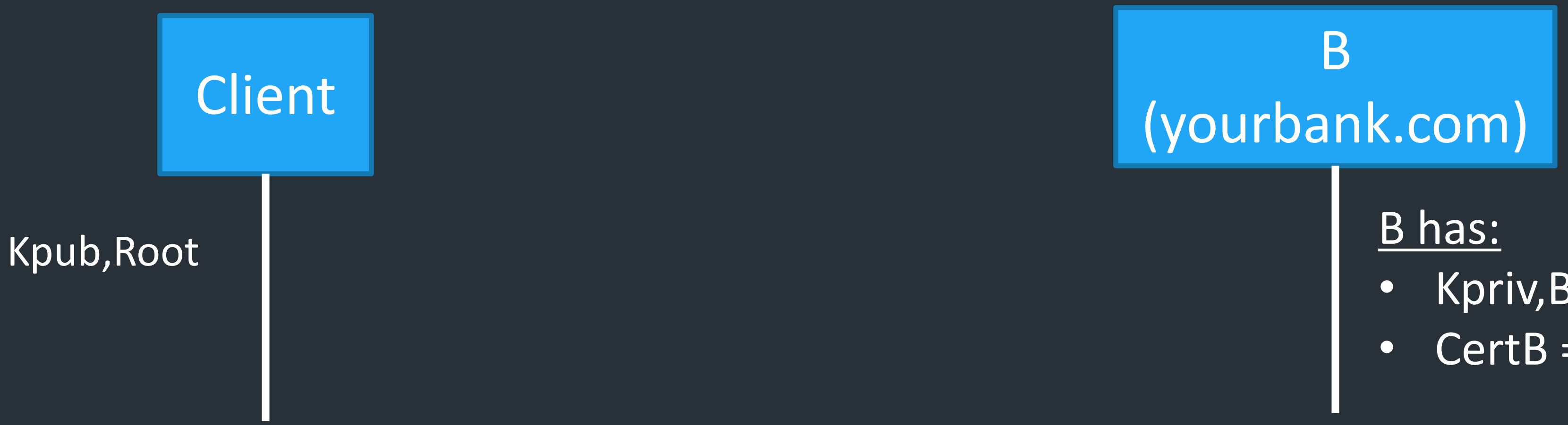
What happens if a root is compromised?

How the hierarchy works

Ex. Server has certificate from Intermediate CA_{Int}



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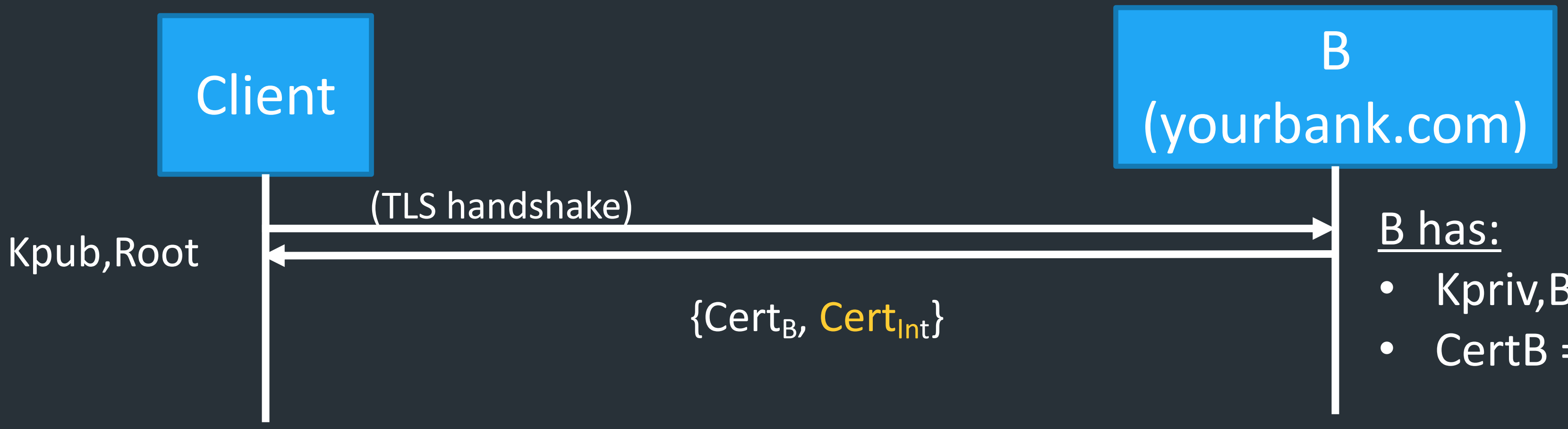

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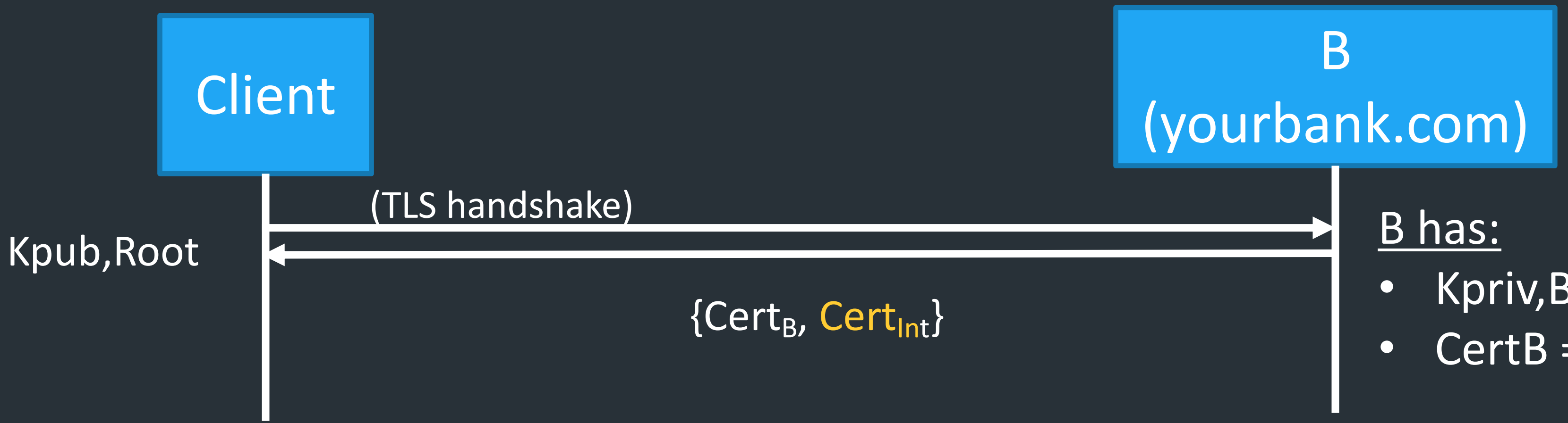

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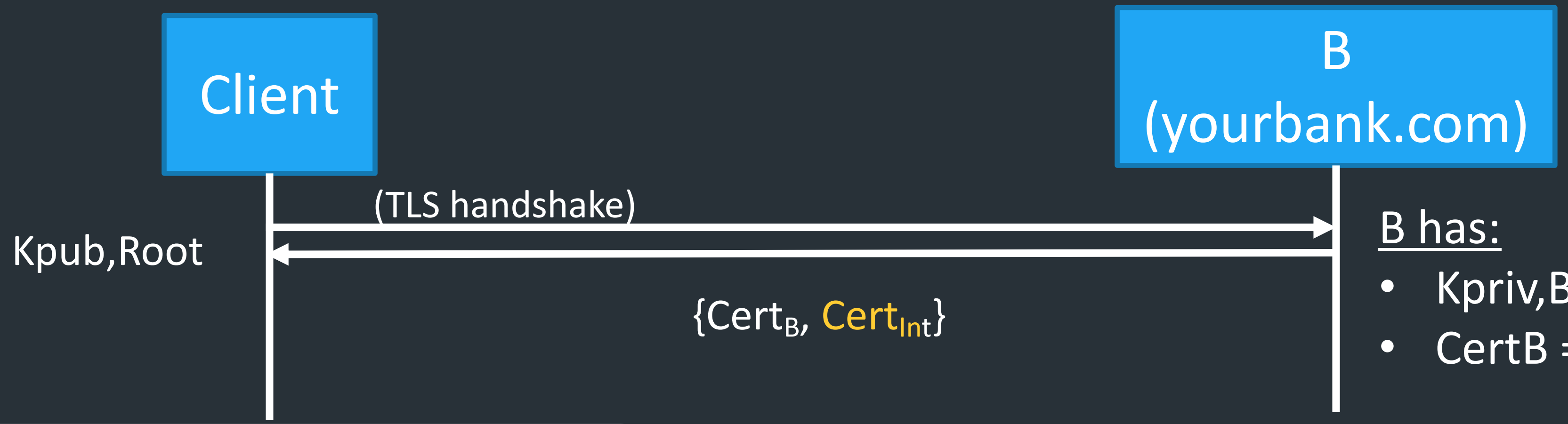

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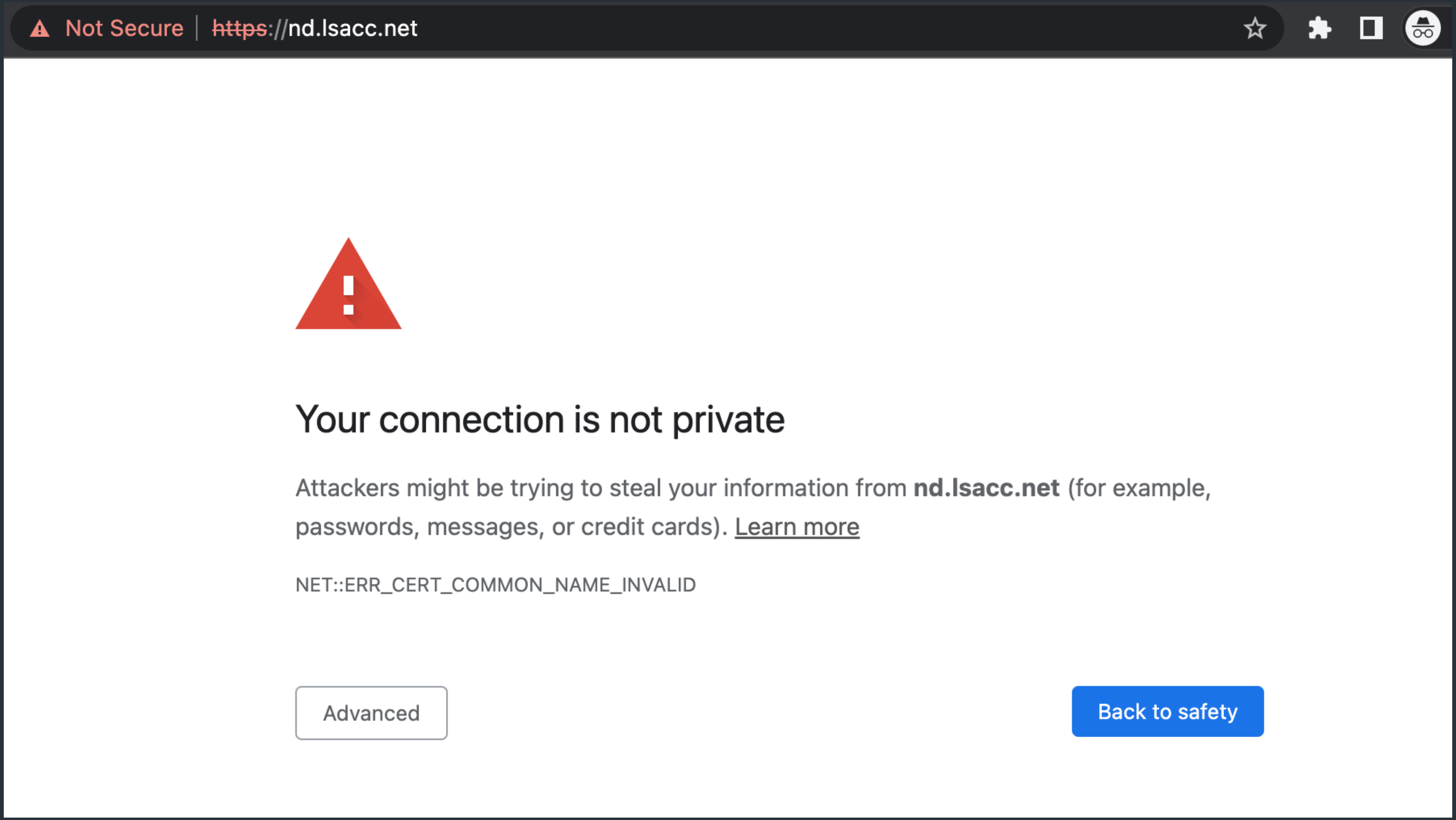
=> To verify integrity, need to verify certificates back to (trusted) root certificate

=> OK if verification passes and metadata correct: 🔒


Not Secure
https://nd.lsacc.net
Your connection is not private
Attackers might be trying to steal your information from nd.lsacc.net (for example, passwords, messages, or credit cards). Learn more
NET::ERR_CERT_COMMON_NAME_INVALID
Advanced
Back to safety

Most common TLS errors you might see

- Common name (eg. yourbank.com) invalid
- Self-signed
- Certificate expired

When is it okay to click "proceed"? What happens if you do?

Most common TLS errors you might see

- Common name invalid
- Self-signed
- Certificate expired

When is it okay to click "proceed"? What happens if you do?

=> Might occur if webserver configured improperly, or if you're setting up a system

Rogue Certificates?

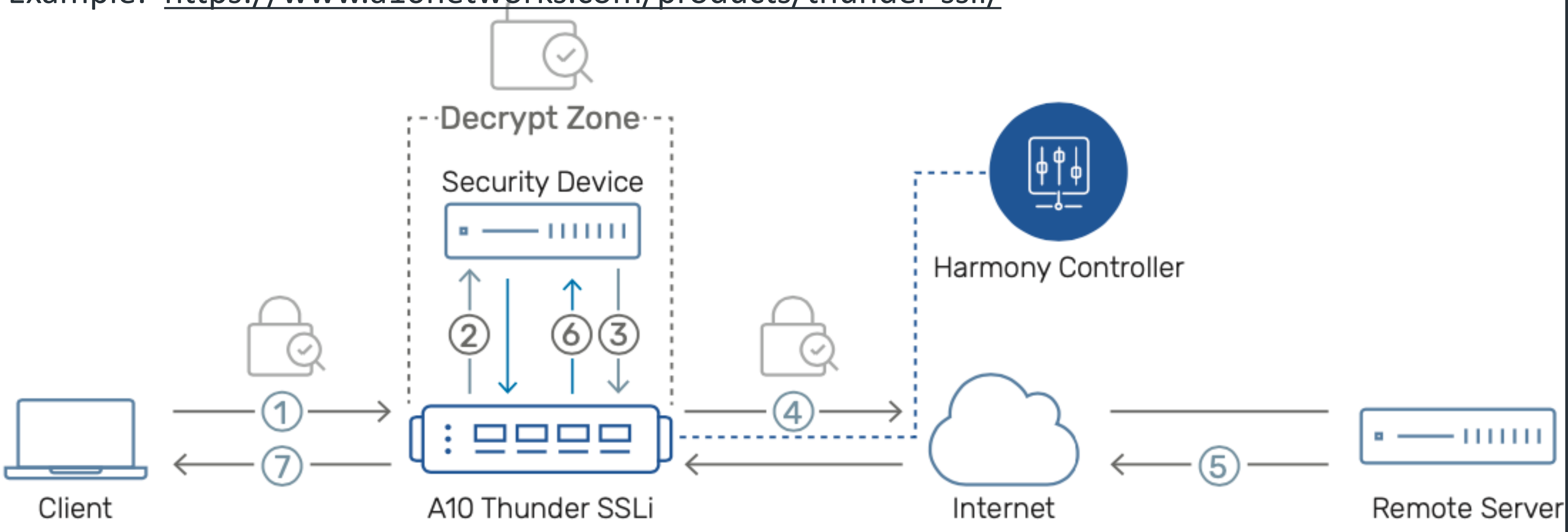
- In 2011, DigiNotar, a Dutch root certificate authority, was compromised
- The attacker created rogue certificates for popular domains like google.com and yahoo.com
- DigiNotar was distrusted by browsers and filed for bankruptcy
- See the incident investigation report by Fox-IT

- In 2017, Google questioned the certificate issuance policies and practices of Symantec
- Google's Chrome would start distrusting Symantec's certificates unless certain remediation steps were taken
- See back and forth between Ryan Sleevi (Chromium team) and Symantec
- The matter was settled with DigiCert acquiring Symantec's certificate business

TLS decryption

What happens when an organization wants to view TLS traffic on its network?

Example: https://www.a10networks.com/products/thunder-ssli/



1. Encrypted traffic from the client is intercepted by Thunder SSLi and decrypted.
2. Thunder SSLi sends the decrypted traffic to a security device, which inspects it in clear-text.
3. The security device, after inspection, sends the traffic back to Thunder SSLi, which intercepts and re-encrypts it.
4. Thunder SSLi sends the re-encrypted traffic to the server.
5. The server processes the request and sends an encrypted response to Thunder SSLi.
6. Thunder SSLi decrypts the response traffic and forwards it to the same security device for inspection.
7. Thunder SSLi receives the traffic from the security device, re-encrypts it and sends it to the client.

PKIs, TLS, and HTTPS

The story so far

- Asymmetric crypto: each entity gets a key in two parts
  - K_{priv}: Private key, kept secret
  - K_{pub}: Public key, shared with everyone
- Can provide important security properties
  - Authentication/Integrity: A *signs* message with $K_{priv,A}$, anyone with $K_{pub,A}$ can verify message came from A
  - Confidentiality: A *encrypts* message to B with $K_{pub,B}$, B can decrypt with $K_{priv,B}$
- But: how do we know if we can trust a public key?

Public Key Infrastructure (PKI)

Public key crypto is *very* powerful …

- … but the realities of tying public keys to real world identities turn out to be quite hard

- PKI: *Trust distribution* mechanism
  - Authentication via Digital Certificates
- Note: Trust doesn't mean someone is honest, just that they are who they say they are…

Managing Trust

- The most solid level of trust is rooted in our direct personal experience
  - E.g., Alice's trust that Bob is who they say they are
  - Clearly doesn't scale to a global network!

- In its absence, we rely on *delegation*
  - Alice trusts Bob's identity because Charlie attests to it ….
  - …. and Alice trusts Charlie

Managing Trust, con’t

- Trust is not particularly transitive
  - Should Alice trust Bob because she trusts Charlie …
  - … and Charlie vouches for Donna …
  - … and Donna says Eve is trustworthy …
  - … and Eve vouches for Bob’s identity?

- Two models of delegating trust
  - Rely on your set of friends and their friends
    - “Web of trust” -- e.g., PGP
  - Rely on trusted, well-known authorities (*and those they trust…*)
    - “Trusted root” -- e.g., HTTPS

PKI Conceptual framework

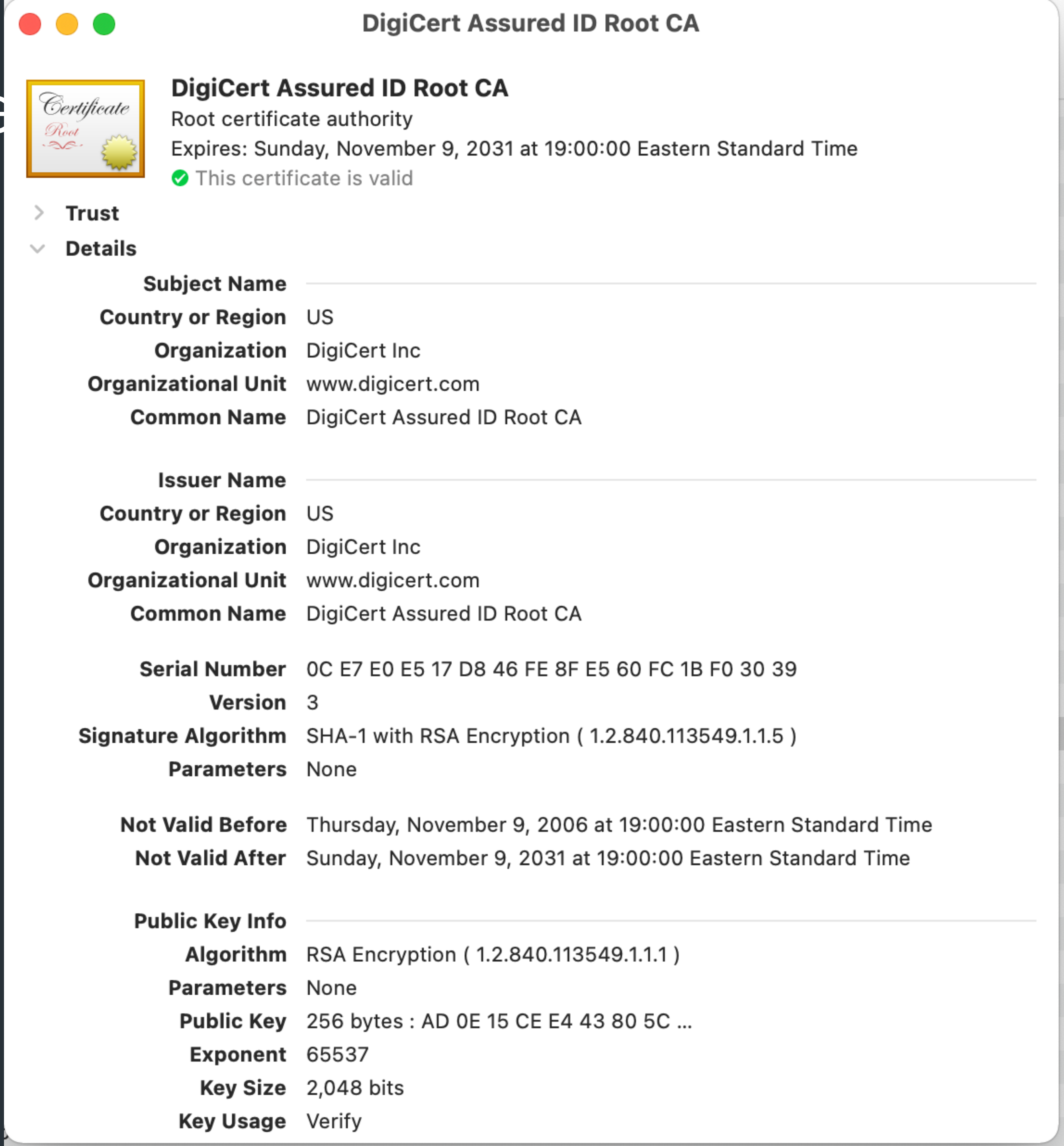
Public keys managed by Certificate Authorities (CAs)

- Everyone knows public key for some root CAs
- To publish a public key for entity X, root CA R *signs* X's public key
  - What this means: CA agrees that this is X's public key
  - Creates a Certificate: {$K_{pub,X}$, signature, metadata}

- Given signature, anyone who knows the root can verify
  - Delegates trust of Kpub,X to CA
  - If you trust the CA, you now trust X

- Root CAs: pre-installed in your system/browser

What's in a ce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Trust
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Country or Region US
Organization DigiCert Inc
Organizational Unit www.digicert.com
Common Name DigiCert Assured ID Root CA
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CA Disig Root R1	certificate	--	Jul 19, 2042 at 05:06:56	System Roots
CA Disig Root R2	certificate	--	Jul 19, 2042 at 05:15:30	System Roots
Certigna	certificate	--	Jun 29, 2027 at 11:13:05	System Roots
Certinomis - Autorité Racine	certificate	--	Sep 17, 2028 at 04:28:59	System Roots
Certinomis - Root CA	certificate	--	Oct 21, 2033 at 05:17:18	System Roots
Certplus Root CA G1	certificate	--	Jan 14, 2038 at 19:00:00	System Roots
Certplus Root CA G2	certificate	--	Jan 14, 2038 at 19:00:00	System Roots
certSIGN ROOT CA	certificate	--	Jul 4, 2031 at 13:20:04	System Roots
Certum CA	certificate	--	Jun 11, 2027 at 06:46:39	System Roots
Certum Trusted Network CA	certificate	--	Dec 31, 2029 at 07:07:37	System Roots

PKI hierarchy

- In reality, hierarchy of trust
- Root CAs sign certificates for Intermediate CAs
- Intermediate CAs sign certificates for general users/sites

The further up the hierarchy, the more protections it needs

- CA's often use Hardware Security Modules (HSMs), other physical protections…
- What happens if a CA is compromised?

PKI Example

Inside the Server's Certificate

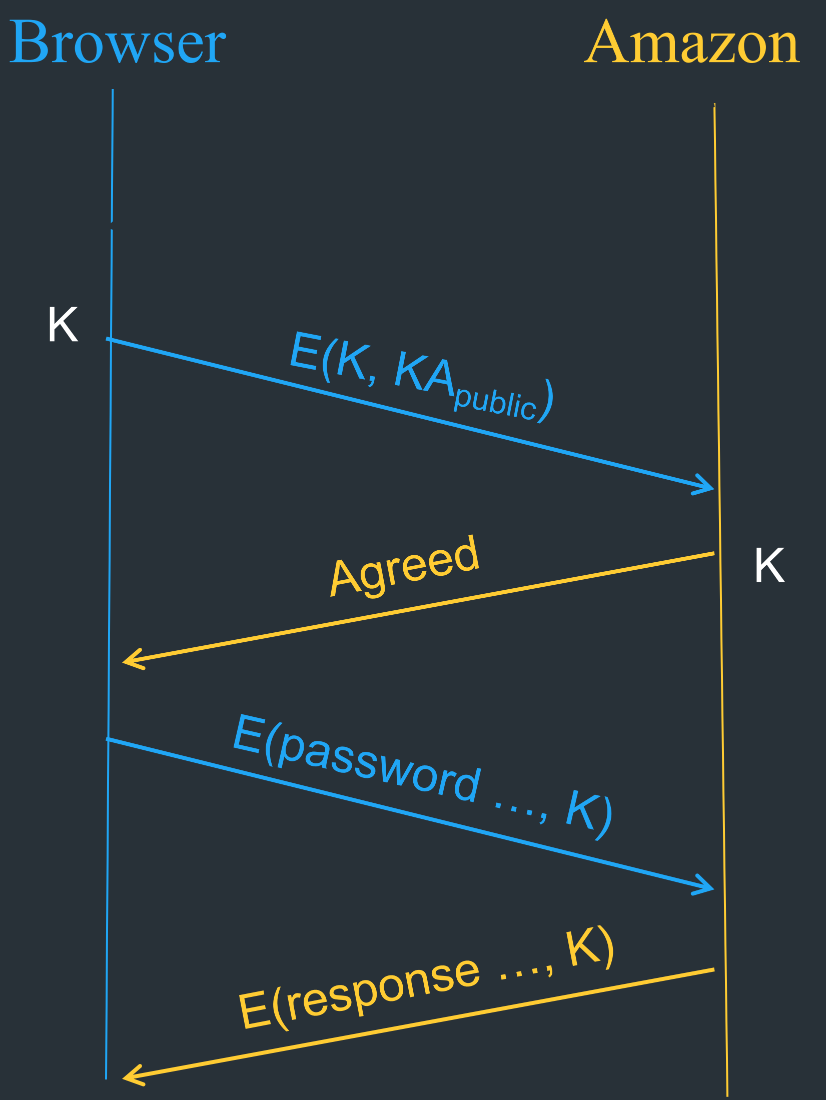
- **Common name: Domain name** for cert (e.g., amazon.com)
- Amazon's **public key**
- A bunch of auxiliary info (physical address, type of cert, expiration time)
- URL to *revocation center* to check for revoked keys
- Name of certificate's **signatory** (who signed it)
- A public-key **signature** of a hash of all this
  - Constructed using the signatory's private RSA key

Validating Amazon's Identity

- Browser retrieves cert belonging to the **signatory**
- If it can't find the cert, then warns the user that site has not been verified
  - And may ask whether to continue
  - *Could* still proceed, just without authentication
- Browser uses public key in signatory's cert to decrypt signature
  - Compares with its own hash of Amazon's cert
- Assuming signature matches, now have high confidence it's indeed Amazon
  - … assuming signatory is trustworthy

HTTPS Connection (SSL/TLS), con't

- Browser constructs a random *session key* K
- Browser encrypts K using Amazon's public key
- Browser sends E(K, KA_{public}) to server
- Browser displays 🔒
- All subsequent communication encrypted w/ symmetric cipher using key K
  - E.g., client can authenticate using a password



When does this break down?

- TLS is hard to implement
- Need to trust the CAs
- Users need to understand warnings

Se

As of July 2021, the Trustworthy Internet Movement estimated the ratio of websites that are vulnerable to TLS attacks.[71]

Survey of the TLS vulnerabilities of the most popular websites

Attacks	Security			
	Insecure	Depends	Secure	Other
Renegotiation attack	0.1% support insecure renegotiation	<0.1% support both	99.2% support secure renegotiation	0.7% no support
RC4 attacks	0.4% support RC4 suites used with modern browsers	6.5% support some RC4 suites	93.1% no support	N/A
TLS Compression (CRIME attack)	>0.0% vulnerable	N/A	N/A	N/A
Heartbleed	>0.0% vulnerable	N/A	N/A	N/A
ChangeCipherSpec injection attack	0.1% vulnerable and exploitable	0.2% vulnerable, not exploitable	98.5% not vulnerable	1.2% unknown
POODLE attack against TLS (Original POODLE against SSL 3.0 is not included)	0.1% vulnerable and exploitable	0.1% vulnerable, not exploitable	99.8% not vulnerable	0.2% unknown
Protocol downgrade	6.6% Downgrade defence not supported	N/A	72.3% Downgrade defence supported	21.0% unknown

Wikipedia table, source: https://www.ssllabs.com/ssl-pulse/

Keychain Access

Search

All Items | Passwords | Secure Notes | My Certificates | Keys | Certificates

Amazon Root CA 1
Root certificate authority
Expires: Saturday, January 16, 2038 at 19:00:00 Eastern Standard Time
This certificate is valid

Name	Kind	Date Modified	Expires	Keychain
AAA Certificate Services	certificate	--	Dec 31, 2028 at 18:59:59	System Roots
AC RAIZ FNMT-RCM	certificate	--	Dec 31, 2029 at 19:00:00	System Roots
Actalis Authentication Root CA	certificate	--	Sep 22, 2030 at 07:22:02	System Roots
AffirmTrust Commercial	certificate	--	Dec 31, 2030 at 09:06:06	System Roots
AffirmTrust Networking	certificate	--	Dec 31, 2030 at 09:08:24	System Roots
AffirmTrust Premium	certificate	--	Dec 31, 2040 at 09:10:36	System Roots
AffirmTrust Premium ECC	certificate	--	Dec 31, 2040 at 09:20:24	System Roots
Amazon Root CA 1	certificate	--	Jan 16, 2038 at 19:00:00	System Roots
Amazon Root CA 2	certificate	--	May 25, 2040 at 20:00:00	System Roots
Amazon Root CA 3	certificate	--	May 25, 2040 at 20:00:00	System Roots
Amazon Root CA 4	certificate	--	May 25, 2040 at 20:00:00	System Roots
ANF Global Root CA	certificate	--	Jun 5, 2033 at 13:45:38	System Roots
Apple Root CA	certificate	--	Feb 9, 2035 at 16:40:36	System Roots
Apple Root CA - G2	certificate	--	Apr 30, 2039 at 14:10:09	System Roots
Apple Root CA - G3	certificate	--	Apr 30, 2039 at 14:19:06	System Roots
Apple Root Certificate Authority	certificate	--	Feb 9, 2025 at 19:18:14	System Roots
Atos TrustedRoot 2011	certificate	--	Dec 31, 2030 at 18:59:59	System Roots
Autoridad de Certificacion Firmaprofesional CIF A62634068	certificate	--	Dec 31, 2030 at 03:38:15	System Roots
Autoridad de Certificacion Raiz del Estado Venezolano	certificate	--	Dec 17, 2030 at 18:59:59	System Roots
Baltimore CyberTrust Root	certificate	--	May 12, 2025 at 19:59:00	System Roots
Buypass Class 2 Root CA	certificate	--	Oct 26, 2040 at 04:38:03	System Roots
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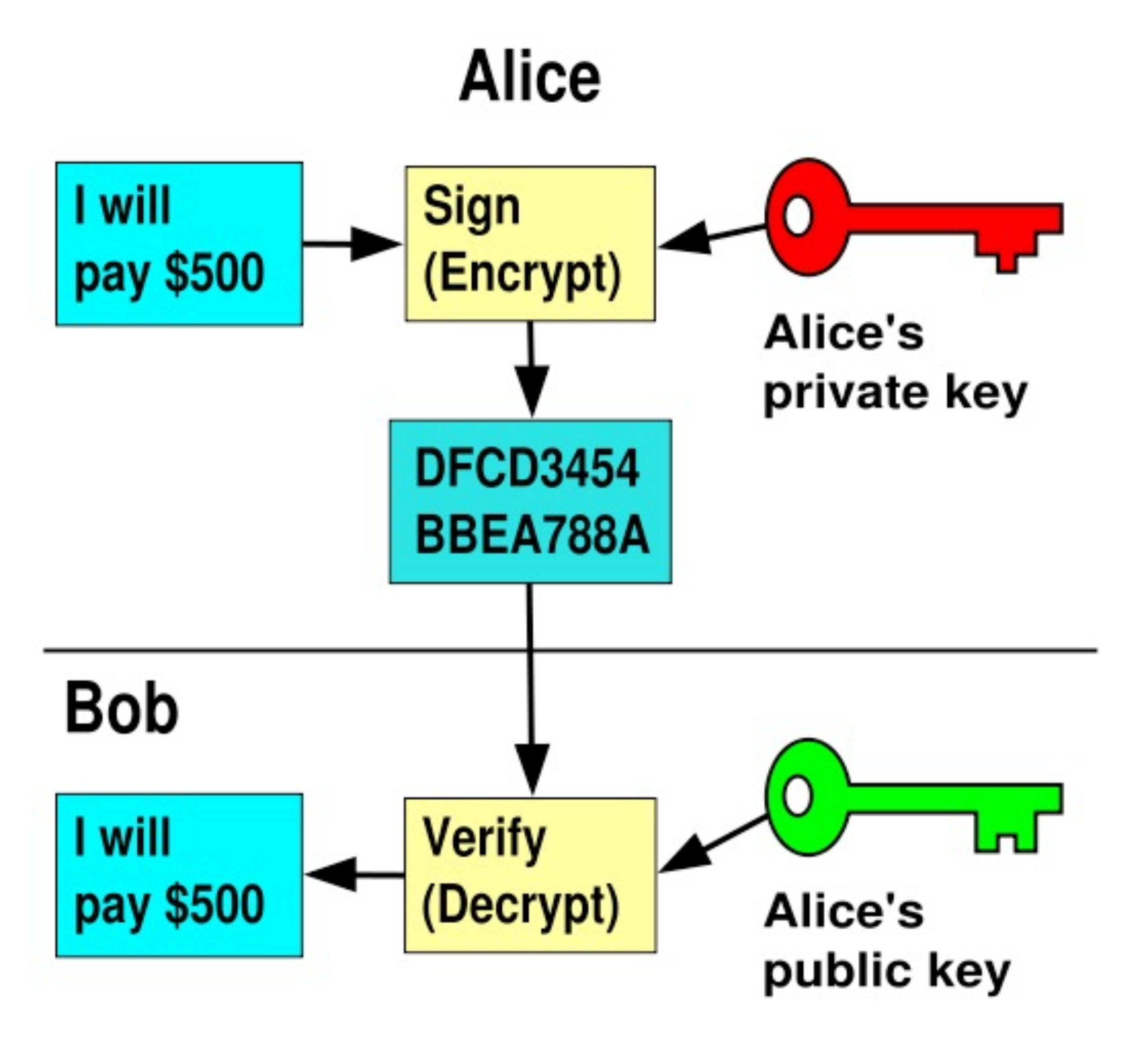
Digital Signatures

- Suppose Alice has published public key K_E
- If she wishes to prove who she is, she can send a message x encrypted with her private key K_D
  - Therefore: anyone w/ public key K_E can recover x, verify that Alice must have sent the message
  - It provides a digital signature
  - Alice can't deny later deny it ⇒ non-repudiation

RSA Crypto & Signatures, con't



Summary of Our Crypto Toolkit

- **If** we can securely distribute a key, then
  - Symmetric ciphers (e.g., AES) offer fast, presumably strong confidentiality
- Public key cryptography can make this easier (can share public keys anywhere)
  - But not as computationally efficient
  - Use public key crypto to exchange session key, which is used for symmetric encryption
  - And not guaranteed secure
    - but **major** result if not

Summary of Our Crypto Toolkit, con't

- Cryptographically strong hash functions provide major building block for integrity (e.g., SHA-256)
  - As well as providing concise digests
  - And providing a way to prove you know something (e.g., passwords) without revealing it (non-invertibility)
  - But: worrisome recent results regarding their strength (MD5, SHA1)
- Public key also gives us signatures
  - Including sender non-repudiation
- Turns out there's a crypto trick based on similar algorithms that allows two parties *who don't know each other's public key* to securely negotiate a secret key even in the presence of eavesdroppers
  - Look up: Diffie-Hellman Key Exchange