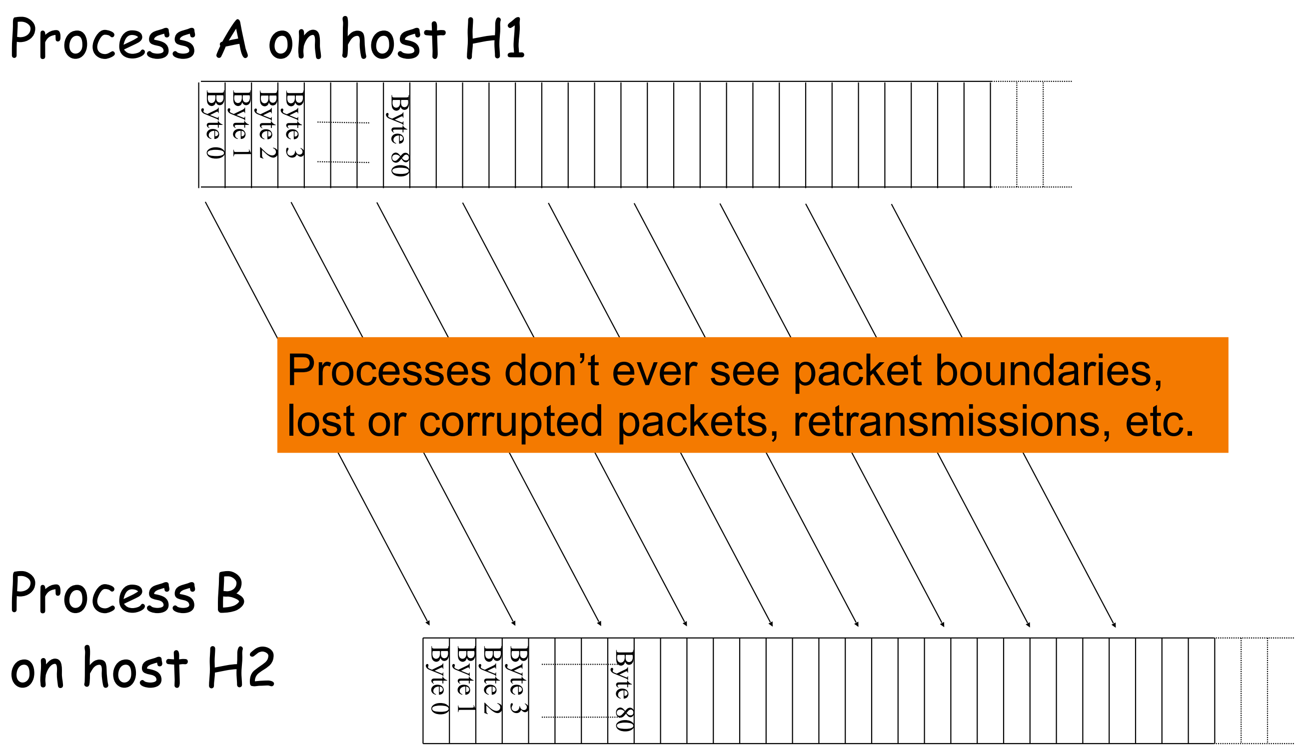
Network Security 4

“Best Effort” is Lame! What to do?

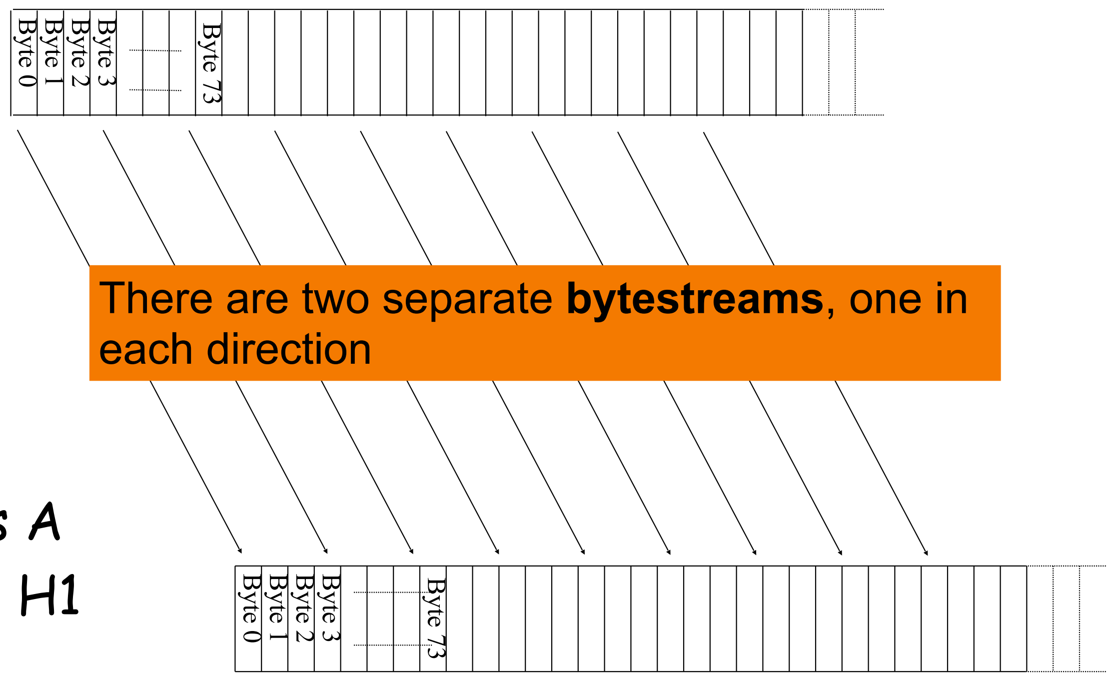
- It’s the job of our Transport (layer 4) protocols to build data delivery services that our apps need out of IP’s modest layer-3 service
- #1 workhorse: TCP (Transmission Control Protocol)
- Service provided by TCP:
  - Connection oriented (explicit set-up / tear-down)
    - End hosts (processes) can have multiple concurrent long-lived communication
  - **Reliable**, in-order, *byte-stream* delivery
    - Robust detection & retransmission of lost data

TCP "Bytestream" Service



Bidirectional communication:

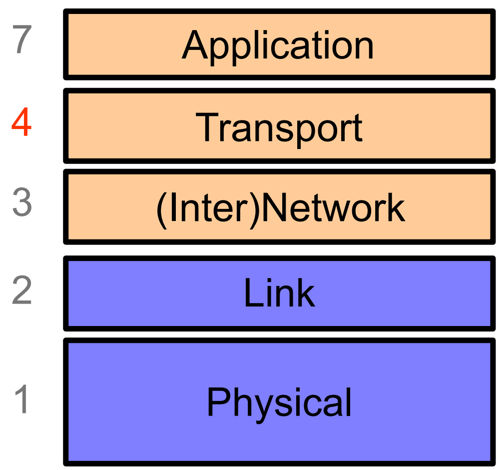
Process B on host H2

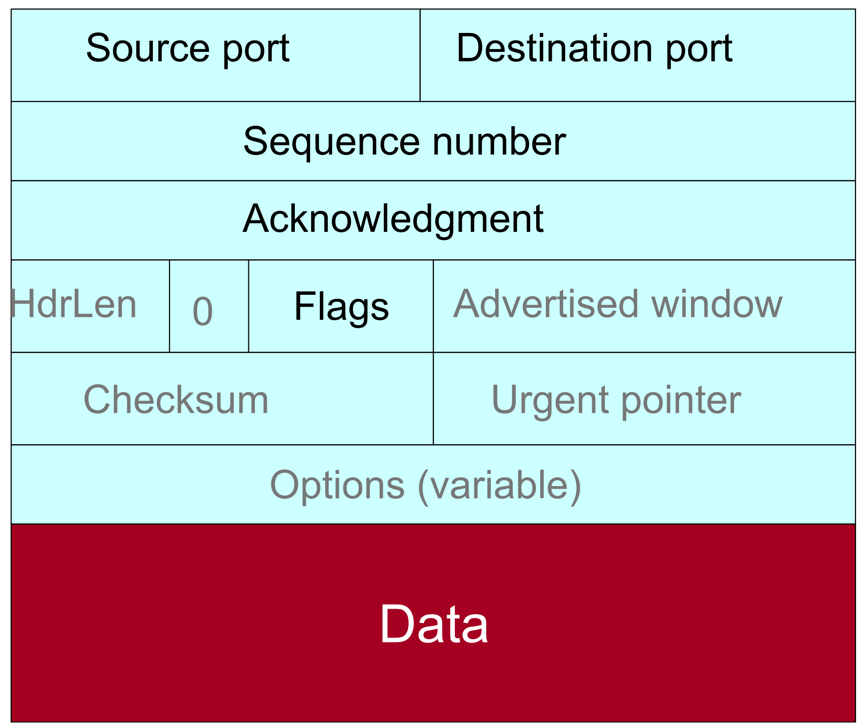


There are two separate **bytestreams**, one in each direction

Process A on host H1

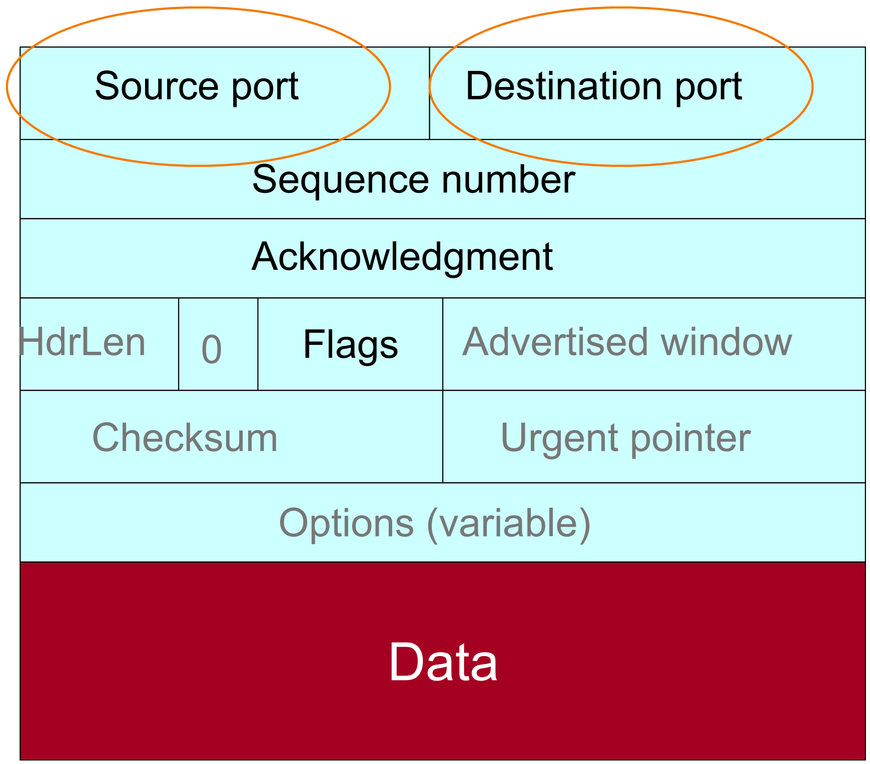
TCP


7 Application
4 Transport
3 (Inter)Network
2 Link
1 Physical

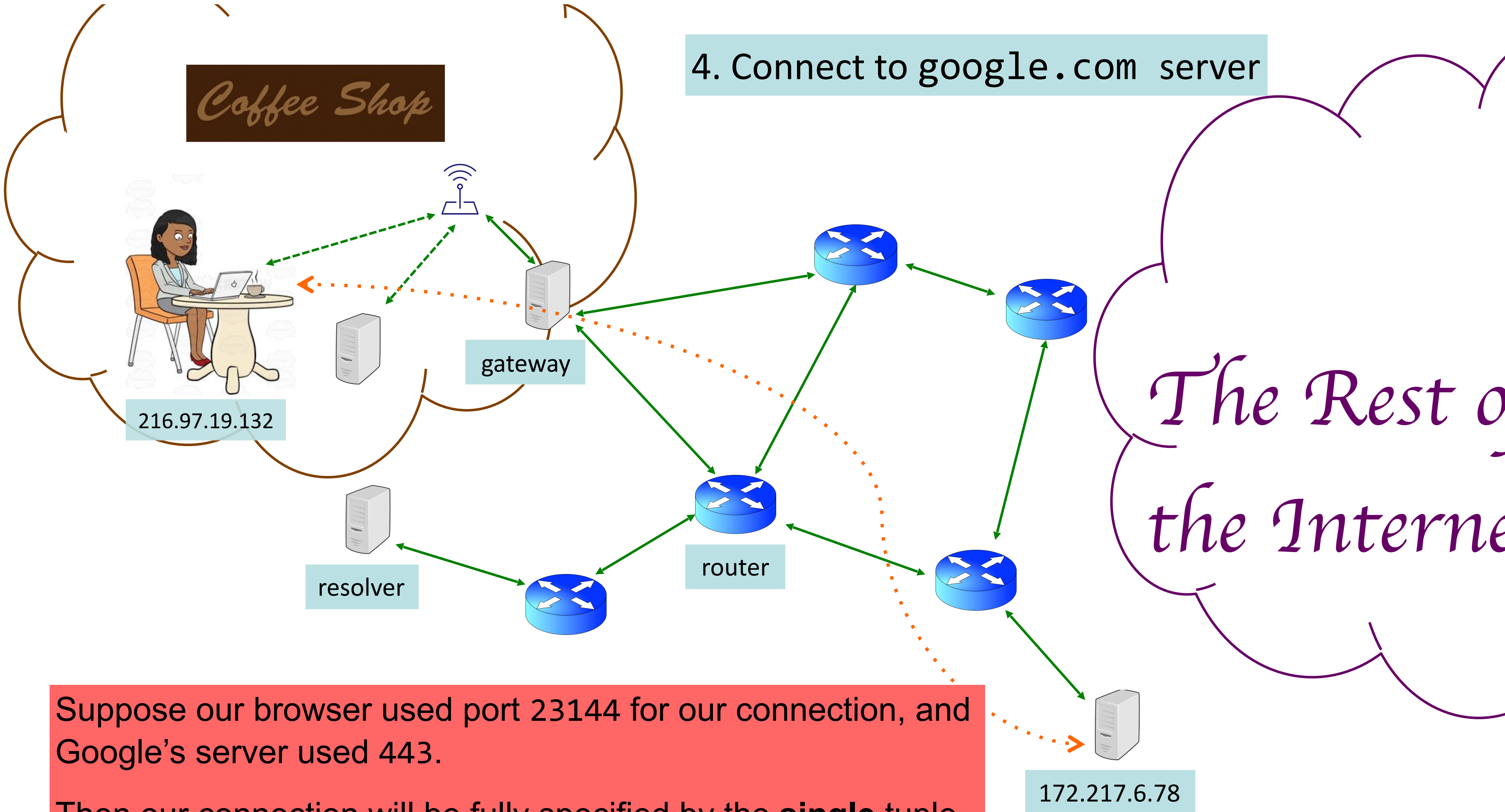

Source port
Destination port
Sequence number
Acknowledgment
HdrLen
0
Flags
Advertised window
Checksum
Urgent pointer
Options (variable)
Data

TCP

These plus IP addresses define
a given connection



4. Connect to `google.com` server

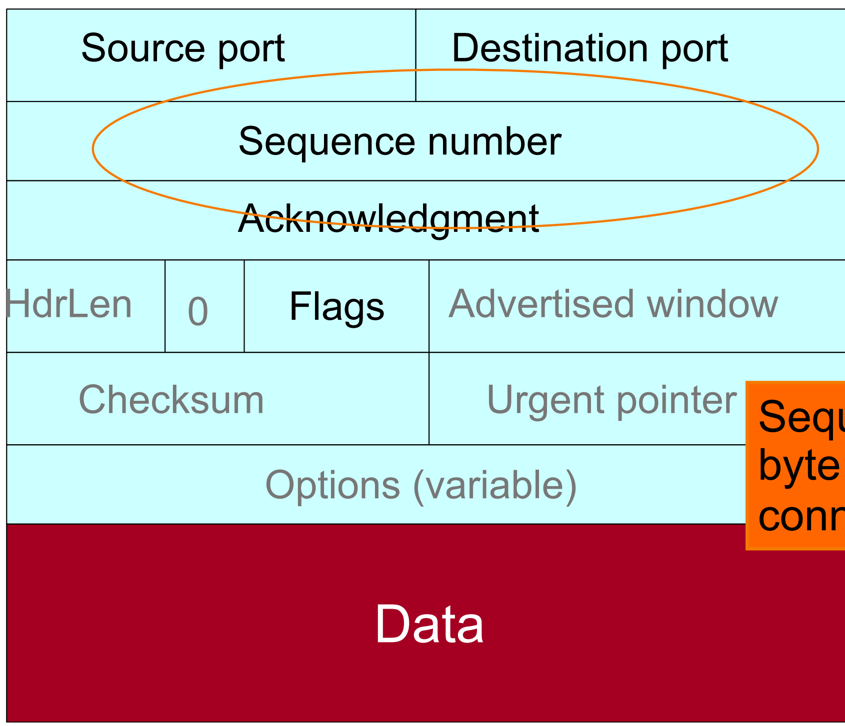


Suppose our browser used port 23144 for our connection, and Google's server used 443.

Then our connection will be fully specified by the **single** tuple `<216.97.19.132, 23144, 172.217.6.78, 443,TCP>`

TCP

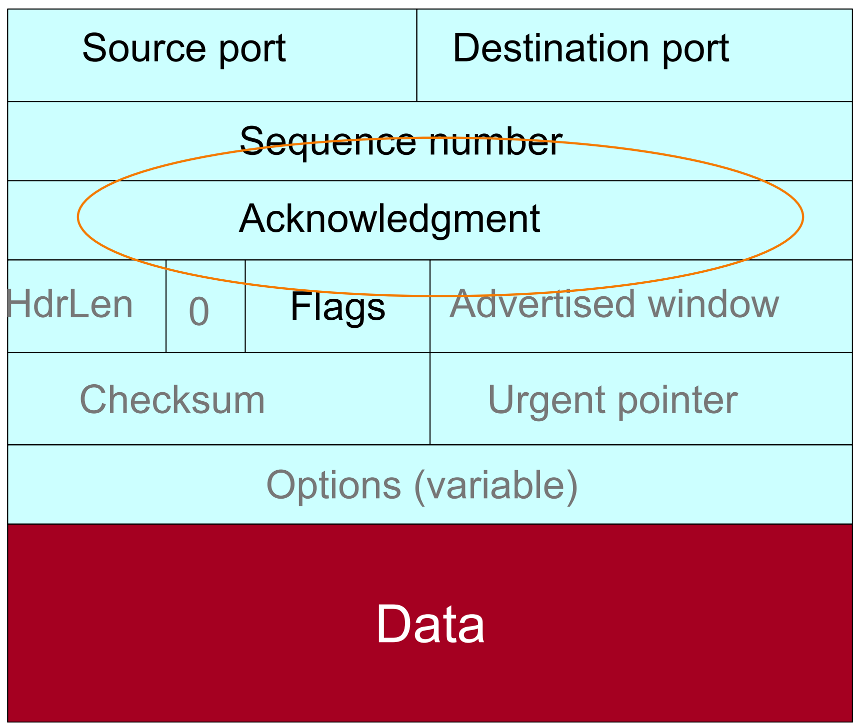
Used to order data in the connection: client program receives data ***in order***



Sequence number assigned to start of byte stream is picked when connection begins; **doesn't** start at 0

TCP

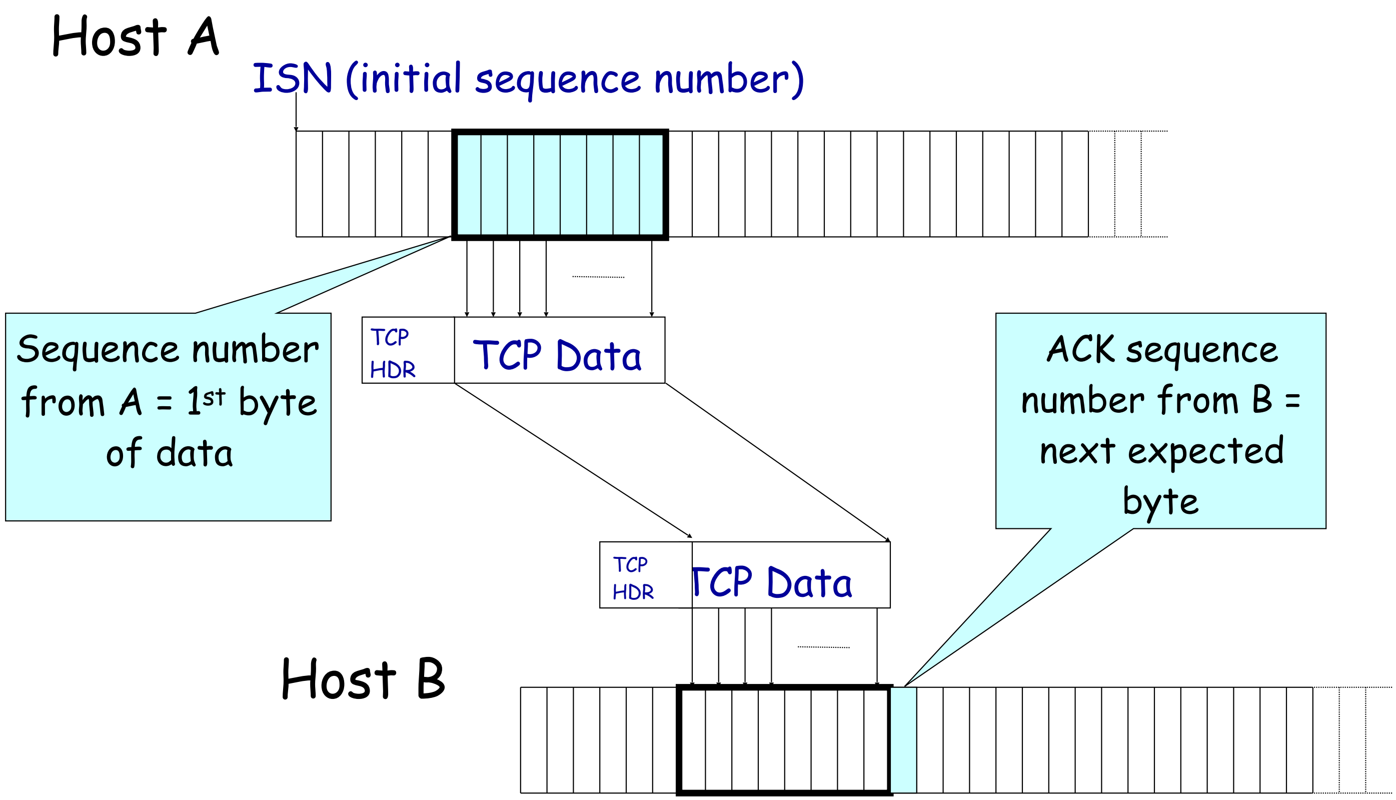
Used to say how much data has been received



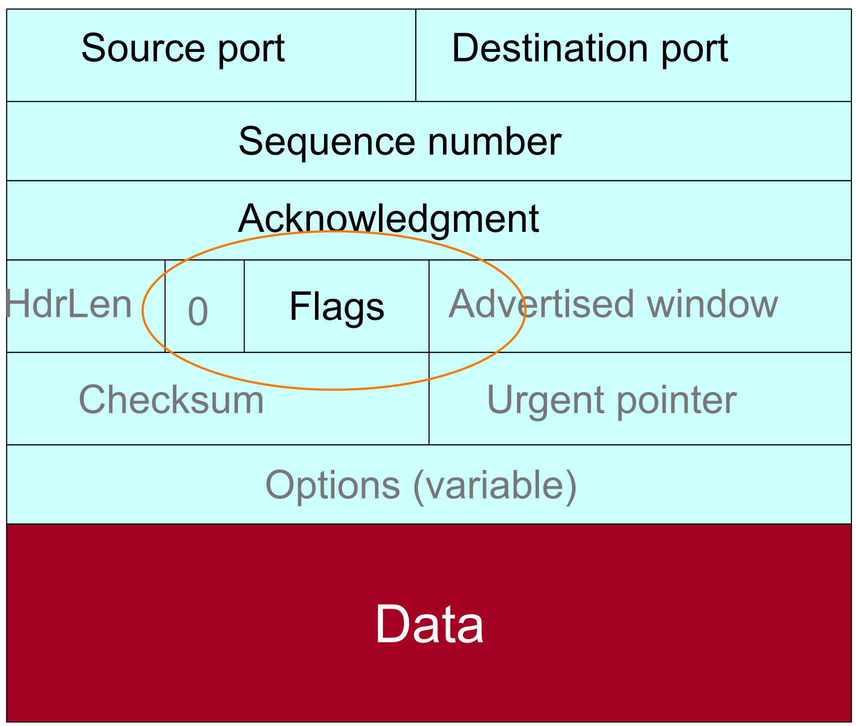
Acknowledgment gives seq # **just beyond** highest seq. received **in order**.

If sender successfully sends **N** bytestream bytes starting at seq **S** then "ack" for that will be **S+N**.

Sequence Numbers



TCP



Flags have different meaning:

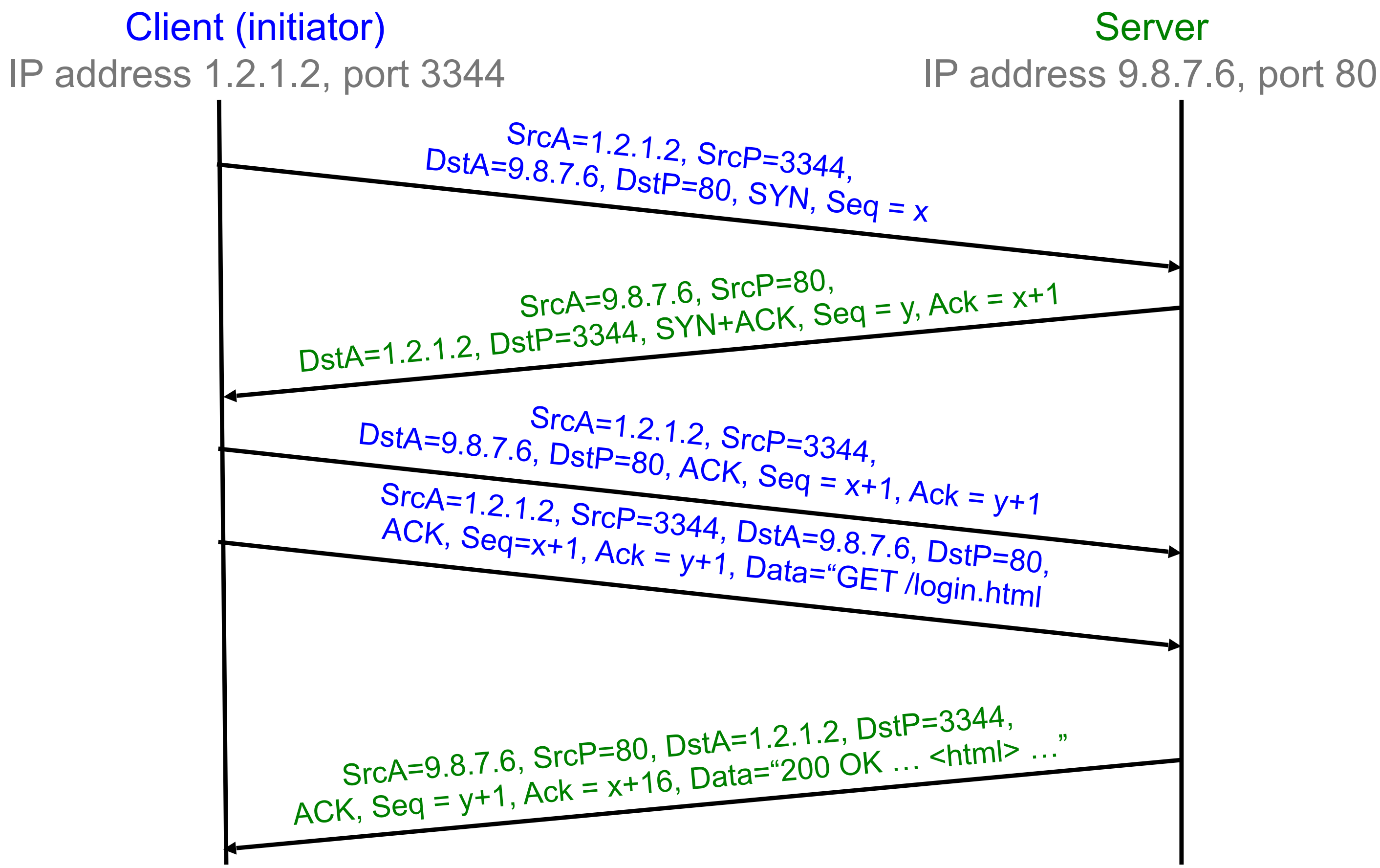
SYN: Synchronize,
used to initiate a connection

ACK: Acknowledge,
used to indicate
acknowledgement of data

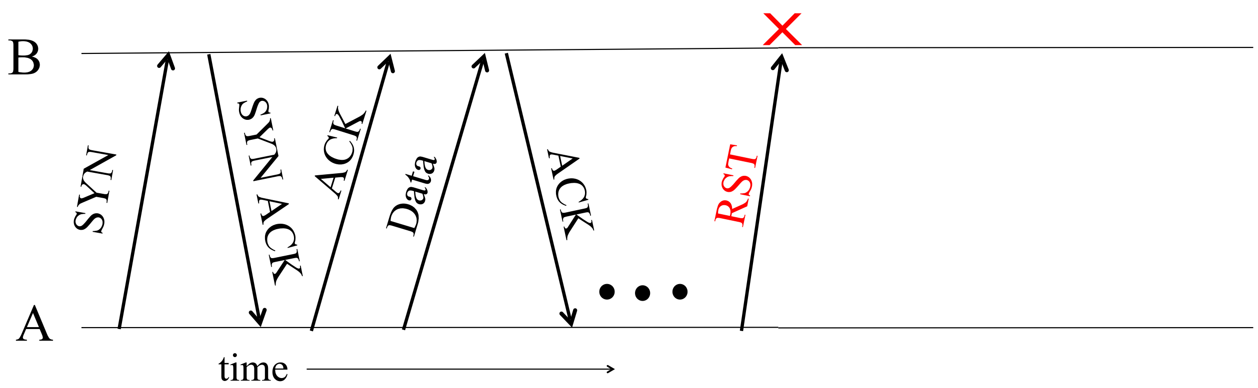
FIN: Finish,
used to indicate no more data
will be sent (but can still receive
and acknowledge data)

RST: Reset,
used to terminate the
connection completely

TCP Conn. Setup & Data Exchange



Abrupt Termination



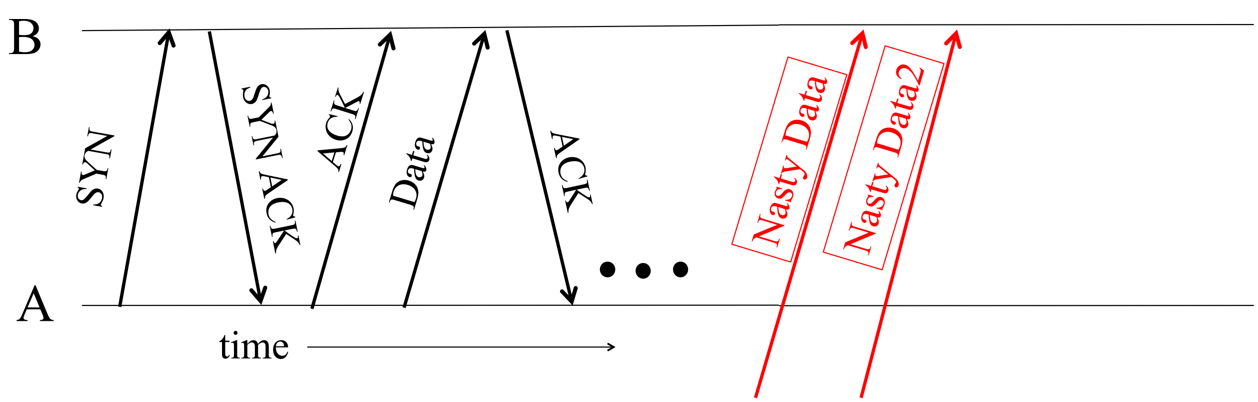
- A sends a TCP packet with RESET (**RST**) flag to B
  - E.g., because app. process on A crashed
  - (Could instead be that B sends a RST to A)
- Assuming that the sequence numbers in the **RST** fit with what B expects, That's It:
  - B's user-level process receives: `ECONNRESET`
  - No further communication on connection is possible

Disruption

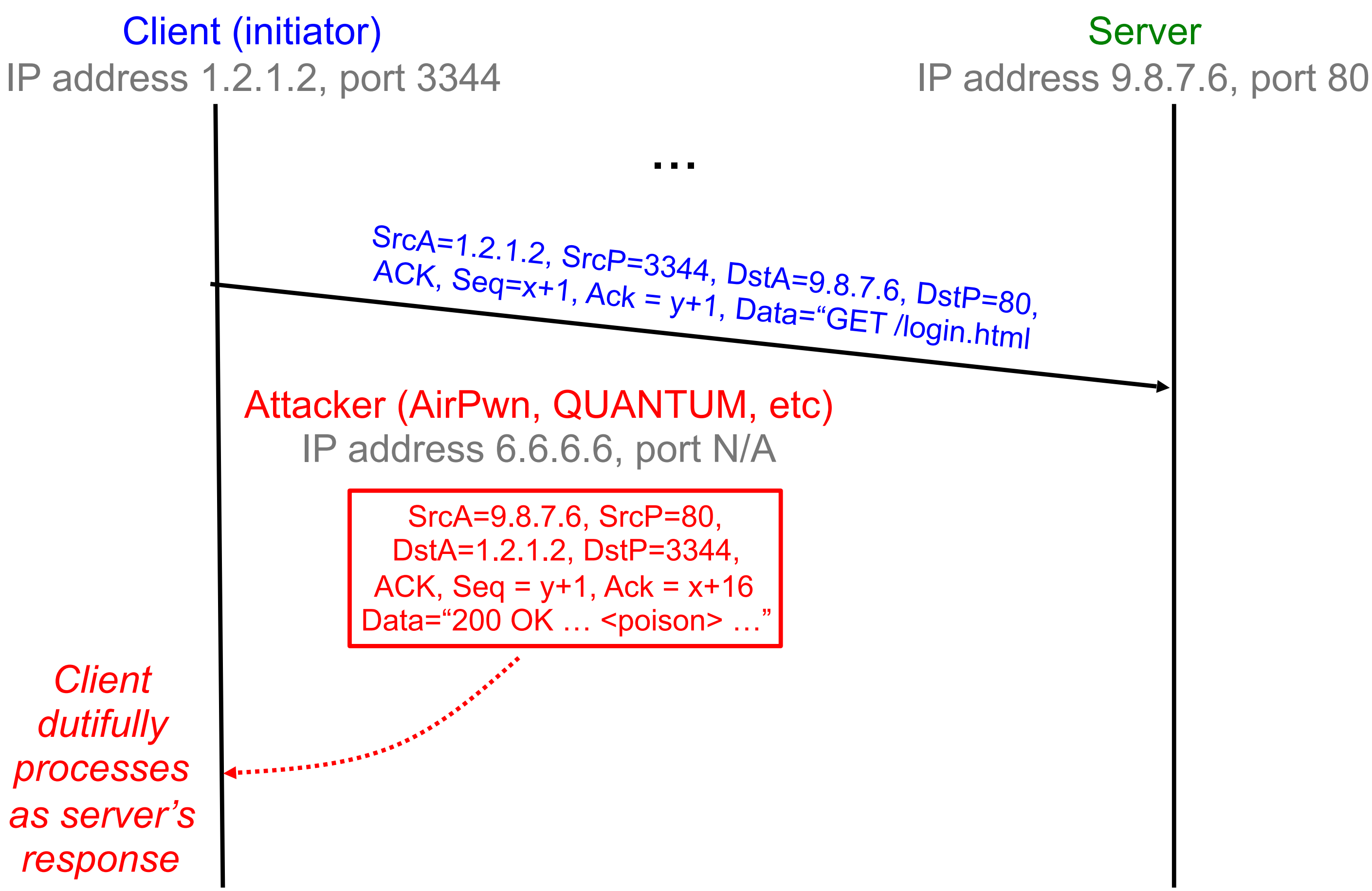
- Normally, TCP finishes ("closes") a connection by each side sending a `FIN` control message
  - Reliably delivered, since other side must ack
- But: if a TCP endpoint finds unable to continue (process dies; info from other "peer" is inconsistent), it abruptly terminates by sending a **RST** control message
  - Unilateral
  - Takes effect immediately (no ack needed)
  - Only accepted by peer if has correct* sequence number

TCP Threat: Data Injection

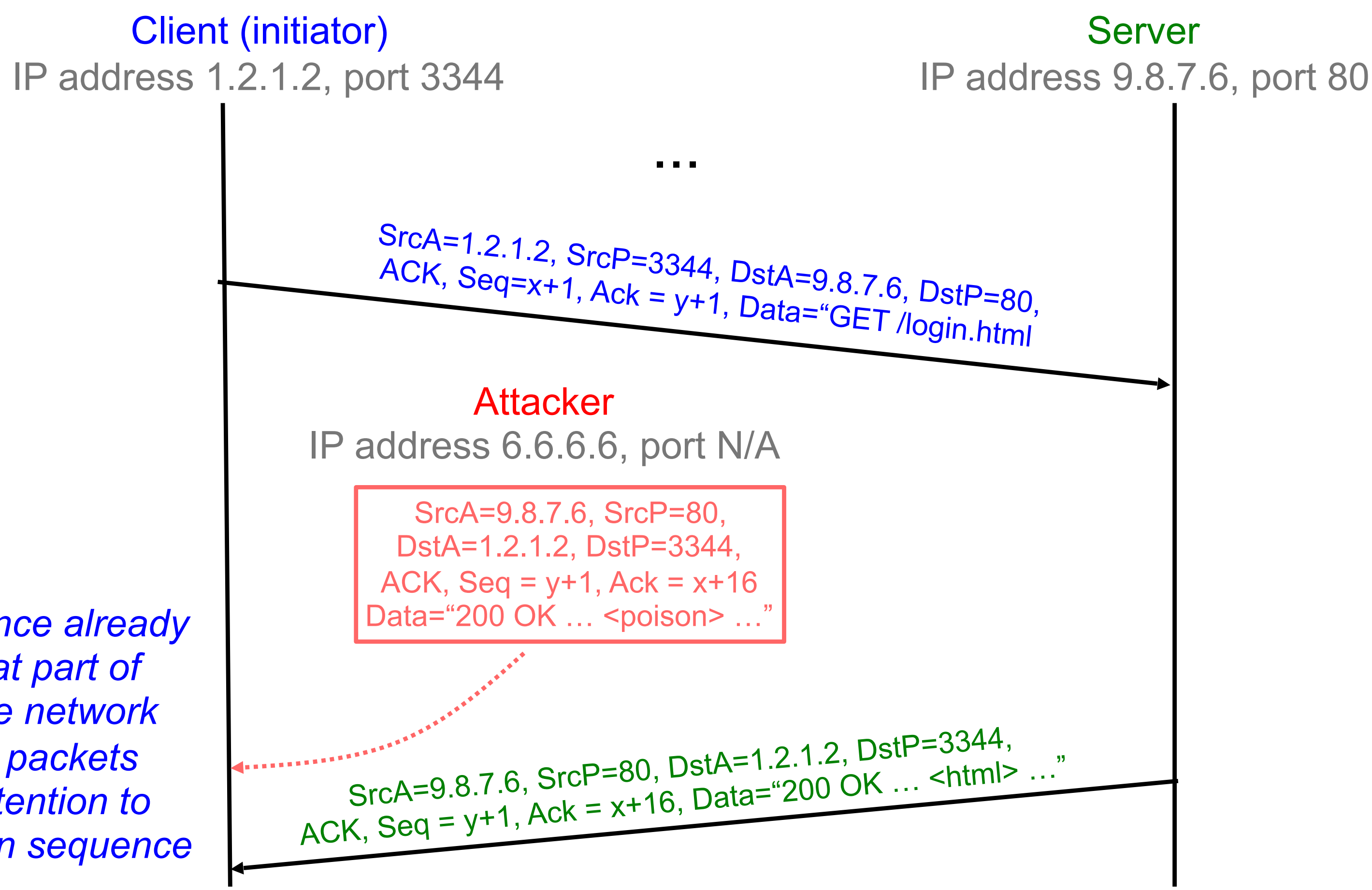
- If attacker knows ports & sequence numbers (e.g., on-path attacker), attacker can inject data into any TCP connection
  - Receiver B is *none the wiser!*
- Termed TCP connection hijacking (or "*session hijacking*")
  - A general means to take over an already-established connection!
- We are toast if an attacker can see our TCP traffic!
  - Because then they immediately know the port & sequence numbers



TCP Data Injection



TCP Data Injection



Client ignores since already processed that part of bytestream: the network can duplicate packets so only pay attention to the first version in sequence

TCP Threat: Disruption aka RST injection

- The attacker can also inject RST packets instead of payloads
  - TCP clients must respect RST packets and stop all communication
    - Because its a real world error recovery mechanism
    - So "just ignore RSTs don't work"
- Who uses this?
  - China: The Great Firewall does this to TCP requests
  - A long time ago: Comcast, to block BitTorrent uploads
  - Some intrusion detection systems: To hopefully mitigate an attack in progress

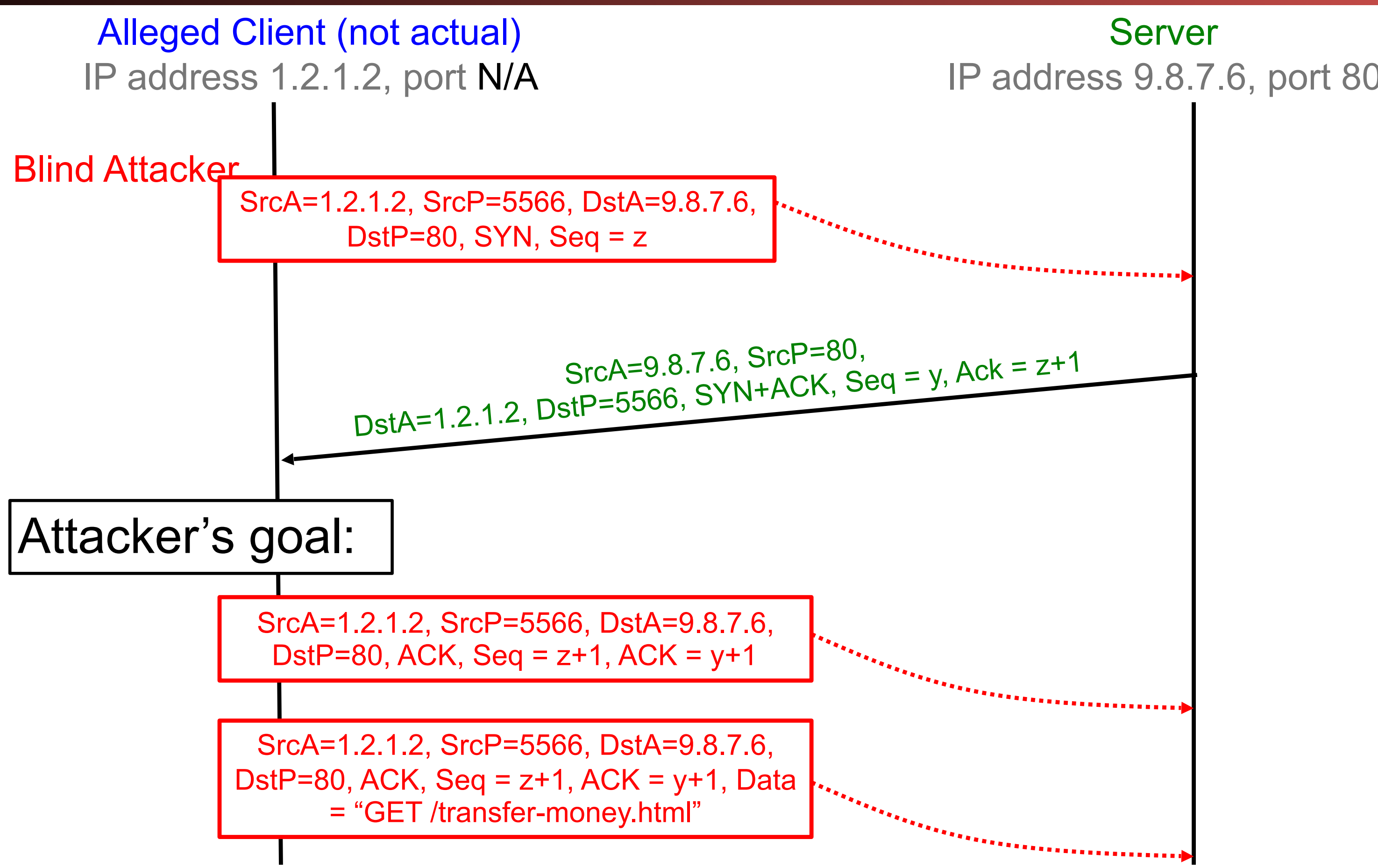
TCP Threat: Blind Hijacking

- Is it possible for an off-path attacker to inject into a TCP connection even if they can't see our traffic?
- YES: if somehow they can infer or guess the port and sequence numbers

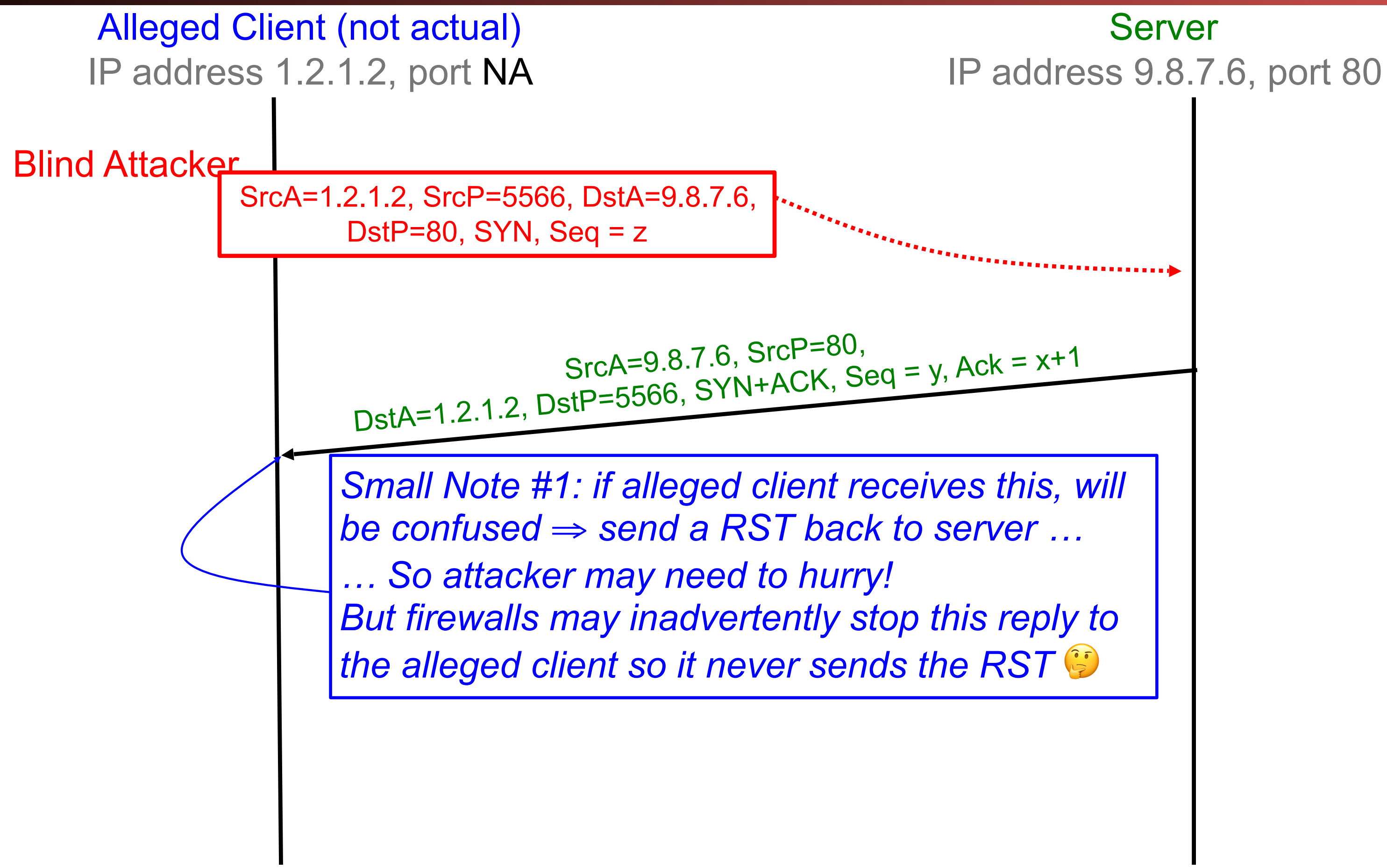
TCP Threat: Blind Spoofing

- Is it possible for an off-path attacker to create a fake TCP connection, even if they can't see responses?
- YES: if somehow they can infer or guess the TCP initial sequence numbers
- Why would an attacker want to do this?
  - Perhaps to leverage a server's trust of a given client as identified by its IP address
  - Perhaps to frame a given client so the attacker's actions during the connections can't be traced back to the attacker

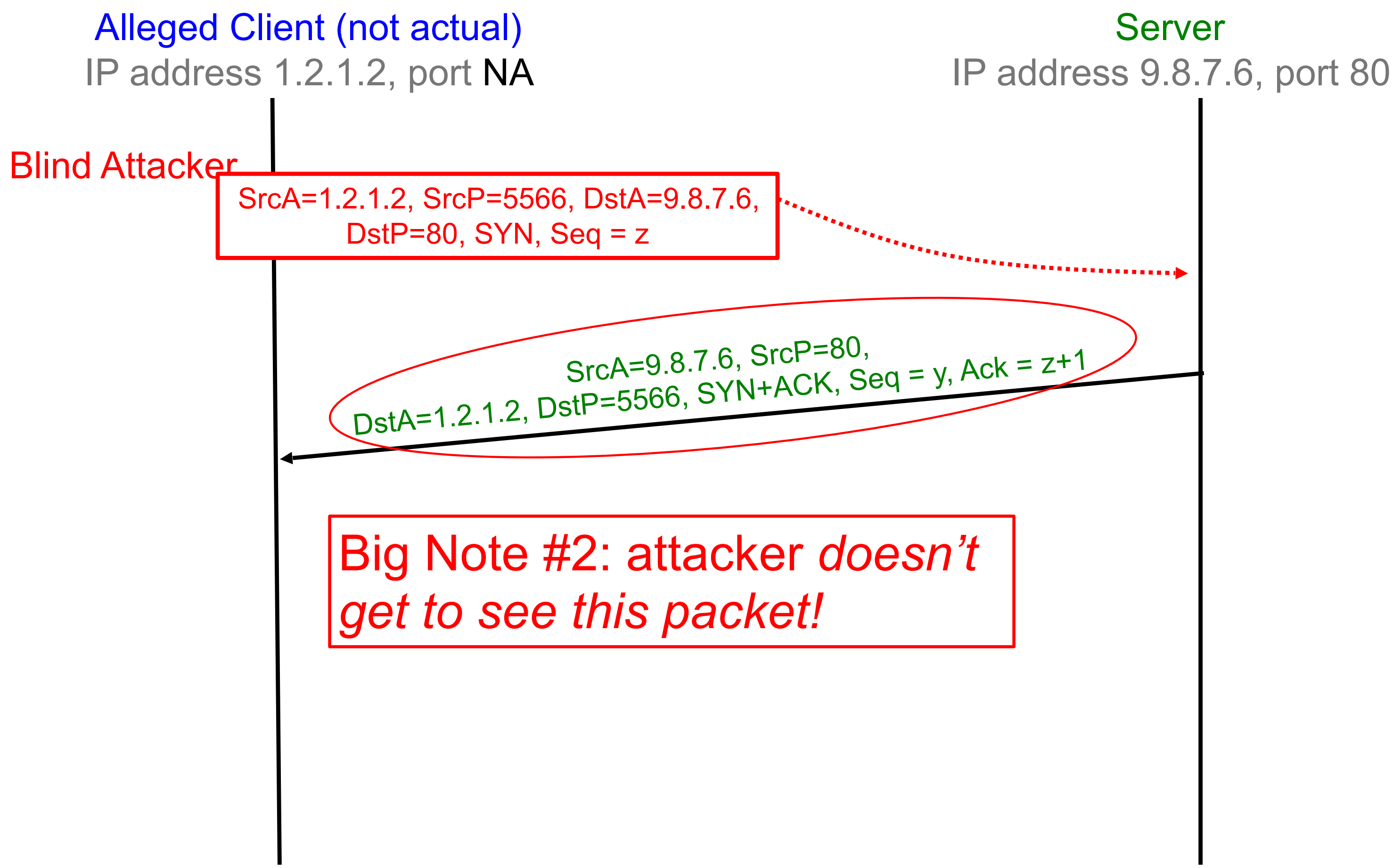
Blind Spoofing on TCP Handshake



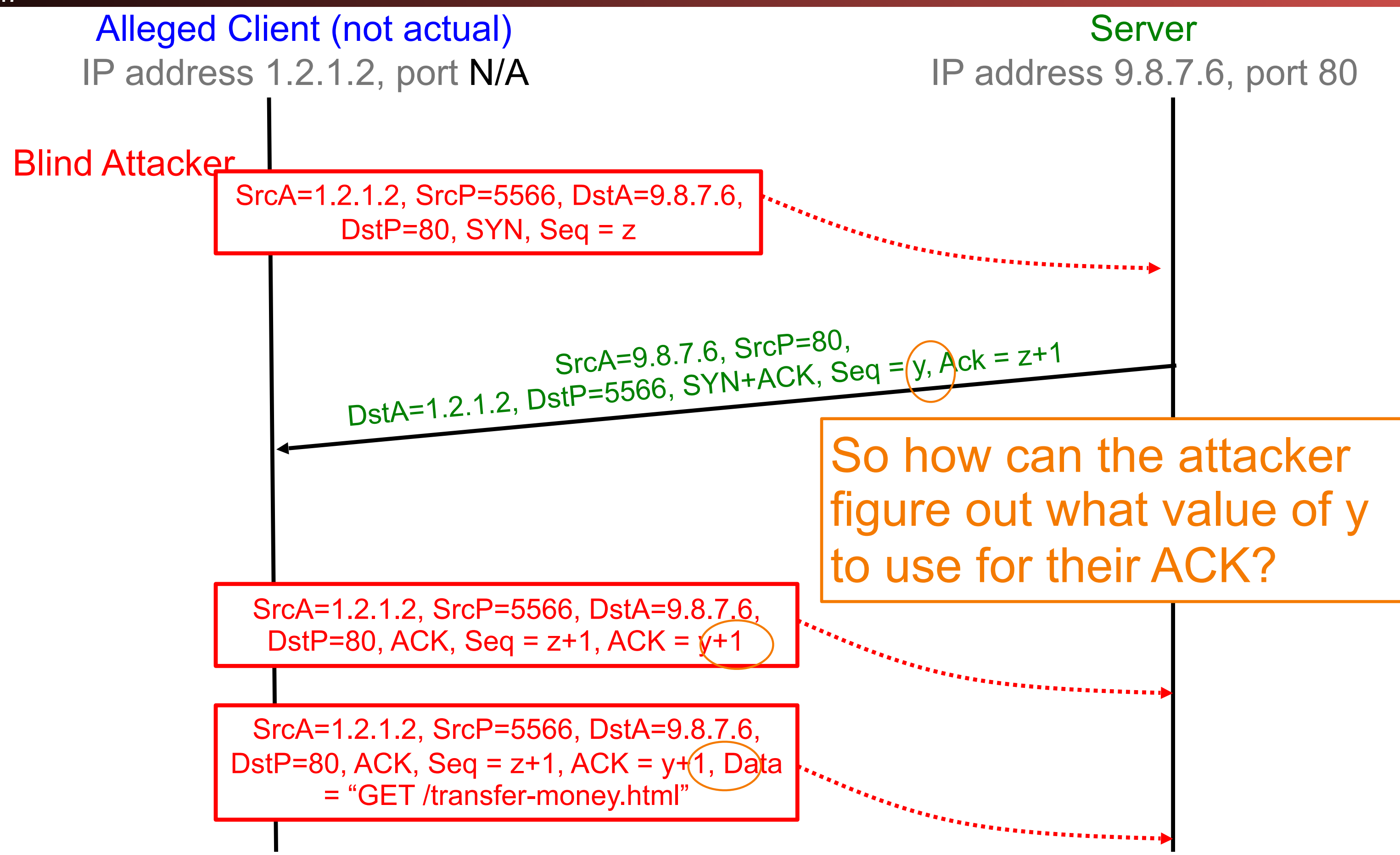
Blind Spoofing on TCP Handshake



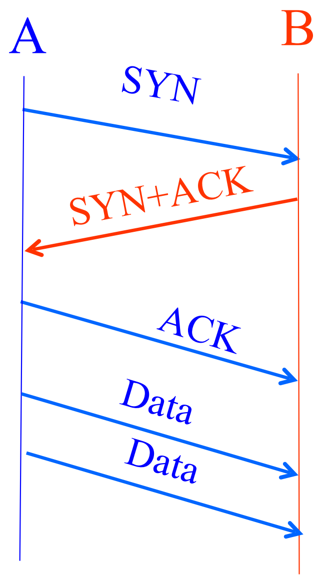
Blind Spoofing on TCP Handshake



Blind Spoofing on TCP Handshake



Reminder: Establishing a TCP Connection



Each host tells its *Initial Sequence Number* (ISN) to the other host.

(Spec says to pick based on local clock)

Hmm, any way for the attacker to know *this?*

How Do We Fix This?

Use a (Pseudo)-*Random* ISN

Sure – make a non-spoofed connection *first*, and see what server used for ISN y then!

Summary of TCP Security Issues

- An attacker who can observe your TCP connection can manipulate it:
  - Forcefully terminate by forging a RST packet
  - Inject (spoof) data into either direction by forging data packets
  - Works because they can include in their spoofed traffic the correct sequence numbers (both directions) and TCP ports
  - Remains a major threat today

Summary of TCP Security Issues

- An attacker who can observe your TCP connection can manipulate it:
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  - Inject (spoof) data into either direction by forging data packets
  - Works because they can include in their spoofed traffic the correct sequence numbers (both directions) and TCP ports
  - Remains a major threat today
- If attacker could predict the ISN chosen by a server, could “blind spoof” a connection to the server
  - Makes it appear that host ABC has connected, and has sent data of the attacker’s choosing, when in fact it hasn’t
  - Undermines any security based on trusting ABC’s IP address
  - Allows attacker to “frame” ABC or otherwise avoid detection
  - Fixed (mostly) today by choosing random ISNs

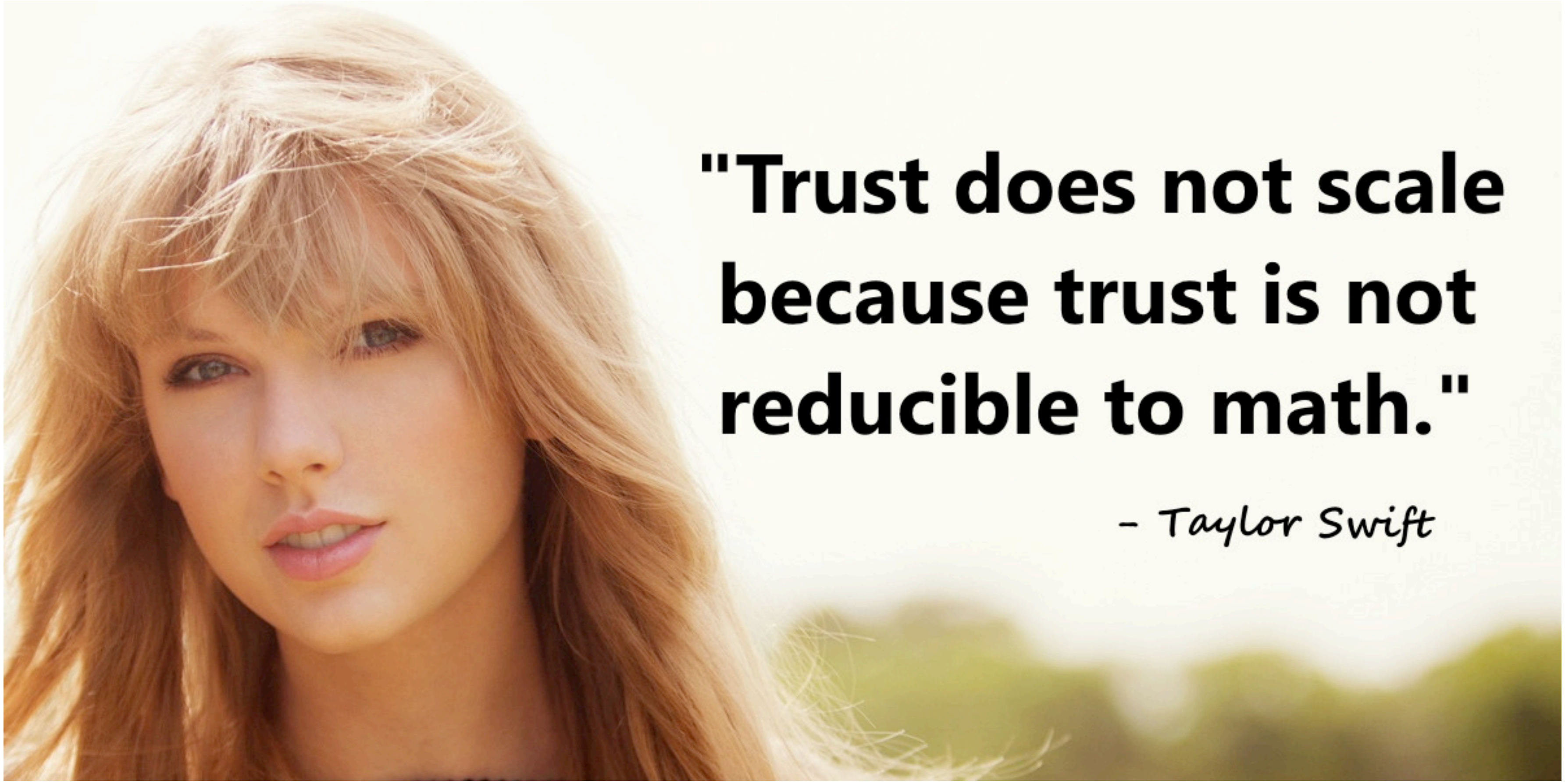
But wasn't fixed completely...

- CVE-2016-5696
  - "Off-Path TCP Exploits: Global Rate Limit Considered Dangerous" Usenix Security 2016
  - https://www.usenix.org/conference/usenixsecurity16/technical-sessions/presentation/cao
- Key idea:
  - RFC 5961 added some global rate limits that acted as an ***information leak***:
    - Could determine if two clients were communicating on a given port
    - Could determine if you could correctly guess the sequence #s for this communication
      - Required a third host to probe this and at the same time spoof packets
  - Once you get the sequence #s, you can then inject arbitrary content into the TCP stream (d'oh)

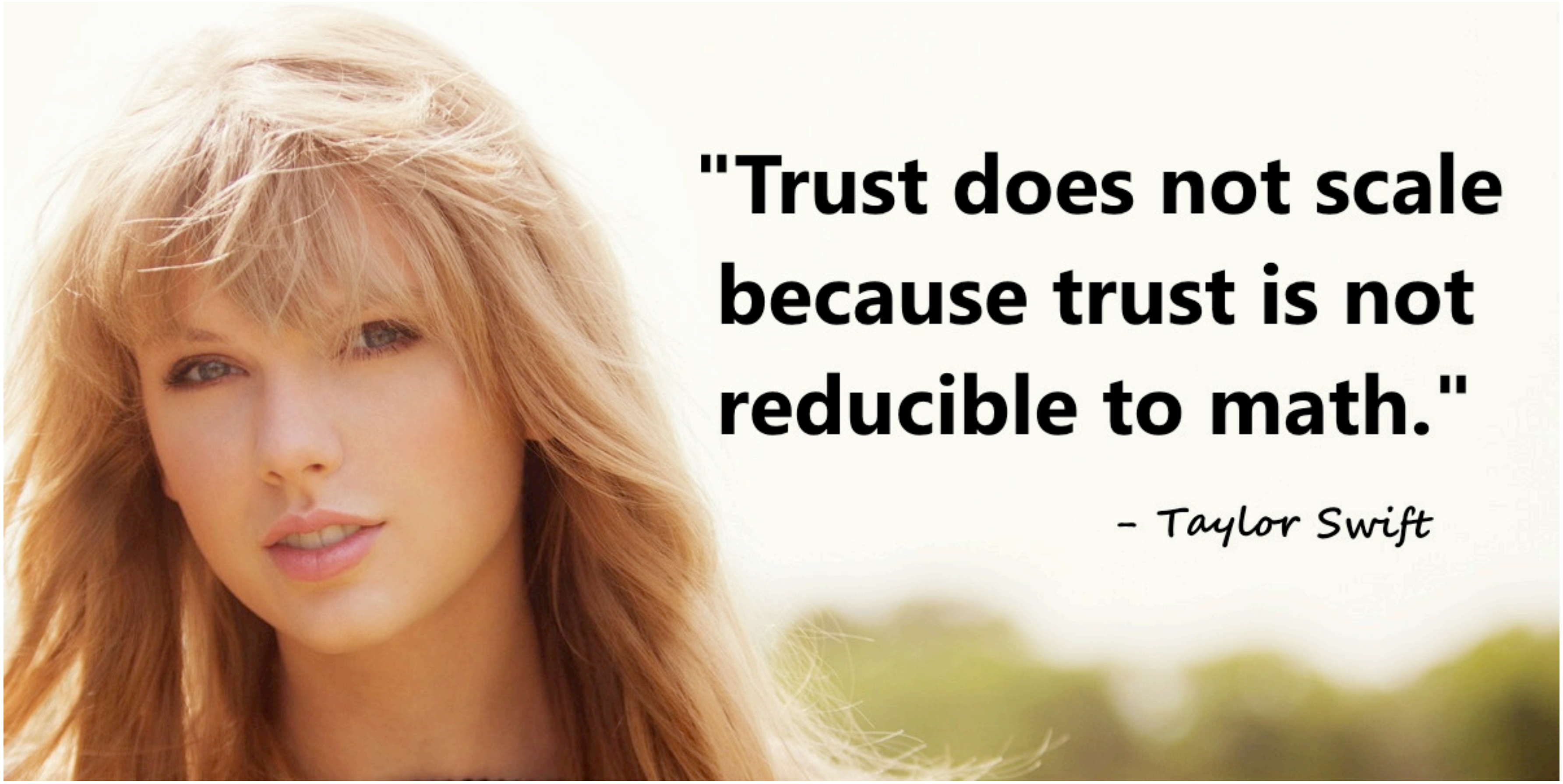
And the Firewall...

- Attackers can't attack what they can't talk to!
  - If you don't accept ***any*** communication from an attacker, you can't be exploited
- The firewall is a network device (or software filter on the end host) that restricts communication
  - Primarily just by IP/Port or network/Port
- Default deny:
  - By default, disallow any contact to this host on any port
- Default allow:
  - By default, allow any contact to this host on any port
- More when we discuss Intrusion Detection next week

Theme of The Rest Of This Lecture...



But Trust Can Be Delegated…



The Rest of Today's Lecture:

- Applying crypto technology in practice
- Two simple abstractions cover 80% of the use cases for crypto:
  - "Sealed blob": Data that is encrypted and authenticated under a particular key
  - Secure channel: Communication channel that can't be eavesdropped on or tampered with
- Today: TLS – a secure channel
  - In network parlance, this is an "application layer" protocol but…
  - designed to have any application over it, so really "layer 6.5" is a better description

Building Secure End-to-End Channels

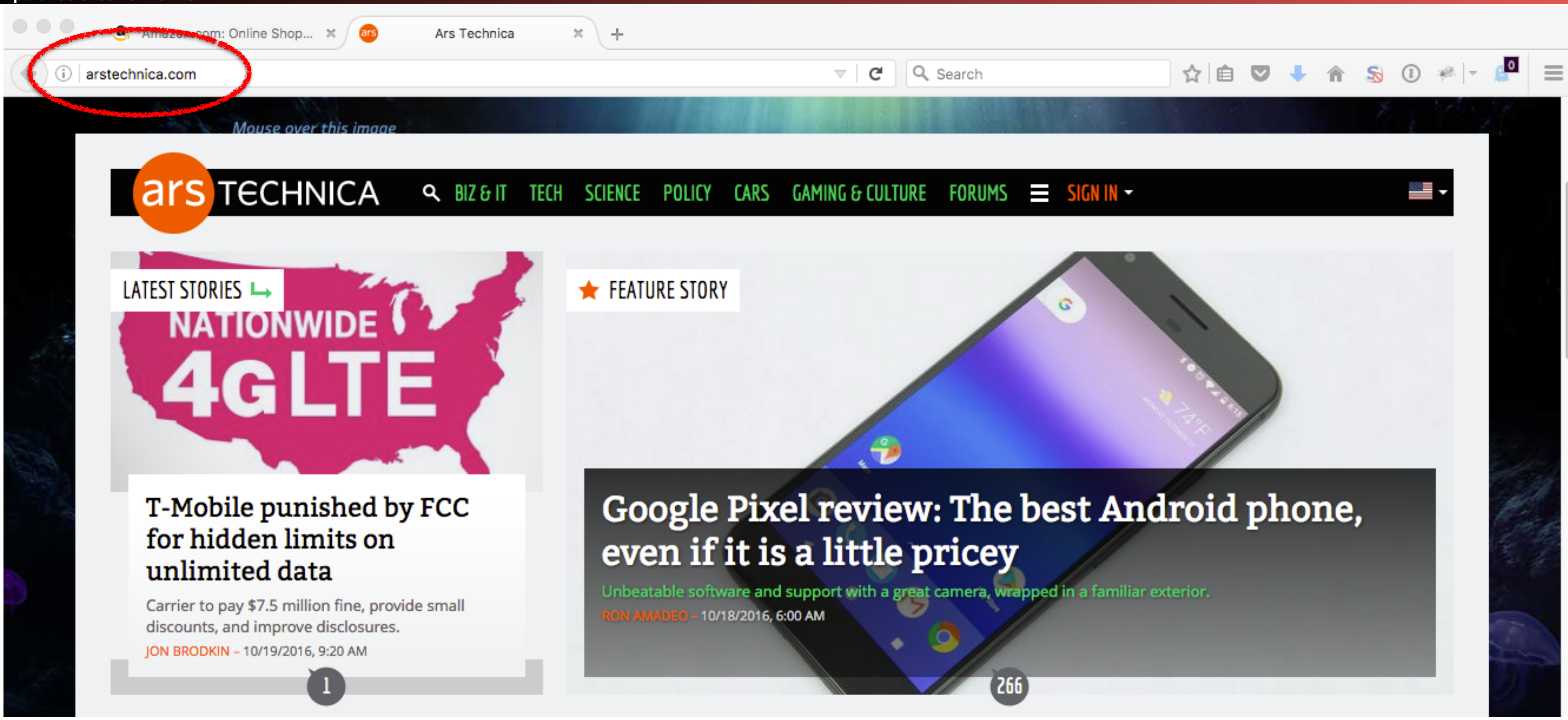
- End-to-end = communication protections achieved all the way from originating client to intended server
  - With no need to trust intermediaries
- Dealing with threats:
  - Eavesdropping?
    - Encryption (including session keys)
  - Manipulation (injection, MITM)?
    - Integrity (use of a MAC); replay protection
  - Impersonation?
    - Signatures

(What's missing?
Availability …)

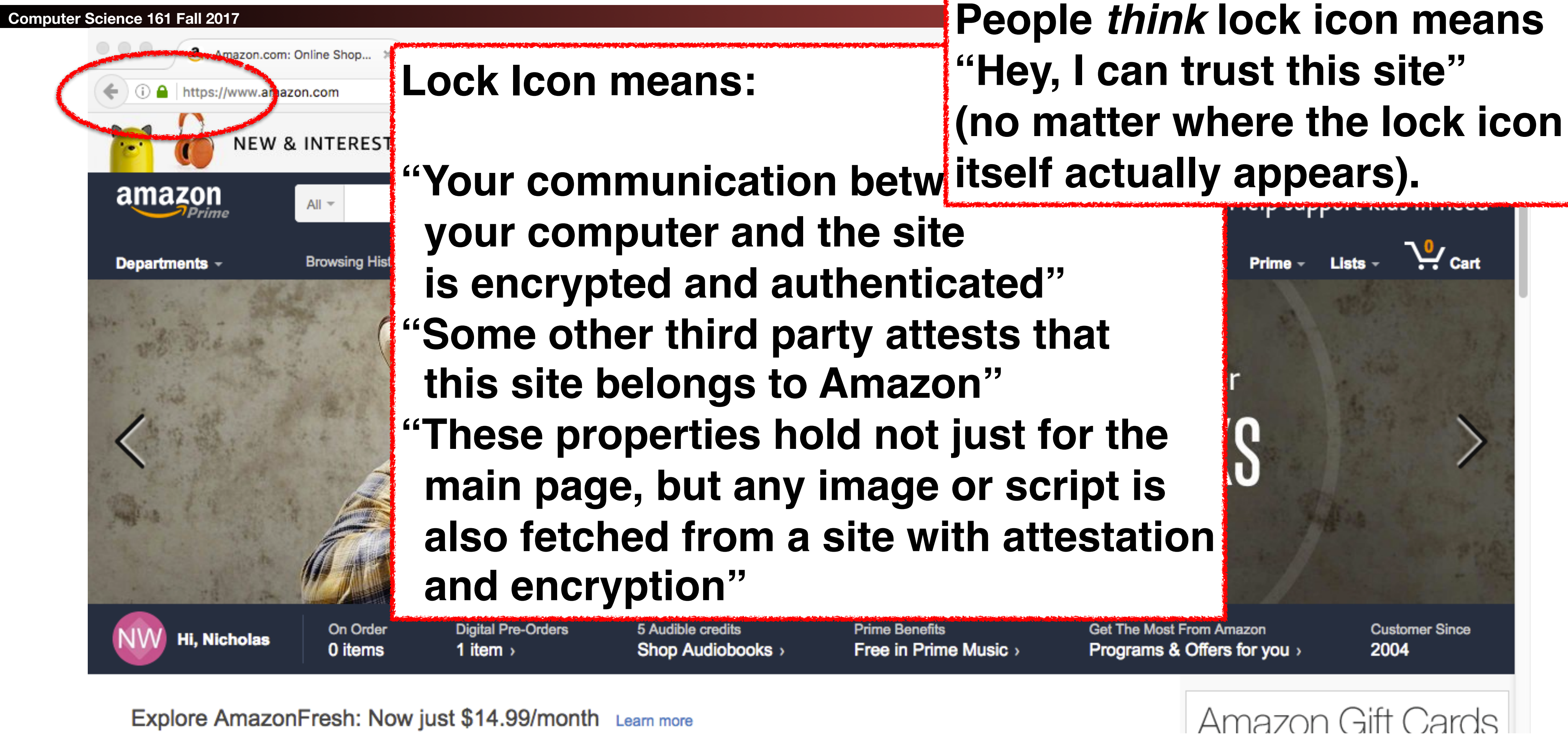
Building A Secure End-to-End Channel: SSL/TLS

- SSL = Secure Sockets Layer (predecessor)
- TLS = Transport Layer Security (standard)
  - Both terms used interchangeably
- Security for any application that uses TCP
  - Secure = encryption/confidentiality + integrity + authentication (of server, but not of client)
- Multiple uses
  - Puts the ‘s’ in “https”
  - Secures mail sent between servers (STARTTLS)
  - Virtual Private Networks

An “Insecure” Web Page



A “Secure” Web Page



Lock Icon means:

“Your communication between your computer and the site is encrypted and authenticated”

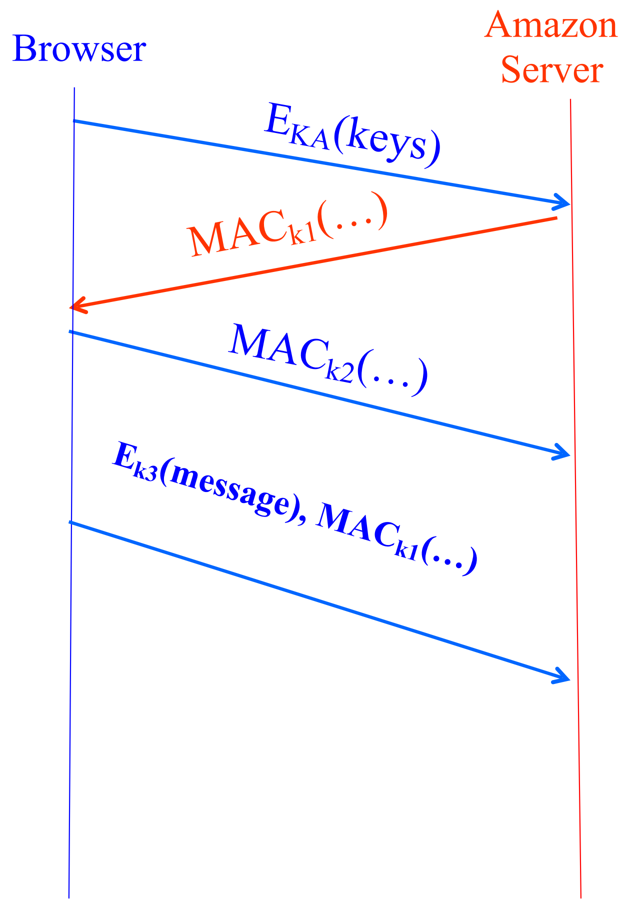
“Some other third party attests that this site belongs to Amazon”

“These properties hold not just for the main page, but any image or script is also fetched from a site with attestation and encryption”

People *think* lock icon means “Hey, I can trust this site” (no matter where the lock icon itself actually appears).

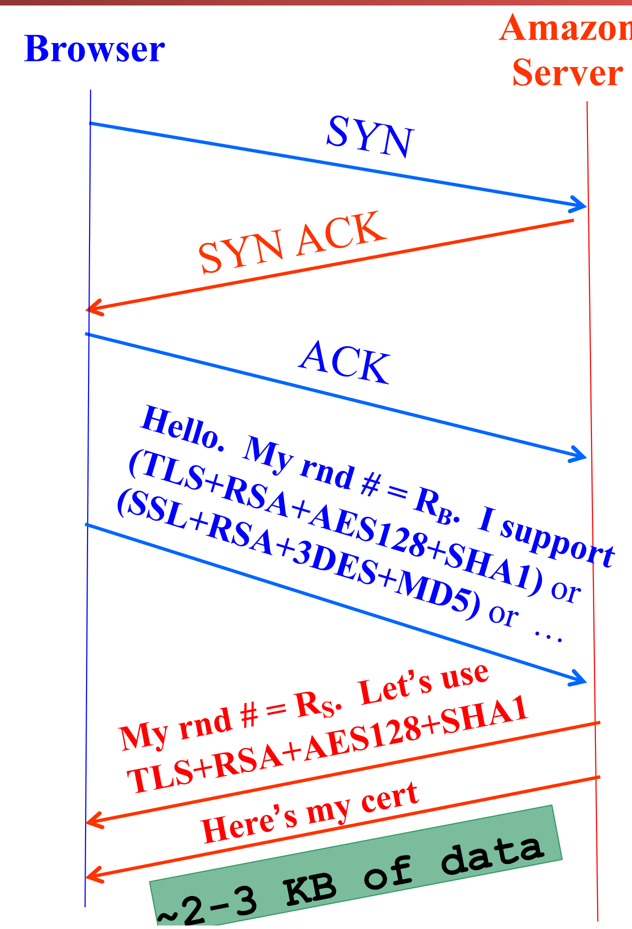
Basic idea

- Browser (client) picks some symmetric keys for encryption + authentication
- Client sends them to server, encrypted using RSA public-key encryption
- Both sides send MACs
- Now they use these keys to encrypt and authenticate all subsequent messages, using symmetric-key crypto



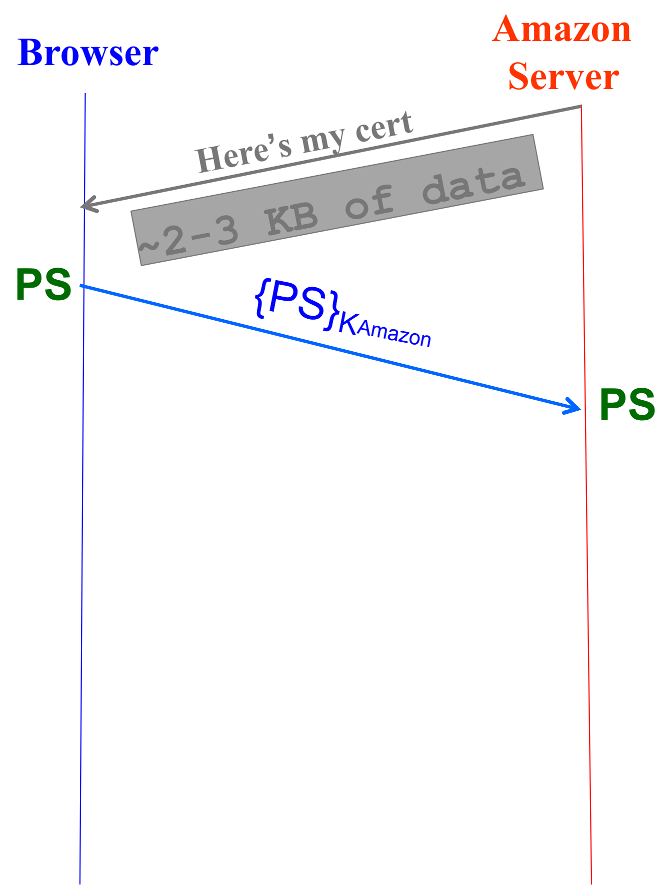
HTTPS Connection (SSL / TLS)

- Browser (client) connects via TCP to Amazon's HTTPS server
- Client picks 256-bit random number R_B, sends over list of crypto protocols it supports
- Server picks 256-bit random number R_S, selects protocols to use for this session
- Server sends over its certificate
  - (all of this is in the clear)
- Client now ***validates*** cert



HTTPS Connection (SSL / TLS), cont.

- For RSA, browser constructs "Premaster Secret" PS
- Browser sends PS encrypted using Amazon's public RSA key K_{Amazon}
- Using PS, R_B, and R_S, browser & server derive symmetric cipher keys (C_B, C_S) & MAC integrity keys (I_B, I_S)
  - One pair to use in each direction
  - Done by seeding a pRNG in common between the browser and the server:
    Repeated calls to the pRNG then create the common keys



HTTPS Connection (SSL / TLS), cont.

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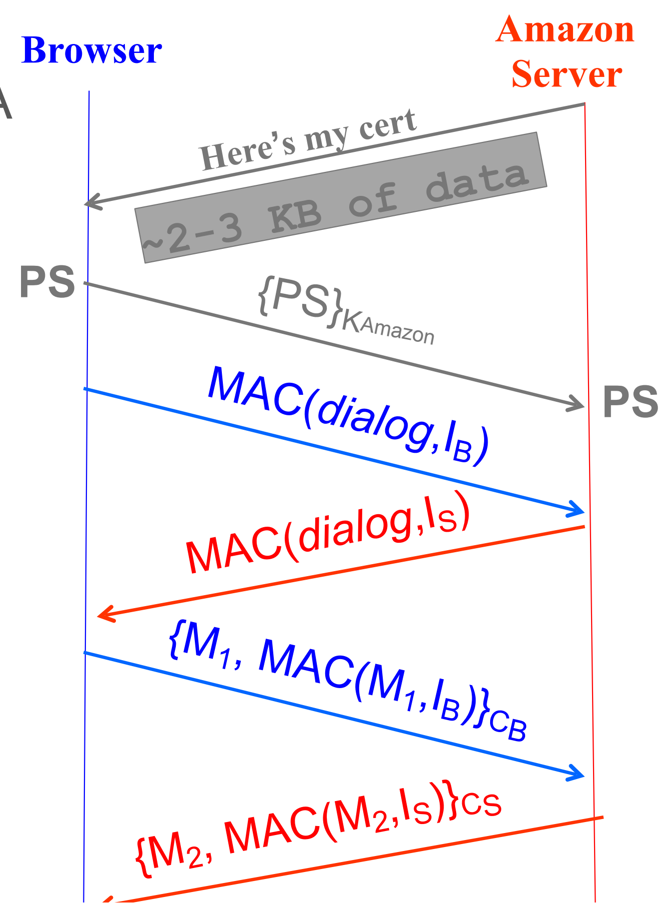
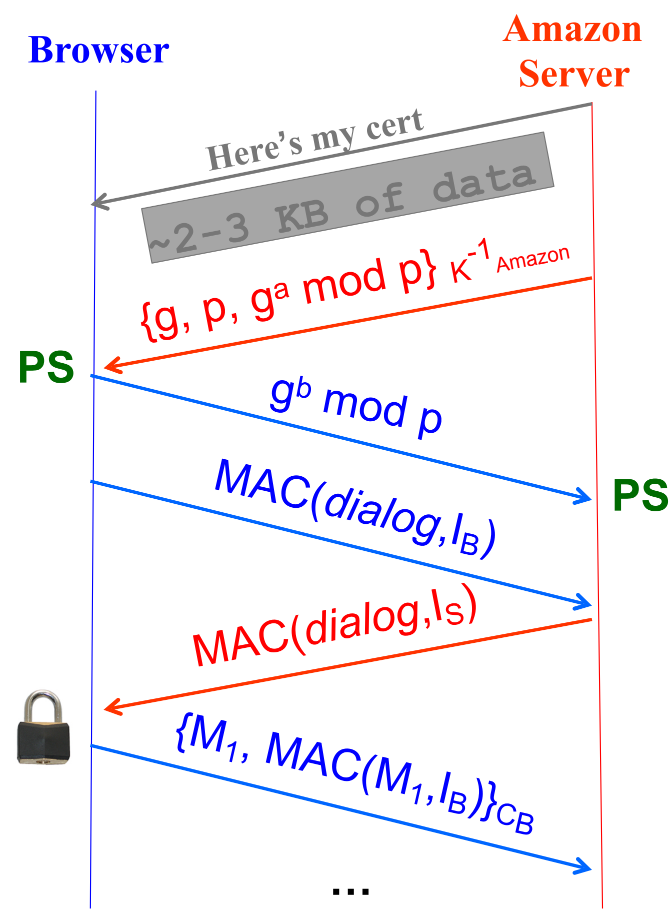
- Browser sends PS encrypted using Amazon's public RSA key KAmazon
- Using PS, R_B, and R_S, browser & server derive symm. cipher keys (C_B, C_S) & MAC integrity keys (I_B, I_S)
  - One pair to use in each direction
- Browser & server exchange MACs computed over entire dialog so far
- If good MAC, Browser displays 🔒
- All subsequent communication encrypted w/ symmetric cipher (e.g., AES128) cipher keys, MACs
  - Sequence #'s thwart replay attacks



Alternative: Ephemeral Key Exchange via Diffie-Hellman

- For Diffie-Hellman, server generates random a, sends public parameters and g^a mod p
  - Signed with server's private key
- Browser verifies signature
- Browser generates random b, computes PS = g^{ab} mod p, sends g^b mod p to server
- Server also computes PS = g^{ab} mod p
- Remainder is as before: from PS, R_B, and R_S, browser & server derive symm. cipher keys (C_B, C_S) and MAC integrity keys (I_B, I_S), etc…

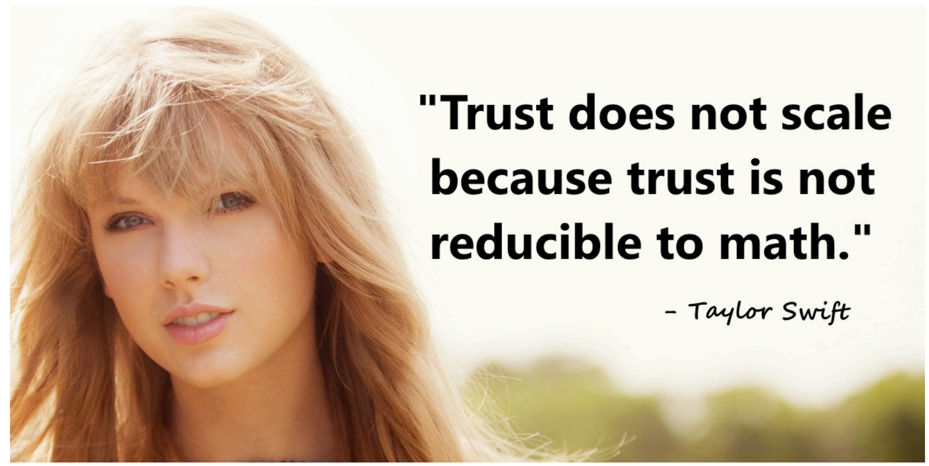


Big Changes for TLS 1.3 Diffie/Hellman and ECDHE only

- The RSA key exchange has a substantial vulnerability
  - If the attacker is ever able to compromise the server and obtain its RSA key… the attacker can decrypt any traffic captured
  - RSA lacks ***forward secrecy***
- So TLS 1.3 uses DHE/ECDHE only
- TLS 1.3 also speeds things up:
  - In the client hello, the client includes {g^b mod p} for preferred parameters
    - If the server finds it suitable, the server returns {g^a mod p}
  - Saves a round-trip time

But What About that "Certificate Validation"

- Certificate validation is used to establish a chain of "trust"
  - It actually is an ***attempt*** to build a scalable trust framework
- This is commonly known as a Public Key Infrastructure (PKI)
  - Your browser is trusting the "Certificate Authority" to be responsible…



Certificates

- Cert = signed statement about someone's public key
  - Note that a cert does not say anything about the identity of who gives you the cert
  - It simply states a given public key K_{Bob} belongs to Bob …
    - … and backs up this statement with a digital signature made using a different public/private key pair, say from Verisign (a "Certificate Authority")
- Bob then can prove his identity to you by you sending him something encrypted with K_{Bob} …
  - … which he then demonstrates he can read
- … or by signing something he demonstrably uses
- Works provided you trust that you have a valid copy of Verisign's public key …
  - … and you trust Verisign to use prudence when she signs other people's keys

Validating Amazon's Identity

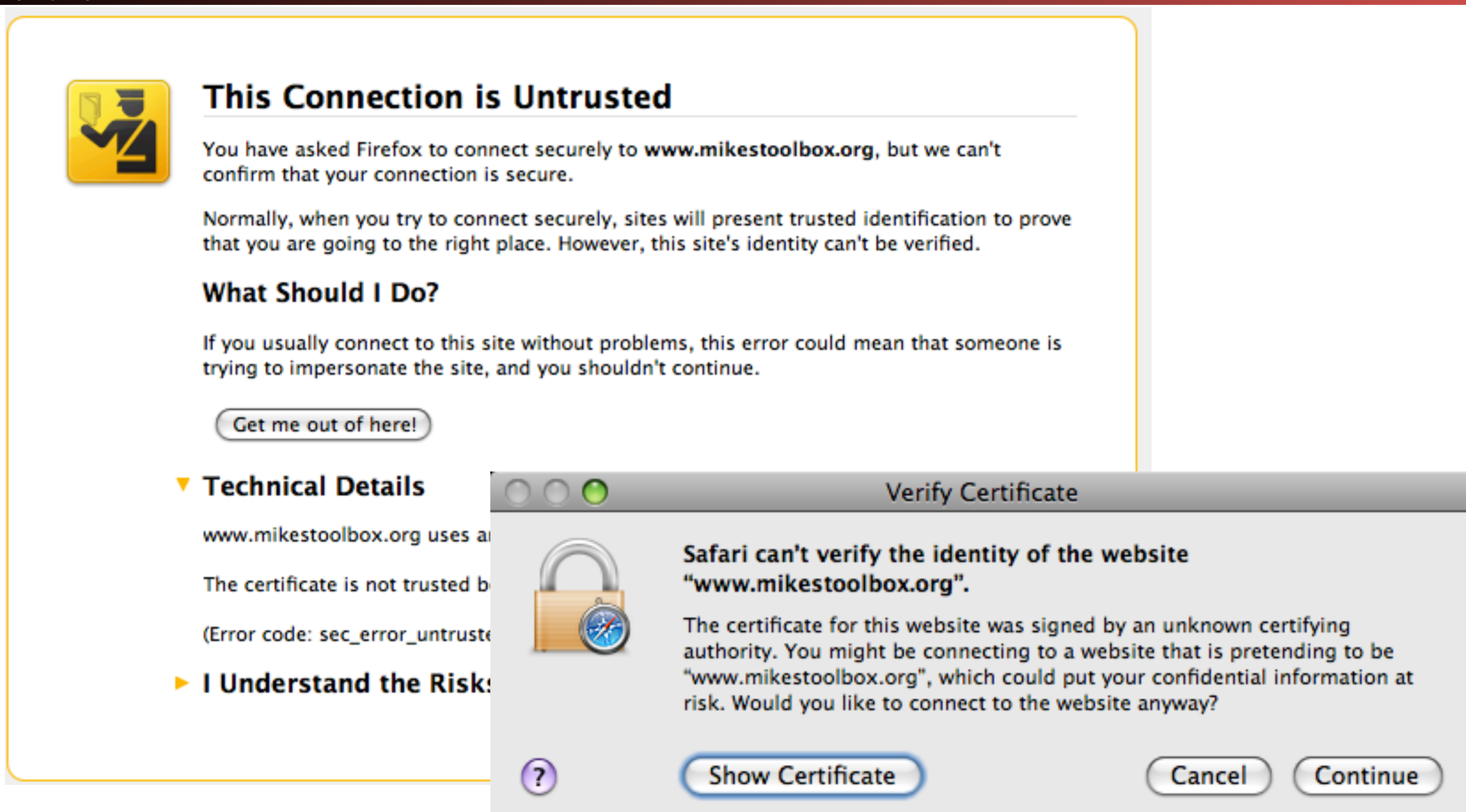
- Browser compares domain name in cert w/ URL
  - Note: this provides an ***end-to-end*** property
    (as opposed to say a cert associated with an IP address)
- Browser accesses separate cert belonging to issuer
  - These are hardwired into the browser – ***and trusted***!
  - There could be a chain of these …
- Browser applies issuer's public key to verify signature **S**, obtaining the hash of what the issuer signed
  - Compares with its own SHA-1 hash of Amazon's cert
- Assuming hashes match, now have high confidence it's indeed Amazon's public key …
  - assuming signatory is trustworthy, didn't lose private key, wasn't tricked into signing someone else's certificate, and that Amazon didn't lose their key either…

End-to-End ⇒ Powerful Protections

- Attacker runs a sniffer to capture our WiFi session?
  - But: encrypted communication is unreadable
    - No problem!
- DNS cache poisoning?
  - Client goes to wrong server
  - But: detects impersonation
    - No problem!
- Attacker hijacks our connection, injects new traffic
  - But: data receiver rejects it due to failed integrity check since all communication has a mac on it
    - No problem!
- Only thing a ***full man-in-the-middle*** attacker can do is inject RSTs, inject invalid packets, or drop packets: limited to a ***denial of service***

Validating Amazon’s Identity, cont.

- Browser retrieves cert belonging to the issuer
  - These are hardwired into the browser – and trusted!
- But what if the browser can’t find a cert for the issuer?


This Connection is Untrusted
You have asked Firefox to connect securely to www.mikestoolbox.org, but we can't confirm that your connection is secure.
Normally, when you try to connect securely, sites will present trusted identification to prove that you are going to the right place. However, this site's identity can't be verified.
What Should I Do?
If you usually connect to this site without problems, this error could mean that someone is trying to impersonate the site, and you shouldn't continue.
Get me out of here!
Technical Details
I Understand the Risks
Verify Certificate
Safari can't verify the identity of the website "www.mikestoolbox.org".
The certificate for this website was signed by an unknown certifying authority. You might be connecting to a website that is pretending to be "www.mikestoolbox.org", which could put your confidential information at risk. Would you like to connect to the website anyway?
Show Certificate
Cancel
Continue

Validating Amazon's Identity, cont.

- Browser retrieves cert belonging to the issuer
  - These are hardwired into the browser – and trusted!
- What if browser can't find a cert for the issuer?
- If it can't find the cert, then warns the user that site has not been verified
  - Can still proceed, just without authentication
- Q: Which end-to-end security properties do we lose if we incorrectly trust that the site is whom we think?
- A: All of them!
  - Goodbye confidentiality, integrity, authentication
  - Active attacker can read everything, modify, impersonate

SSL / TLS Limitations

- Properly used, SSL / TLS provides powerful end-to-end protections
- So why not use it for everything??
- Issues:
  - Cost of public-key crypto (fairly minor)
    - Takes non-trivial CPU processing (but today a minor issue)
    - Note: symmetric key crypto on modern hardware is effectively free
  - Hassle of buying/maintaining certs (fairly minor)
    - LetsEncrypt makes this almost automatic
  - Integrating with other sites that don't use HTTPS
    - Namely, you can't: Non-HTTPS content won't load!
  - Latency: extra round trips ⇒ 1st page slower to load

SSL / TLS Limitations, cont.

- Problems that SSL / TLS does not take care of ?
- Censorship:
  - The censor sees the certificate in the clear, so knows who the client is talking to
  - Optional Server Name Identification (SNI) is also sent in the clear
  - The censor can then inject RSTs or block the communication
- SQL injection/XSS/CSRF/server-side coding/logic flaws
- Vulnerabilities introduced by server inconsistencies

SSL/TLS Problem: Revocation

- A site screws up and an attacker steals the private key associated with a certificate, what now?
  - Certificates have a timestamp and are only good for a specified time
    - But this time is measured in years!?!?
- Two mitigations:
  - Certificate revocation lists
    - Your browser occasionally calls back to get a list of "no longer accepted" certificates
  - OSCP
    - Online Certificate Status Protocol: https://en.wikipedia.org/wiki/Online_Certificate_Status_Protocol

“sslstrip”
(Amazon FINALLY fixed this recently)

Regular web surfing: http: URL

So *no **integrity*** - a MITM attacker can alter pages returned by server …

And when we click here …
… attacker has changed the corresponding link so that it’s ordinary http rather than https!

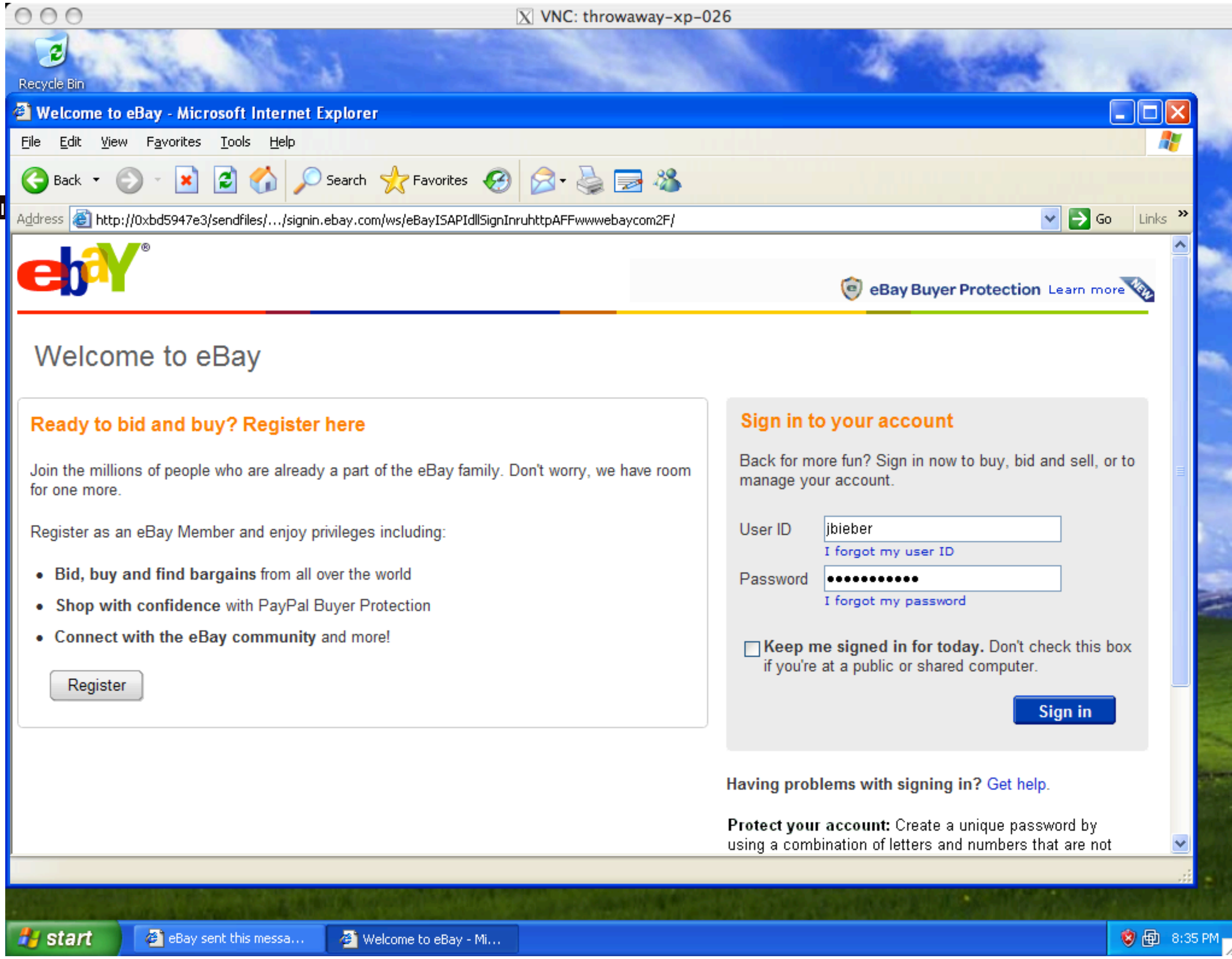
We never get a chance to use TLS’s protections! :-(

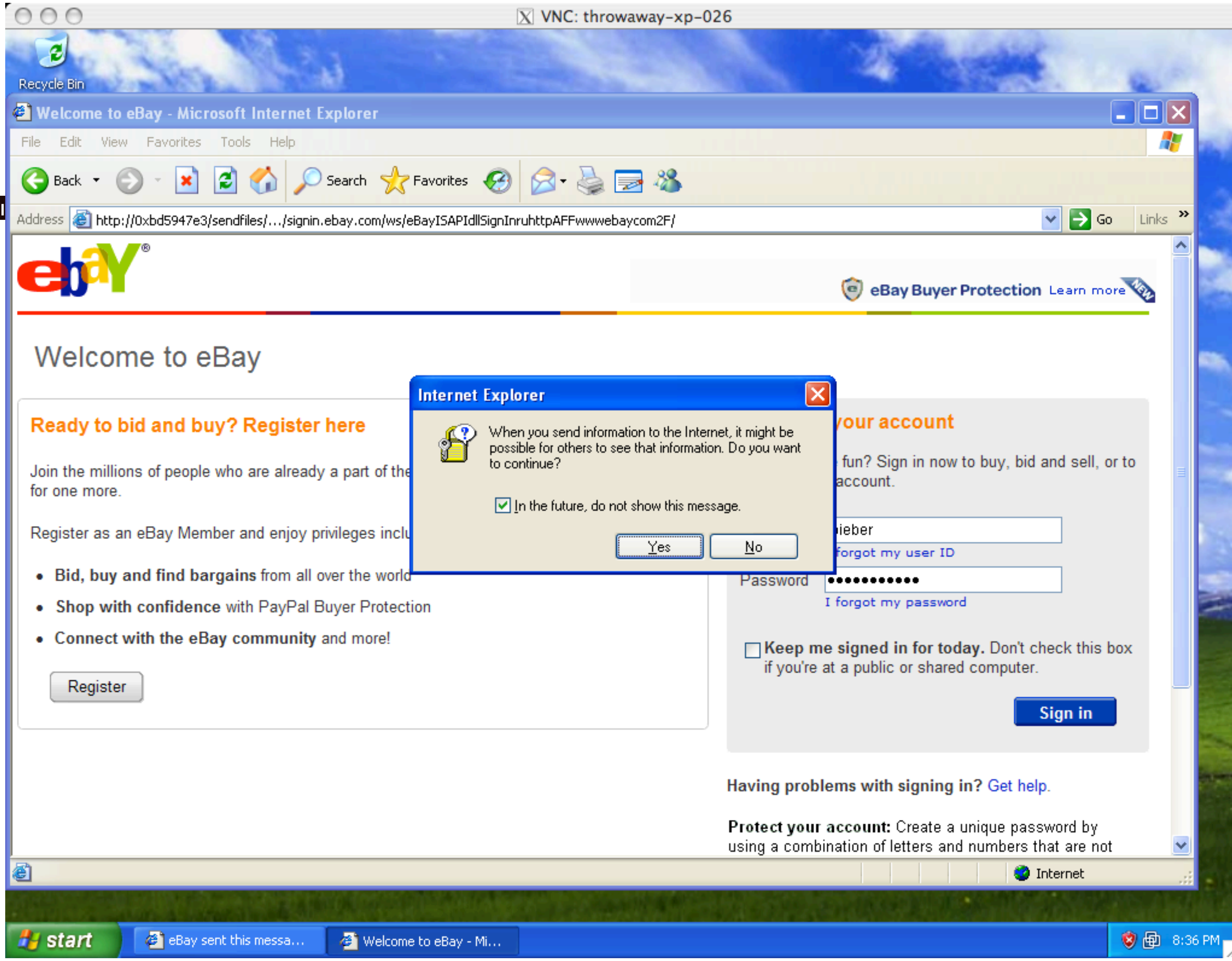
SSL / TLS Limitations, cont.

- Problems that SSL / TLS does not take care of ?
- Censorship
- SQL injection / XSS / server-side coding/logic flaws
- Vulnerabilities introduced by server inconsistencies
- Browser and server bugs
- Bad passwords
- What about the trust?

TLS/SSL Trust Issues

- User has to make correct trust decisions …


VNC: throwaway-xp-026
Recycle Bin
Welcome to eBay - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites
Address http://0xbd5947e3/sendfiles/.../signin.ebay.com/ws/eBayISAPIdllSignInruhttpAFFwwwebaycom2F/
Go Links
eBay Buyer Protection Learn more
Welcome to eBay
Ready to bid and buy? Register here
Join the millions of people who are already a part of the eBay family. Don't worry, we have room for one more.
Register as an eBay Member and enjoy privileges including:
Bid, buy and find bargains from all over the world
Shop with confidence with PayPal Buyer Protection
Connect with the eBay community and more!
Register
Sign in to your account
Back for more fun? Sign in now to buy, bid and sell, or to manage your account.
User ID
jbieber
I forgot my user ID
Password
I forgot my password
Keep me signed in for today. Don't check this box if you're at a public or shared computer.
Sign in
Having problems with signing in? Get help.
Protect your account: Create a unique password by using a combination of letters and numbers that are not
start
eBay sent this messa...
Welcome to eBay - Mi...
8:35 PM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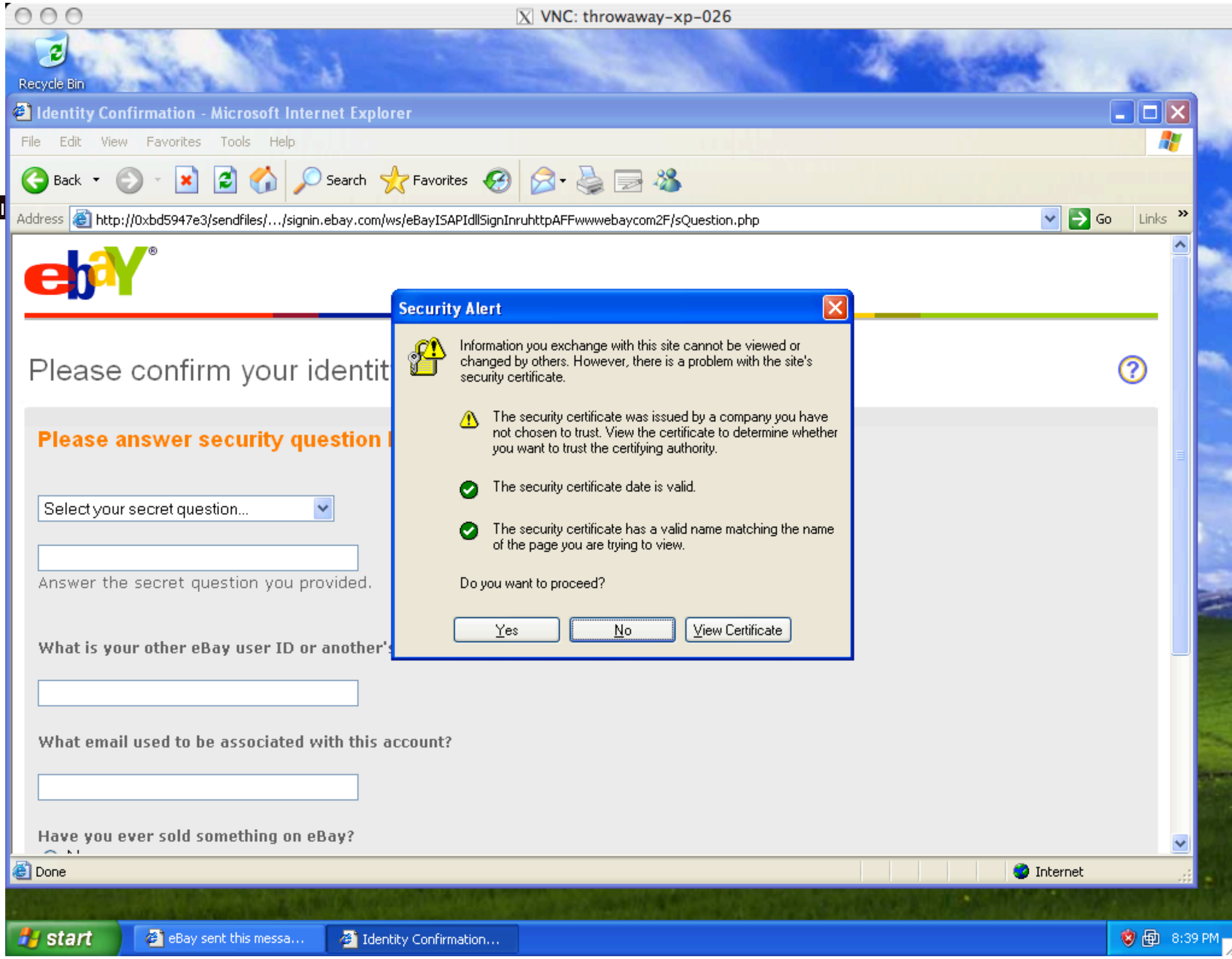
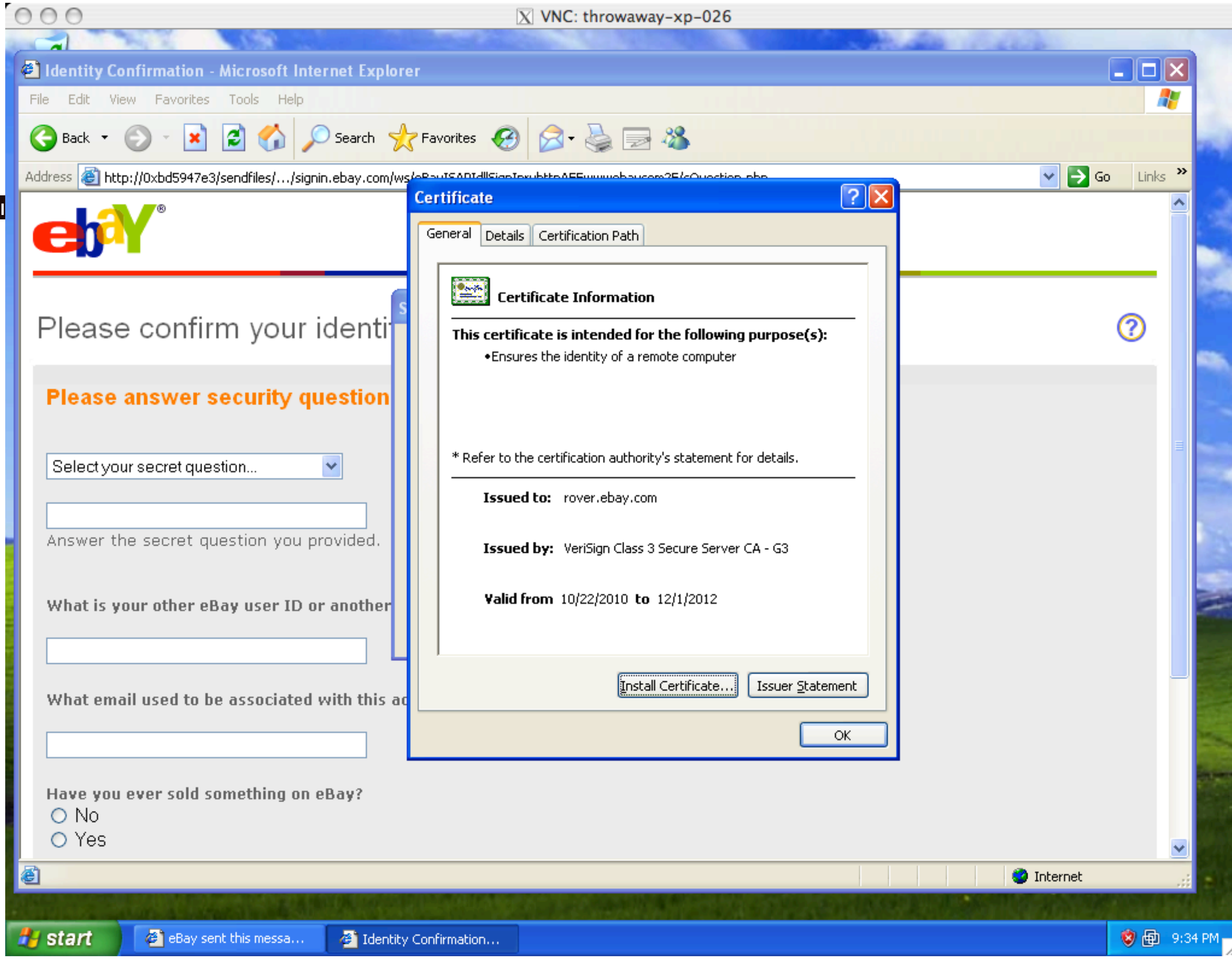
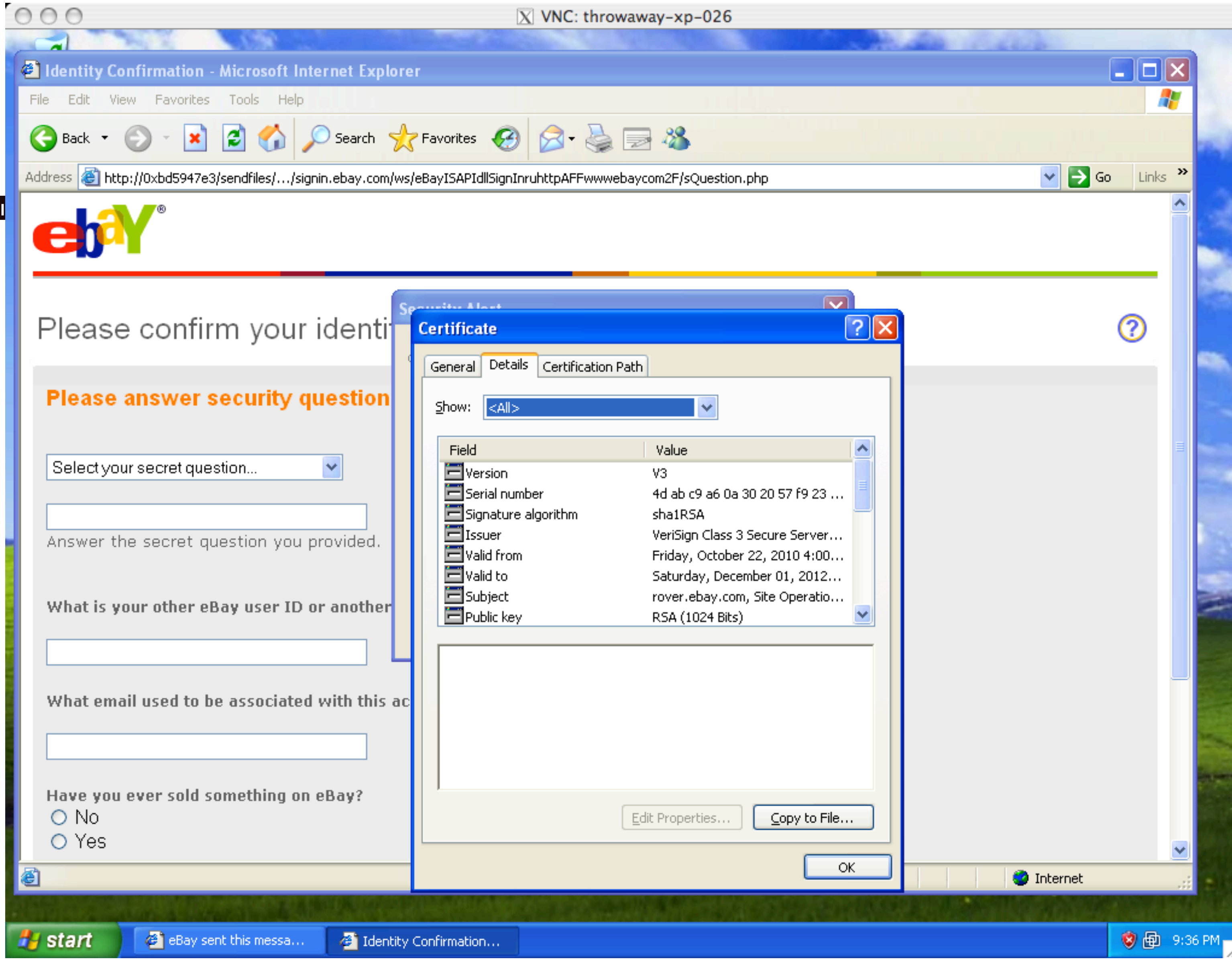
Back
Search
Favorites
Address
http://0xbd5947e3/sendfiles/…/signin.ebay.com/ws/eBayISAPIdllSignInruhttpAFFwwwebaycom2F/
Go
Links
eBay Buyer Protection Learn more
Welcome to eBay
Ready to bid and buy? Register here
Join the millions of people who are already a part of the
for one more.
Register as an eBay Member and enjoy privileges inclu
Bid, buy and find bargains from all over the world
Shop with confidence with PayPal Buyer Protection
Connect with the eBay community and more!
Register
Internet Explorer
When you send information to the Internet, it might be possible for others to see that information. Do you want to continue?
In the future, do not show this message.
Yes
No
your account
fun? Sign in now to buy, bid and sell, or to
account.
ieber
forgot my user ID
Password
I forgot my password
Keep me signed in for today. Don't check this box if you're at a public or shared computer.
Sign in
Having problems with signing in? Get help.
Protect your account: Create a unique password by using a combination of letters and numbers that are not
Internet
start
eBay sent this messa…
Welcome to eBay - Mi…
8:36 PM


VNC: throwaway-xp-026
Recycle Bin
Identity Confirmation - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites
Address http://0xbd5947e3/sendfiles/…/signin.ebay.com/ws/eBayISAPIdllSignInruhttpAFFwwwebaycom2F/sQuestion.php
Go Links
Please confirm your identit
Please answer security question
Select your secret question...
Answer the secret question you provided.
What is your other eBay user ID or another'
What email used to be associated with this account?
Have you ever sold something on eBay?
Security Alert
Information you exchange with this site cannot be viewed or changed by others. However, there is a problem with the site's security certificate.
The security certificate was issued by a company you have not chosen to trust. View the certificate to determine whether you want to trust the certifying authority.
The security certificate date is valid.
The security certificate has a valid name matching the name of the page you are trying to view.
Do you want to proceed?
Yes
No
View Certificate
Done
Internet
start
eBay sent this messa...
Identity Confirmation...
8:39 PM


VNC: throwaway-xp-026
Identity Confirmation - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites
Address http://0xbd5947e3/sendfiles/.../signin.ebay.com/ws/
Go Links
Please confirm your identi
Please answer security question
Select your secret question...
Answer the secret question you provided.
What is your other eBay user ID or another
What email used to be associated with this ac
Have you ever sold something on eBay?
No
Yes
Certificate
General Details Certification Path
Certificate Information
This certificate is intended for the following purpose(s):
•Ensures the identity of a remote computer
* Refer to the certification authority's statement for details.
Issued to: rover.ebay.com
Issued by: VeriSign Class 3 Secure Server CA - G3
Valid from 10/22/2010 to 12/1/2012
Install Certificate... Issuer Statement
OK
Internet
start
eBay sent this messa...
Identity Confirmation...
9:34 PM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Identity Confirmation - Microsoft Internet Explorer
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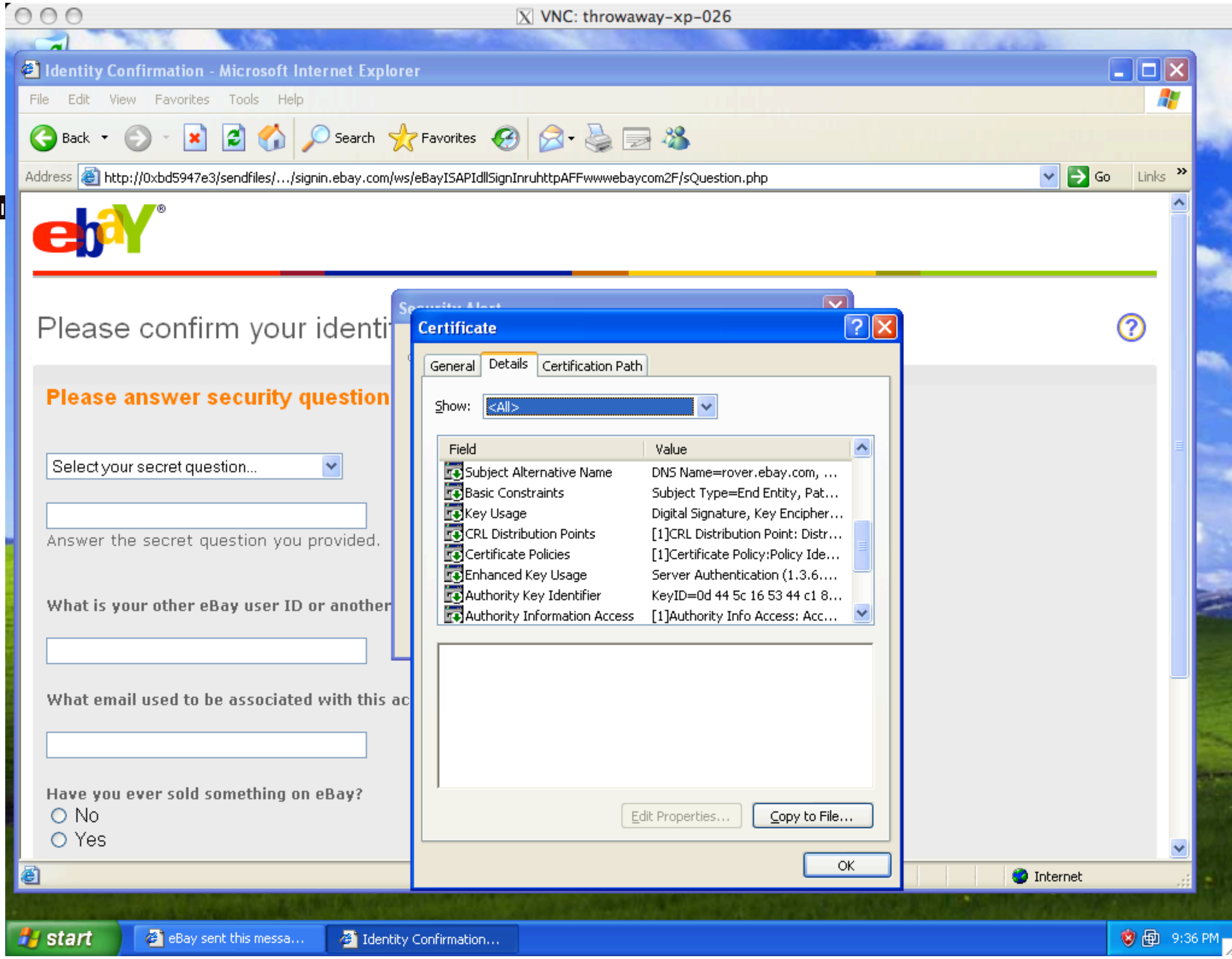
Address http://0xbd5947e3/sendfiles/…/signin.ebay.com/ws/eBayISAPIdllSignInruhttpAFFwwwebaycom2F/sQuestion.php
Go Links
Please confirm your identi
Please answer security question
Select your secret question...
Answer the secret question you provided.
What is your other eBay user ID or another
What email used to be associated with this ac
Have you ever sold something on eBay?
No
Yes
Certificate
General Details Certification Path
Show: <All>
Field Value
Version V3
Serial number 4d ab c9 a6 0a 30 20 57 f9 23 …
Signature algorithm sha1RSA
Issuer VeriSign Class 3 Secure Server…
Valid from Friday, October 22, 2010 4:00…
Valid to Saturday, December 01, 2012…
Subject rover.ebay.com, Site Operatio…
Public key RSA (1024 Bits)
Edit Properties… Copy to File…
OK
Internet
start
eBay sent this messa…
Identity Confirmation…
9:36 PM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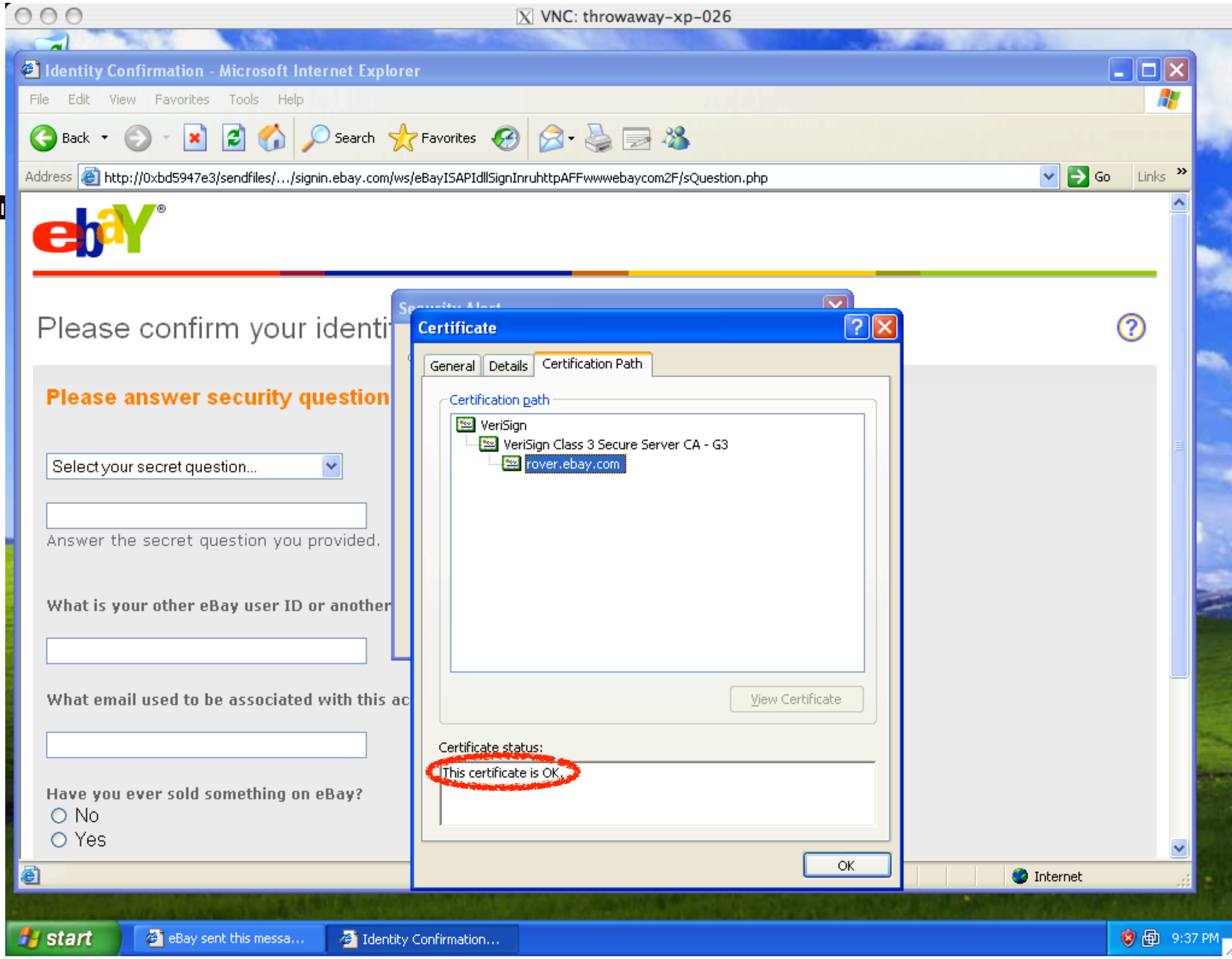
Search
Favorites
Address
http://0xbd5947e3/sendfiles/…/signin.ebay.com/ws/eBayISAPIdllSignInruhttpAFFwwwebaycom2F/sQuestion.php
Go
Links
ebY
Please confirm your identi
Please answer security question
Select your secret question...
Answer the secret question you provided.
What is your other eBay user ID or another
What email used to be associated with this ac
Have you ever sold something on eBay?
No
Yes
Certificate
General
Details
Certification Path
Show:
<All>
Field
Value
Subject Alternative Name
DNS Name=rover.ebay.com, ...
Basic Constraints
Subject Type=End Entity, Pat...
Key Usage
Digital Signature, Key Encipher...
CRL Distribution Points
[1]CRL Distribution Point: Distr...
Certificate Policies
[1]Certificate Policy:Policy Ide...
Enhanced Key Usage
Server Authentication (1.3.6....
Authority Key Identifier
KeyID=0d 44 5c 16 53 44 c1 8...
Authority Information Access
[1]Authority Info Access: Acc...
Edit Properties...
Copy to File...
OK
Internet
start
eBay sent this messa...
Identity Confirmation...
9:36 PM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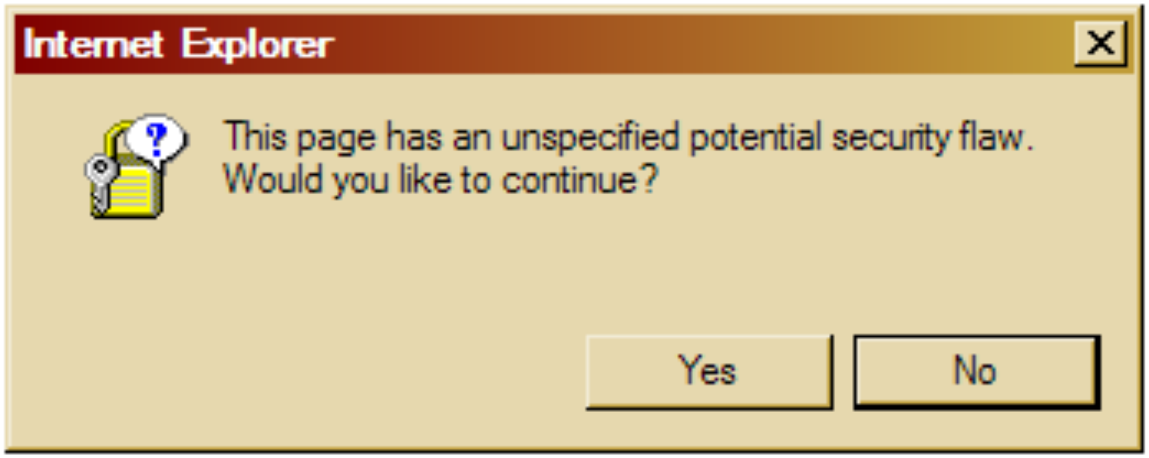
Address http://0xbd5947e3/sendfiles/…/signin.ebay.com/ws/eBayISAPIdllSignInruhttpAFFwwwebaycom2F/sQuestion.php
Go Links
Please confirm your identi
Please answer security question
Select your secret question...
Answer the secret question you provided.
What is your other eBay user ID or another
What email used to be associated with this ac
Have you ever sold something on eBay?
No
Yes
Certificate
General Details Certification Path
Certification path
VeriSign
VeriSign Class 3 Secure Server CA - G3
rover.ebay.com
View Certificate
Certificate status:
This certificate is OK.
OK
Internet
start
eBay sent this messa...
Identity Confirmation...
9:37 PM

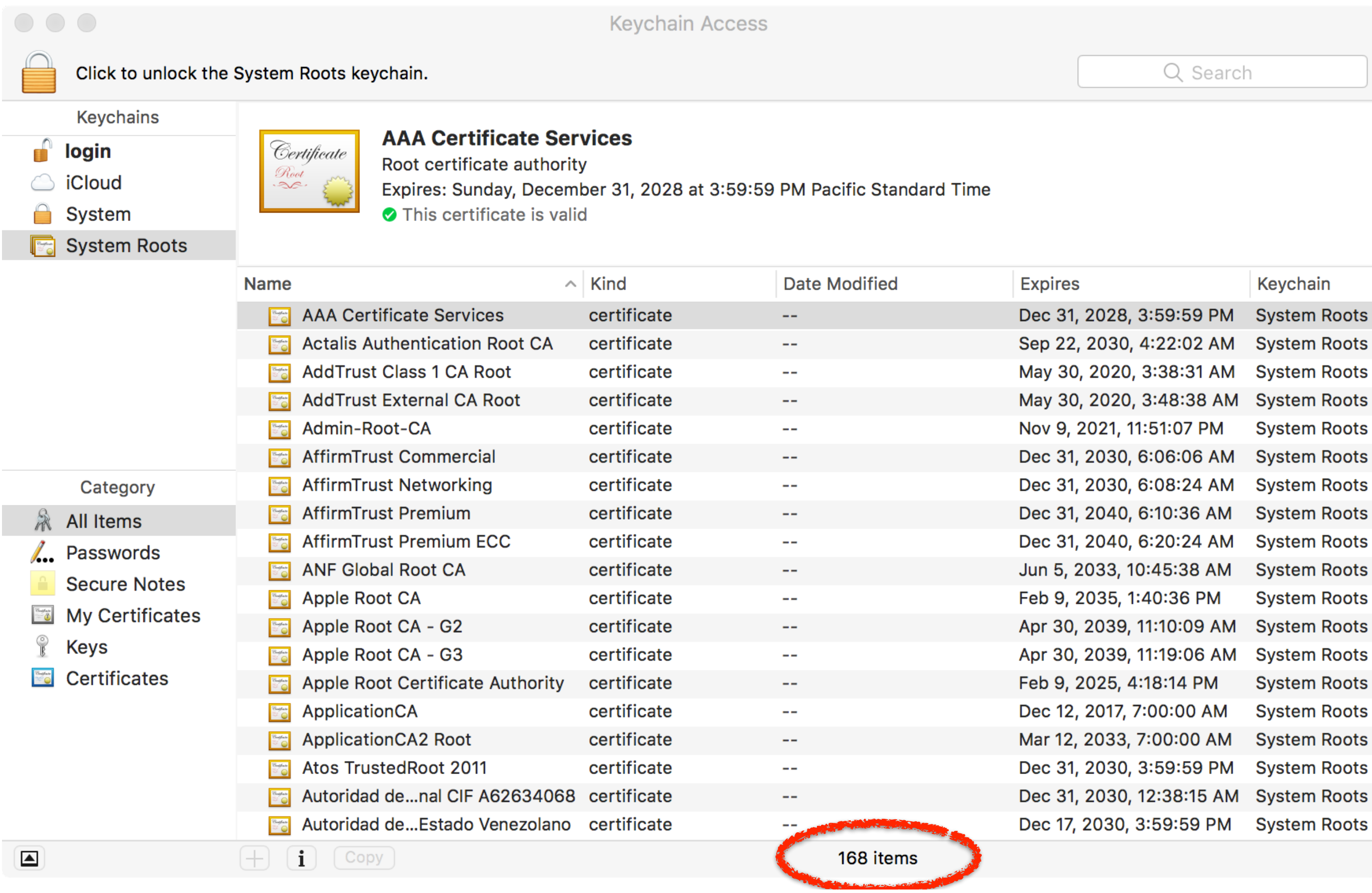
The equivalent as seen by most Internet users:



(note: an actual Windows error message!)

TLS/SSL Trust Issues, cont.

- “*Commercial certificate authorities protect you from anyone from whom they are unwilling to take money*.”
  - Matt Blaze, circa 2001
- So how many CAs do we have to worry about, anyway?



Name	Kind	Date Modified	Expires	Keychain
AAA Certificate Services	certificate	--	Dec 31, 2028, 3:59:59 PM	System Roots
Actalis Authentication Root CA	certificate	--	Sep 22, 2030, 4:22:02 AM	System Roots
AddTrust Class 1 CA Root	certificate	--	May 30, 2020, 3:38:31 AM	System Roots
AddTrust External CA Root	certificate	--	May 30, 2020, 3:48:38 AM	System Roots
Admin-Root-CA	certificate	--	Nov 9, 2021, 11:51:07 PM	System Roots
AffirmTrust Commercial	certificate	--	Dec 31, 2030, 6:06:06 AM	System Roots
AffirmTrust Networking	certificate	--	Dec 31, 2030, 6:08:24 AM	System Roots
AffirmTrust Premium	certificate	--	Dec 31, 2040, 6:10:36 AM	System Roots
AffirmTrust Premium ECC	certificate	--	Dec 31, 2040, 6:20:24 AM	System Roots
ANF Global Root CA	certificate	--	Jun 5, 2033, 10:45:38 AM	System Roots
Apple Root CA	certificate	--	Feb 9, 2035, 1:40:36 PM	System Roots
Apple Root CA - G2	certificate	--	Apr 30, 2039, 11:10:09 AM	System Roots
Apple Root CA - G3	certificate	--	Apr 30, 2039, 11:19:06 AM	System Roots
Apple Root Certificate Authority	certificate	--	Feb 9, 2025, 4:18:14 PM	System Roots
ApplicationCA	certificate	--	Dec 12, 2017, 7:00:00 AM	System Roots
ApplicationCA2 Root	certificate	--	Mar 12, 2033, 7:00:00 AM	System Roots
Atos TrustedRoot 2011	certificate	--	Dec 31, 2030, 3:59:59 PM	System Roots
Autoridad de...nal CIF A62634068	certificate	--	Dec 31, 2030, 12:38:15 AM	System Roots
Autoridad de...Estado Venezolano	certificate	--	Dec 17, 2030, 3:59:59 PM	System Roots

TLS/SSL Trust Issues

- "*Commercial certificate authorities protect you from anyone from whom they are unwilling to take money*."
  - Matt Blaze, circa 2001
- So how many CAs do we have to worry about, anyway?
- Of course, it's not just their greed that matters …

News

Solo Iranian hacker takes credit for Comodo certificate attack

Security researchers split on whether 'ComodoHacker' is the real deal

By Gregg Keizer

March 27, 2011 08:39 PM ET

Comments (5) Recommended (37) Like 84

Computerworld - A solo Iranian hacker on Saturday claimed responsibility for stealing multiple SSL certificates belonging to some of the Web's biggest sites, including Google, Microsoft, Skype and Yahoo.

Early reaction from security experts was mixed, with some believing the hacker's claim, while others were dubious.

CNET › News › InSecurity Complex › Fraudulent Google certificate points to Internet attack

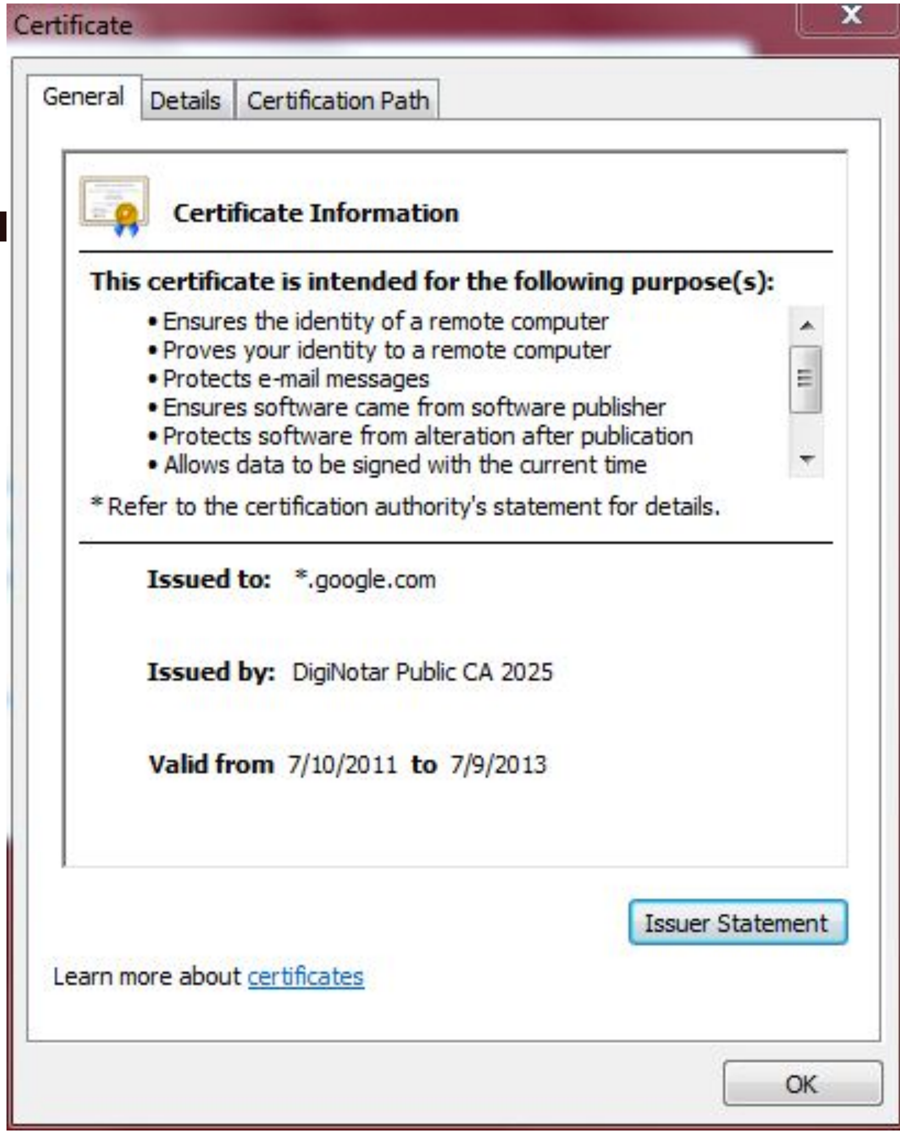
Fraudulent Google certificate points to Internet attack

Is Iran behind a fraudulent Google.com digital certificate? The situation is similar to one that happened in March in which spoofed certificates were traced back to Iran.

by Elinor Mills | August 29, 2011 1:22 PM PDT

A Dutch company appears to have issued a digital certificate for Google.com to someone other than Google, who may be using it to try to re-direct traffic of users based in Iran.

Yesterday, someone reported on a Google support site that when attempting to log in to Gmail the browser issued a warning for the digital certificate used as proof that the site is legitimate, according to this thread on a Google support forum site.



This appears to be a fully valid cert using normal browser validation rules.

Only detected by Chrome due to its introduction of cert "pinning" – requiring that certs for certain domains must be signed by specific CAs rather than any generally trusted CA

October 31, 2012, 10:49AM

Final Report on DigiNotar Hack Shows Total Compromise of CA Servers

The attacker who penetrated the Dutch CA DigiNotar last year had complete control of all eight of the company's certificate-issuing servers during the operation and he may also have issued some rogue certificates that have not yet been identified. The final report from a

Evidence Suggests DigiNotar, Who Issued Fraudulent Google Certificate, Was Hacked *Years* Ago

from the *diginot* dept

The big news in the security world, obviously, is the fact that a **fraudulent Google certificate made its way out into the wild**, apparently targeting internet users in Iran. The Dutch company DigiNotar has put out a statement saying that **it discovered a breach** back on July 19th during a security audit, and that fraudulent certificates were generated for "several dozen" websites. The only one known to have gotten out into the wild is the Google one.

The DigiNotar Fallout

- The result was the “CA Death Sentence”:
  - Web browsers removed it from the trusted root certificate store
- This has just happened again with “WoSign”
  - A Chinese CA
- WoSign would allow an interesting attack
  - If I controlled nweaver.github.com…
  - WoSign would allow me to create a certificate for *.github.com!?!?
  - And a bunch of other shady shenanigans

TLS/SSL Trust Issues

- "Commercial certificate authorities protect you from anyone from whom they are unwilling to take money."
  - Matt Blaze, circa 2001
- So how many CAs do we have to worry about, anyway?
- Of course, it's not just their greed that matters …
- … and it's not just their diligence & security that matters …
  - "*A decade ago, I observed that commercial certificate authorities protect you from anyone from whom they are unwilling to take money. That turns out to be wrong; they don't even do that much*." - Matt Blaze, circa 2010

So the Modern Solution:
Invoke Ronald Reagan, “Trust, but Verify”

- Static Certificate Pinning:
  The chrome browser has a list of certificates or certificate authorities that it trusts for given sites
  - Now creating a fake certificate requires attacking a particular CA
- HPKP Certificate Pinning:
  The web server provides hashes of certificates that should be trusted
  - This is “Leap of Faith”: The first time you assume it is honest but you will catch future changes
- Transparency mechanisms:
  - Public logs provided by certificate authorities
  - Browser extensions (EFF’s TLS observatory)
  - Backbone monitors (ICSI’s TLS notary)