CSCI-1680
How to (try) to be anonymous

Nick DeMarinis

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

Administrivia

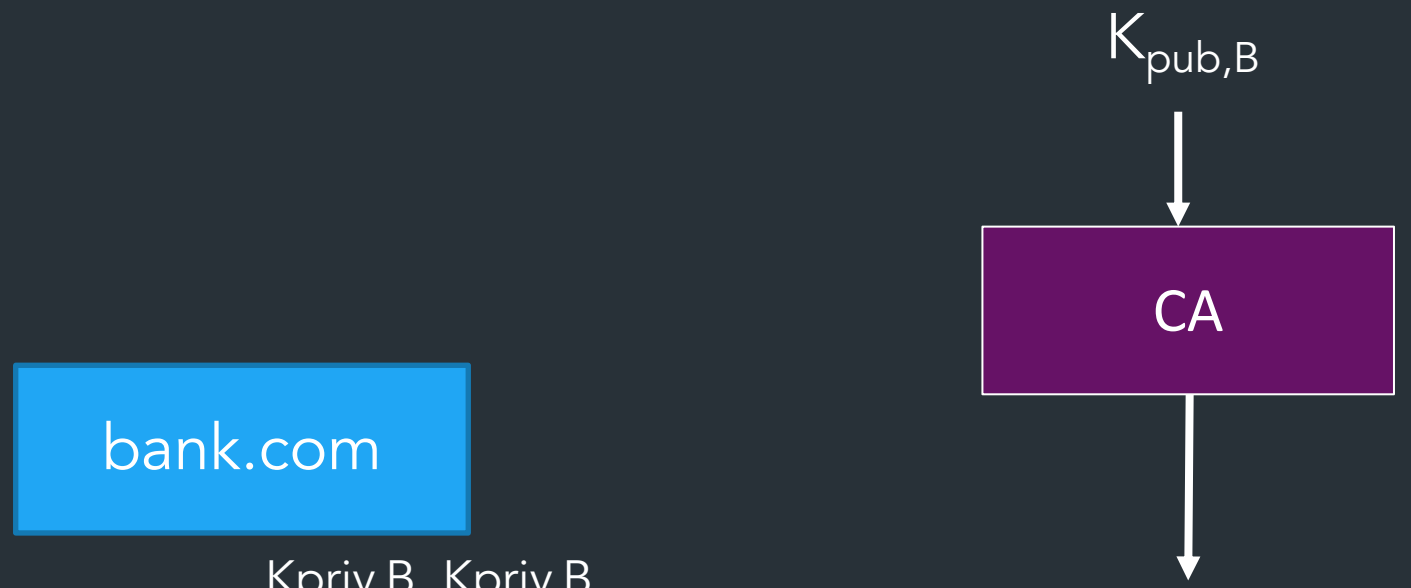
- Final project: proposal feedback on Gradescope
- HW4 (short): due Friday, 12/8
- Most office hours end Friday, some updates this week
  - After 12/8: I will still have hours, but schedule my differ => see calendar

Warmup

bank.com

Kpriv,B, Kpriv,B

Warmup



$s = Sign(K_{priv,CA}, \{K_{pub,B}, \ldots\})$

$Cert_B = \{K_{pub,B}, metadata, s\}$

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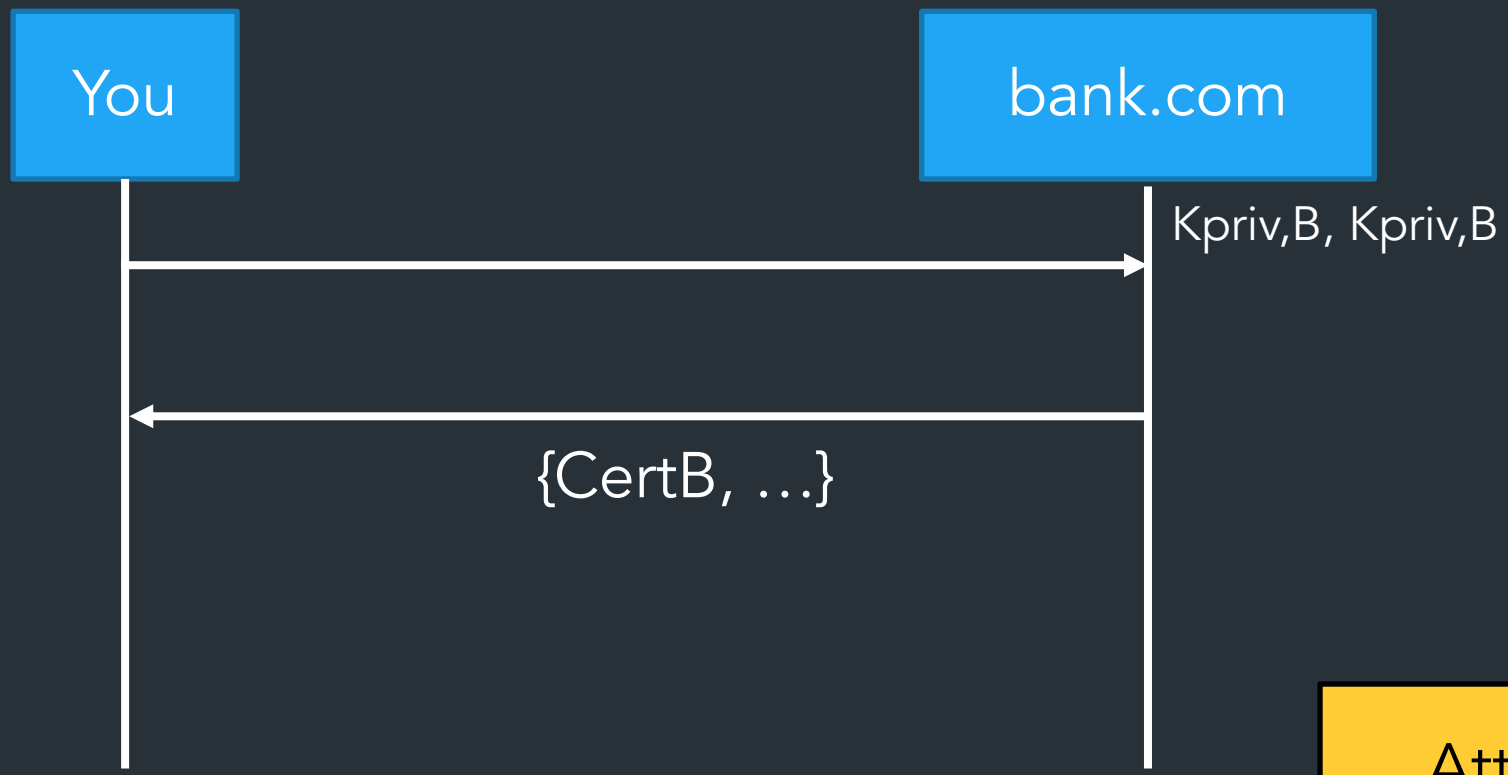

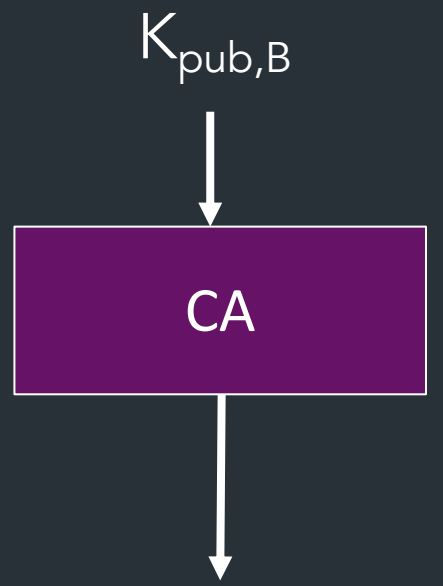

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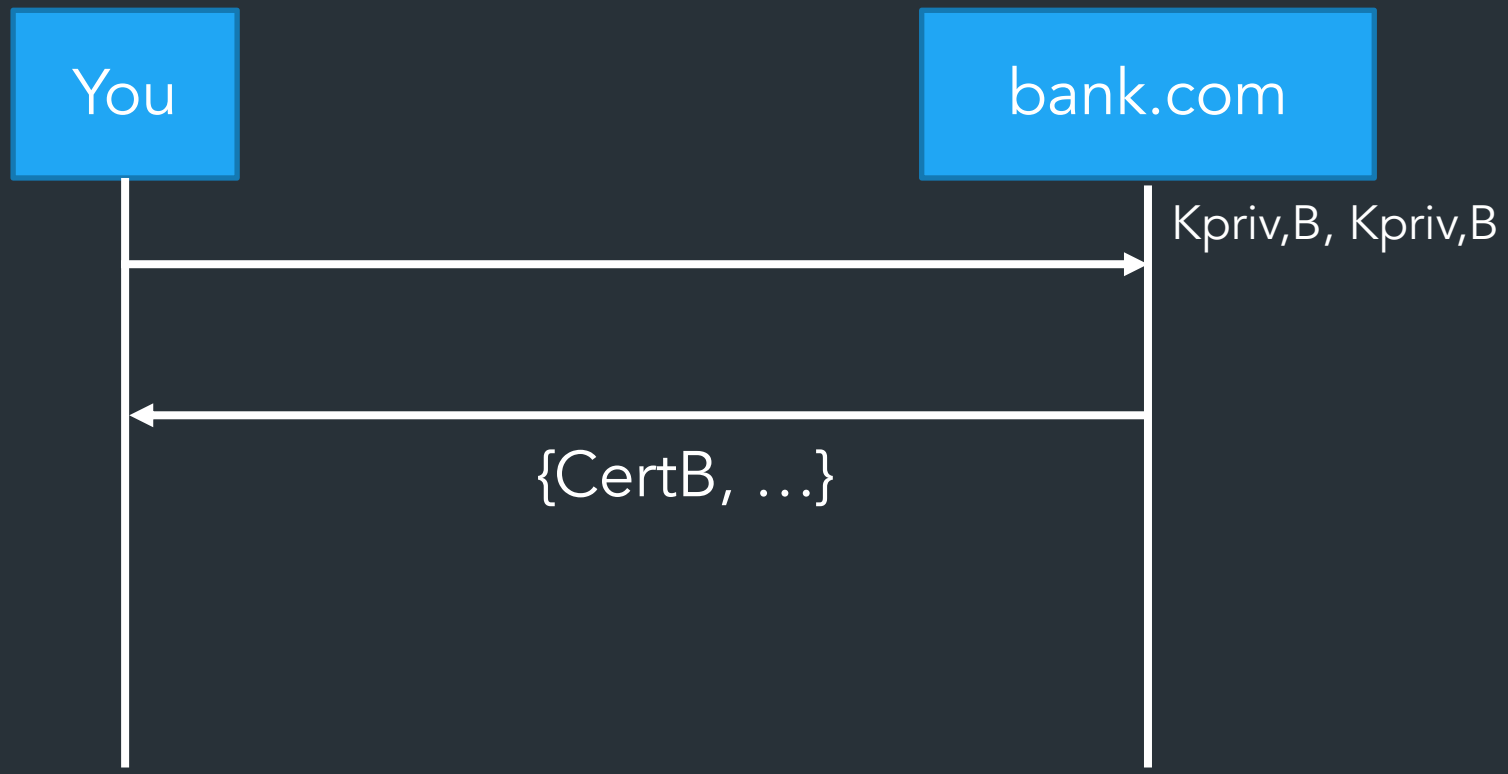
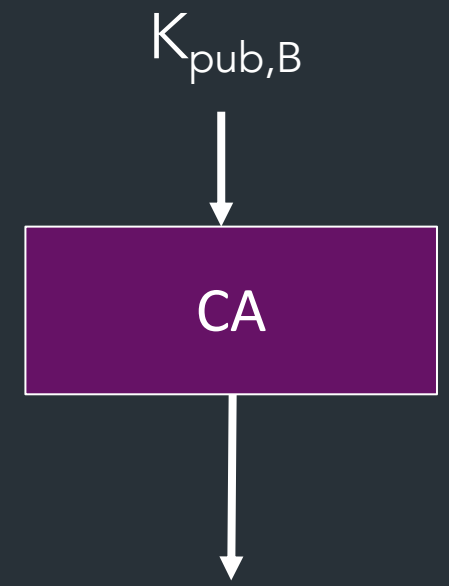
Attacker

Warmup

What happens if attacker obtains Kpriv,B?
What about Kpriv,CA?





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Website protocol support (Sept 2023)

Protocol version	Website support[87]	Security[87][88]
SSL 2.0	0.2%	Insecure
SSL 3.0	1.7%	Insecure[89]
TLS 1.0	30.1%	Deprecated[20][21][22]
TLS 1.1	32.5%	Deprecated[20][21][22]
TLS 1.2	99.9%	Depends on cipher[n 1] and client mitigations[n 2]
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In practice, TLS 1.3 rollout delayed by many broken TLS implementations (eg. in-network middleboxes/proxies) …

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Remember how we said don't propagate buggy behavior in TCP?

In general, implementing security protocols is hard to get right

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=> TLS libraries are very critical and need lots of oversight/auditing

=> Servers (and clients) need to be updated with latest standards/fixes

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

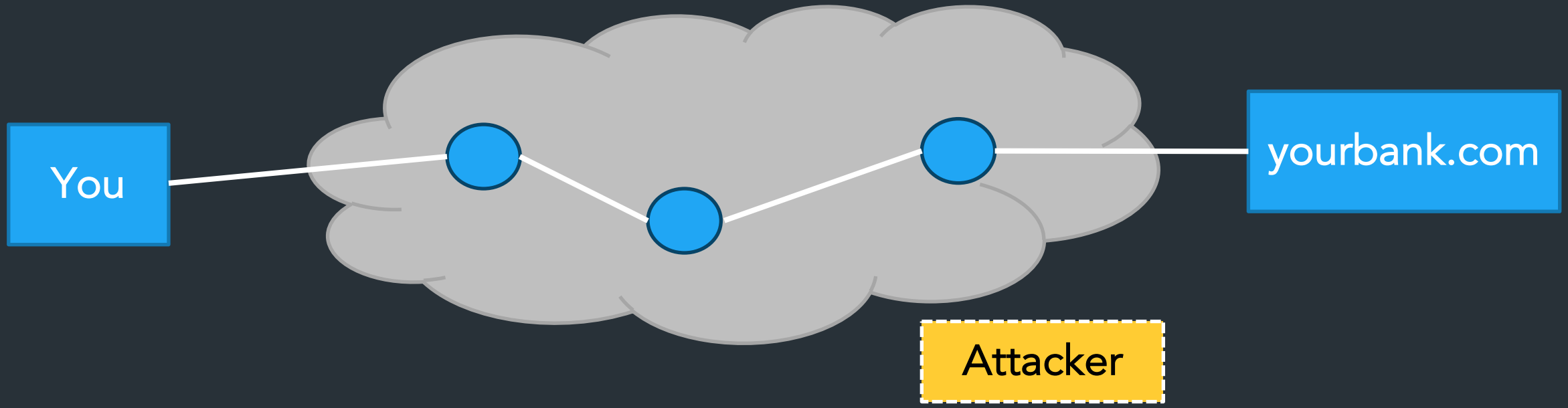
Survey of the TLS vulnerabilities of the most popular websites

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/

So are we good?

If we use TLS, is it enough?


You
yourbank.com
Attacker

Overall, depends on your threat model…

- Server still knows who you are, even if connection is encrypted

- Even encrypted traffic leaks information!

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=> IPs can be traced to location (to varying levels of precision)

=> Your browser may leak info (cookies, mouse usage, etc.)

- Even encrypted traffic leaks information!

=> Name of server: DNS, Server Name Indicator (SNI)

=> Traffic patterns (timing of packets, protocols, …)

Securing the transport layer not enough => info leaks based on other layers

Why?

- Avoiding censorship
- Avoiding surveillance (by person, or an organization)
- Anonymous reporting (journalists, whistleblowers)

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Room 641A: wiretapping room in a datacenter for an Internet backbone…
https://en.wikipedia.org/wiki/Room_641A

How can we deal with this?

Mechanisms to provide more security at the network layer

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Mechanisms to provide more security at the network layer

⇒ Security for all your network traffic => not just one 5-tuple

⇒ Can (try to) provide more anonymity

VPN: secure tunnel for network traffic

=> Connect a host to a private network

Virtual Private Network (VPN)

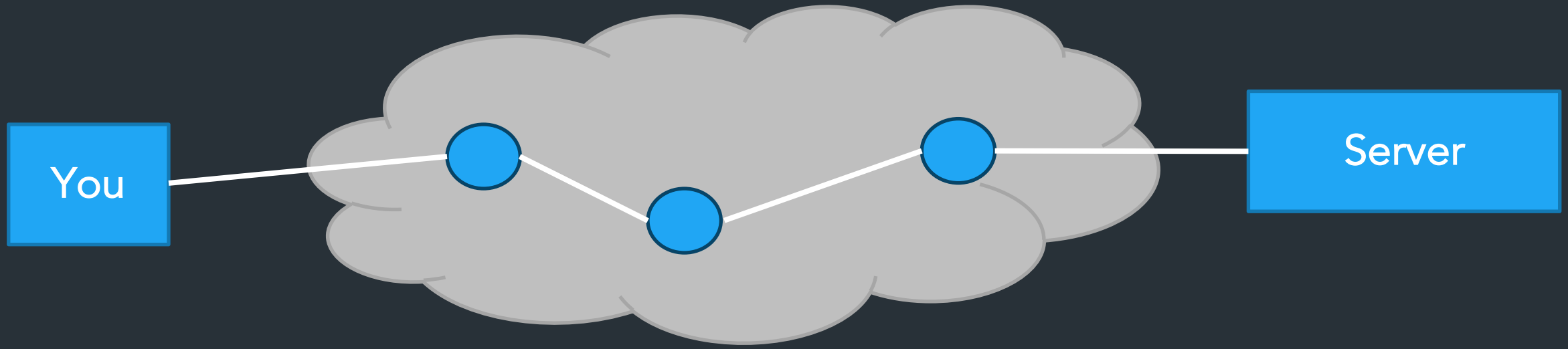
Secure tunnel for arbitrary network traffic (any IP packets)

Use for

=> Accessing a private network (remote access internal network)

=> Secure proxy for your traffic: traffic appears to originate from VPN server

Problems?



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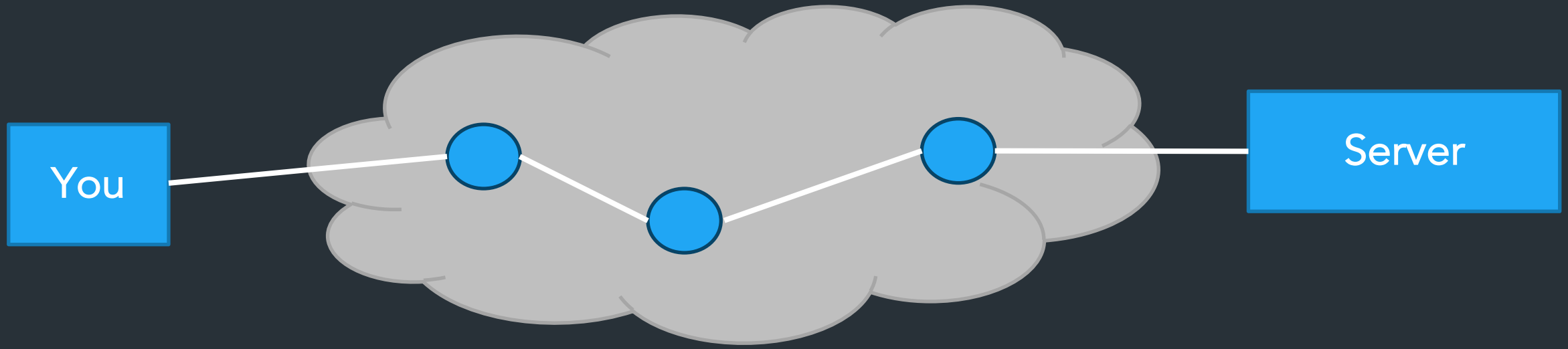
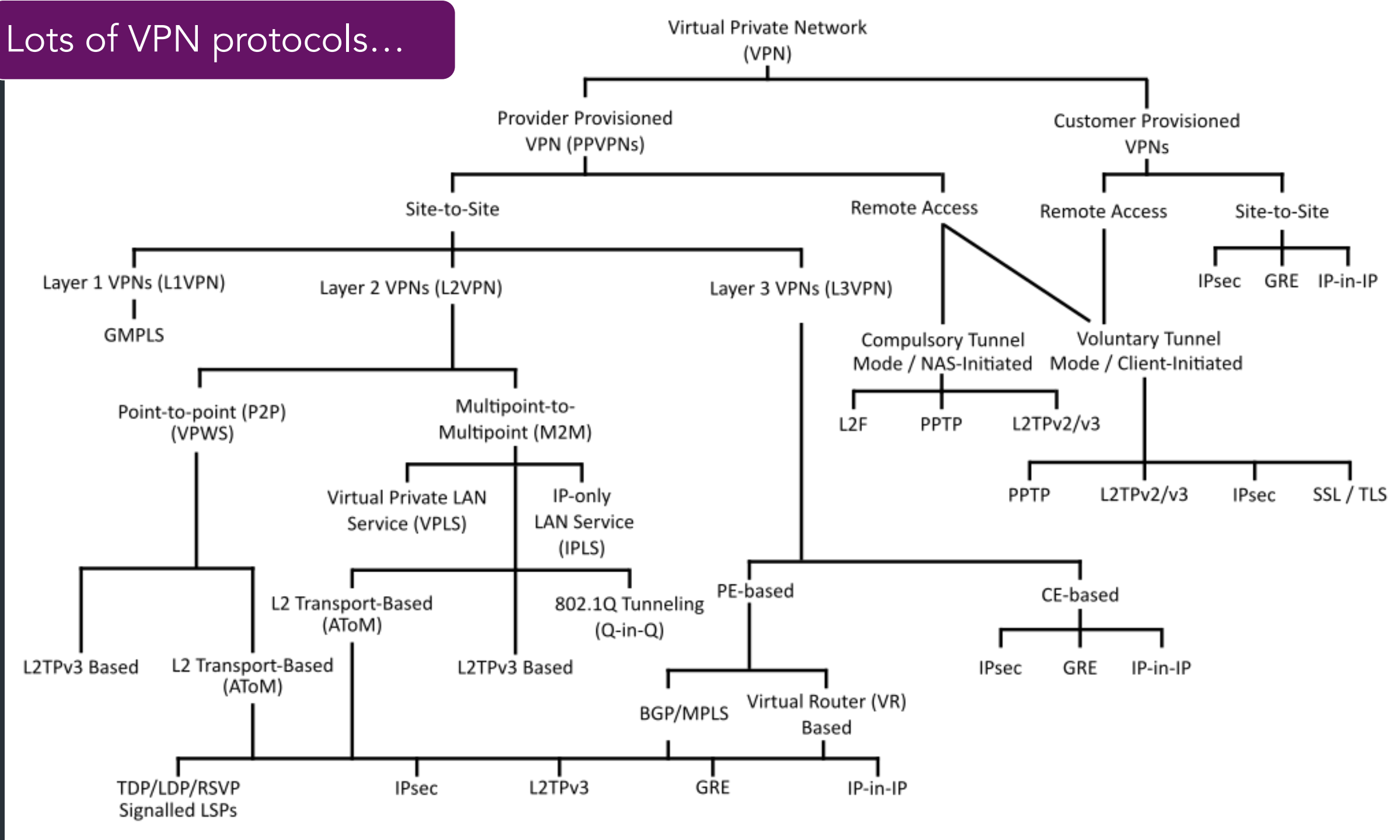
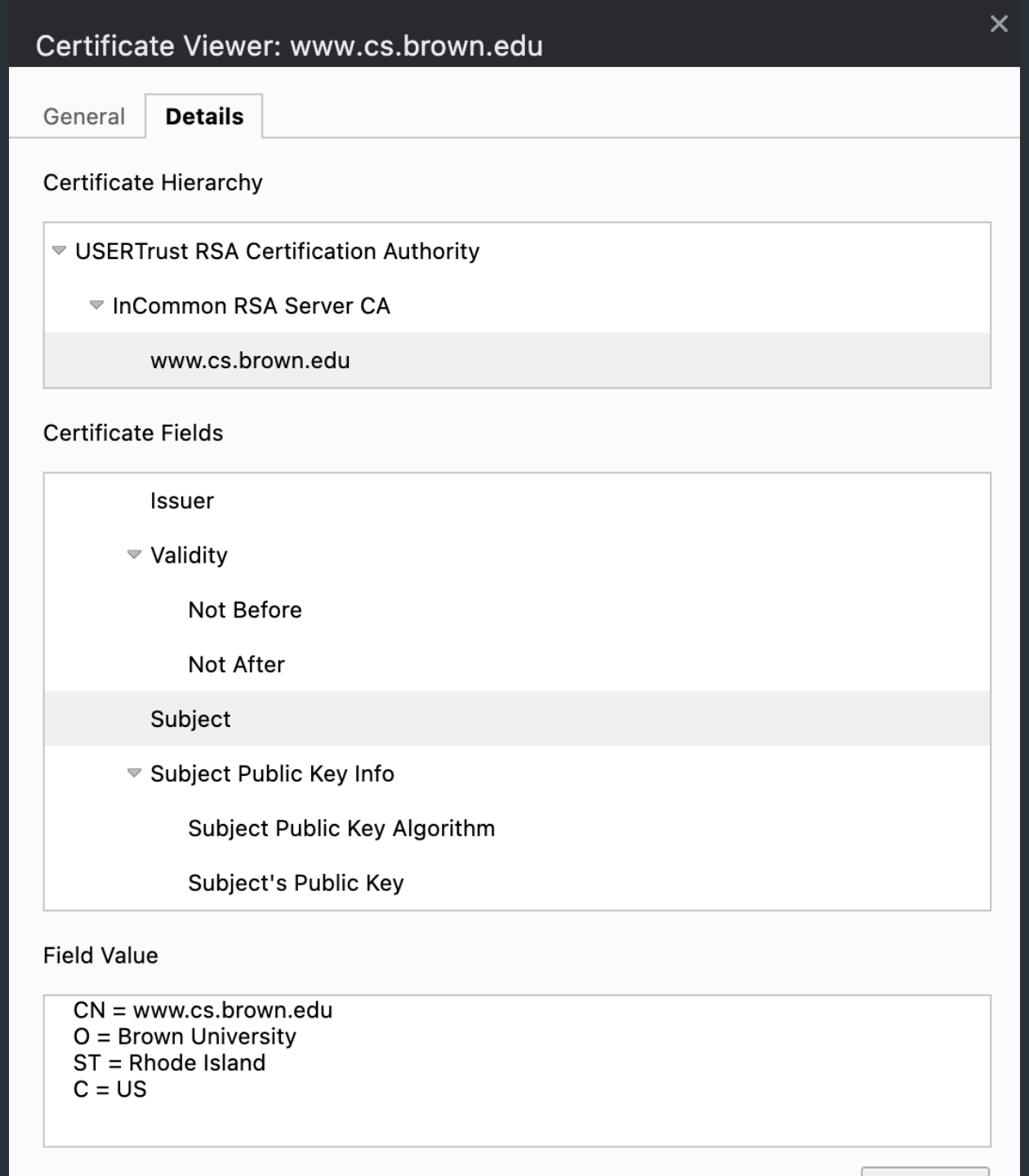
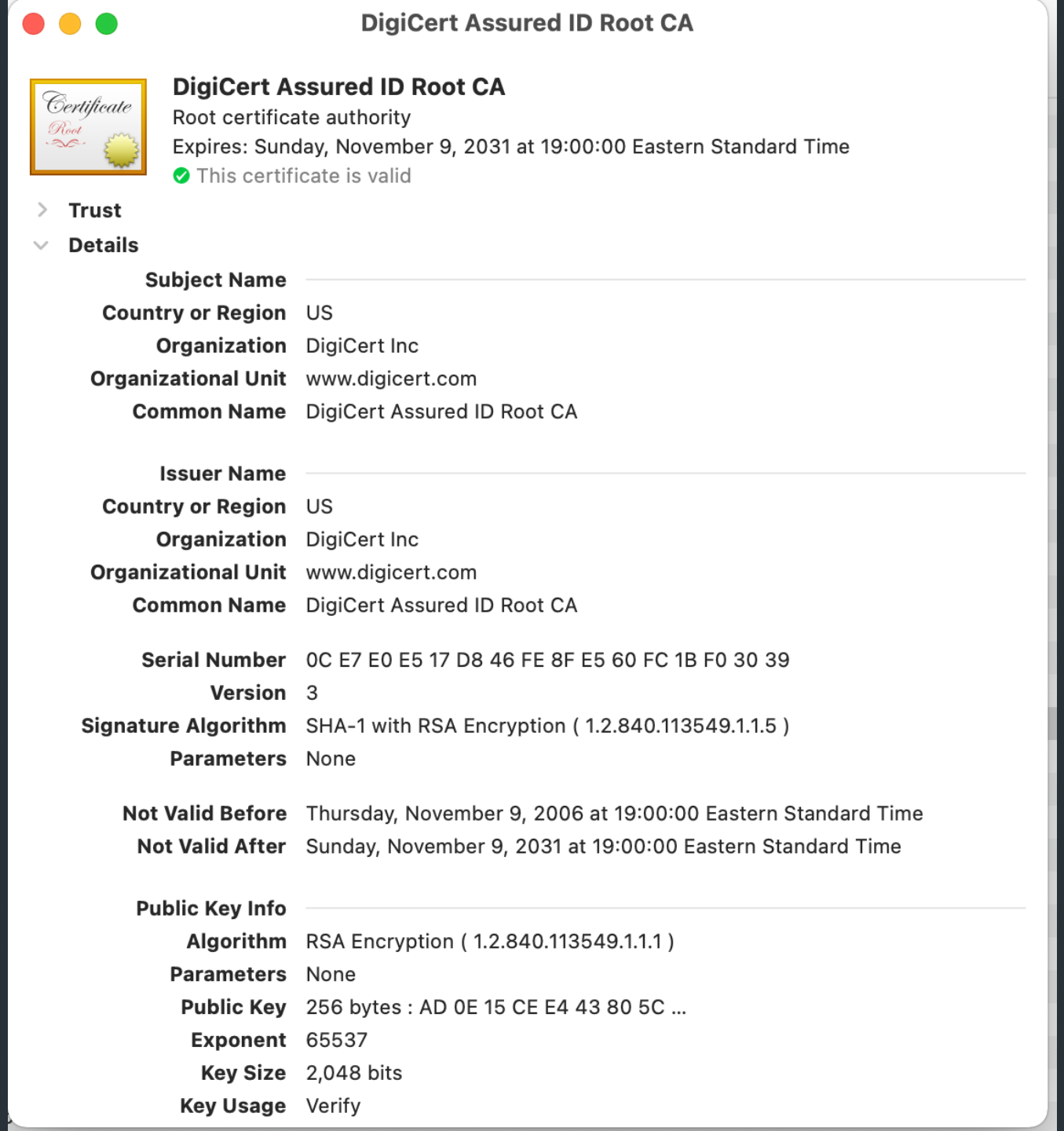


Lots of VPN protocols…



Can we do better?


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
CN = www.cs.brown.edu
O = Brown University
ST = Rhode Island
C = US


DigiCert Assured ID Root CA
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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
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
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AffirmTrust Premium	certificate	--	Dec 31, 2040 at 09:10:36	System Roots
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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
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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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CA Disig Root R1	certificate	--	Jul 19, 2042 at 05:06:56	System Roots
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Certigna	certificate	--	Jun 29, 2027 at 11:13:05	System Roots
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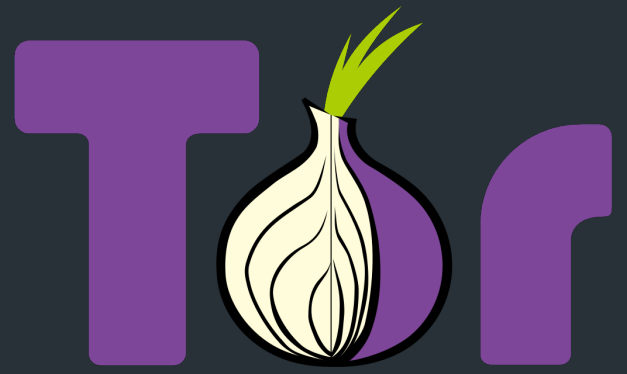
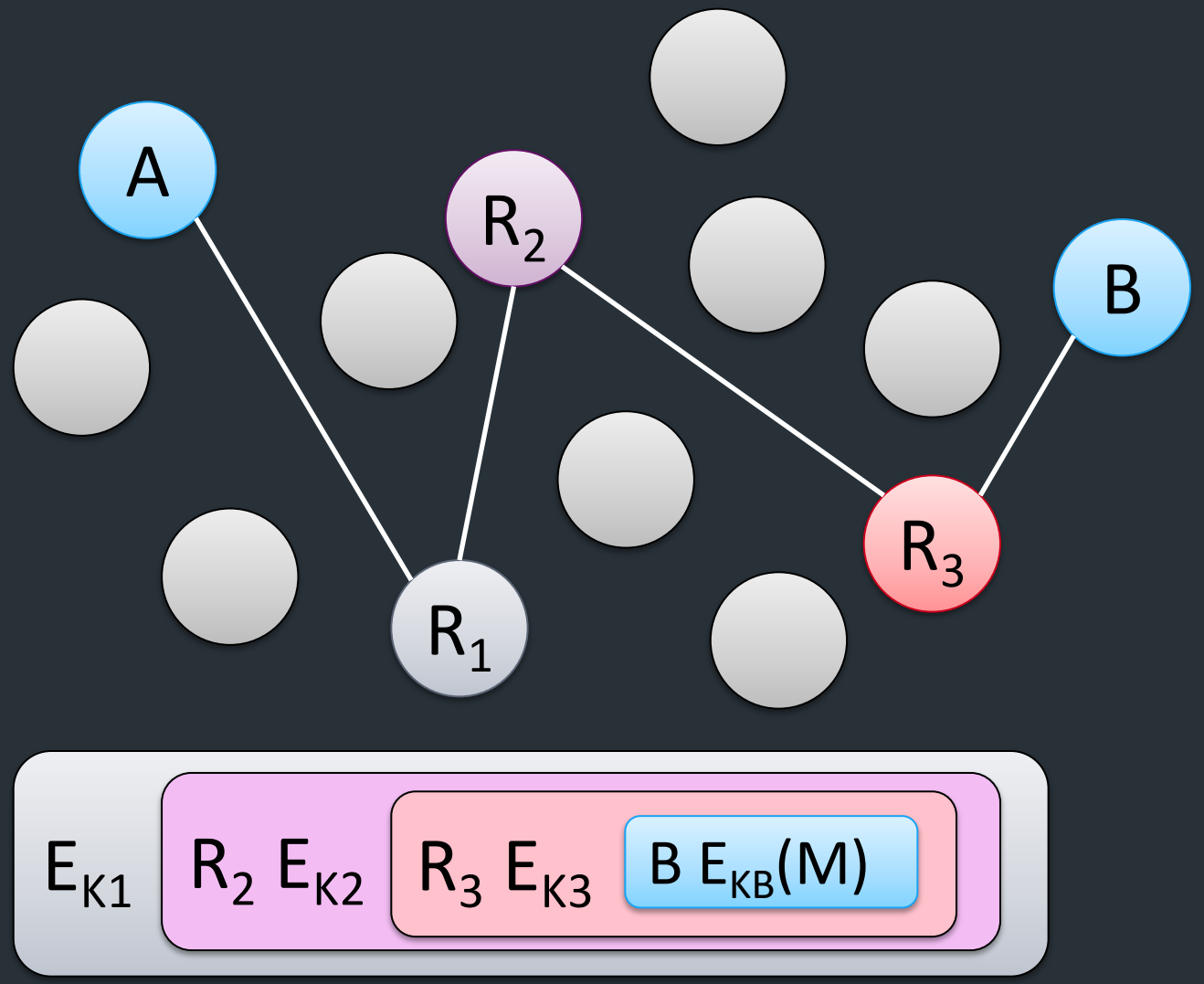
Tor



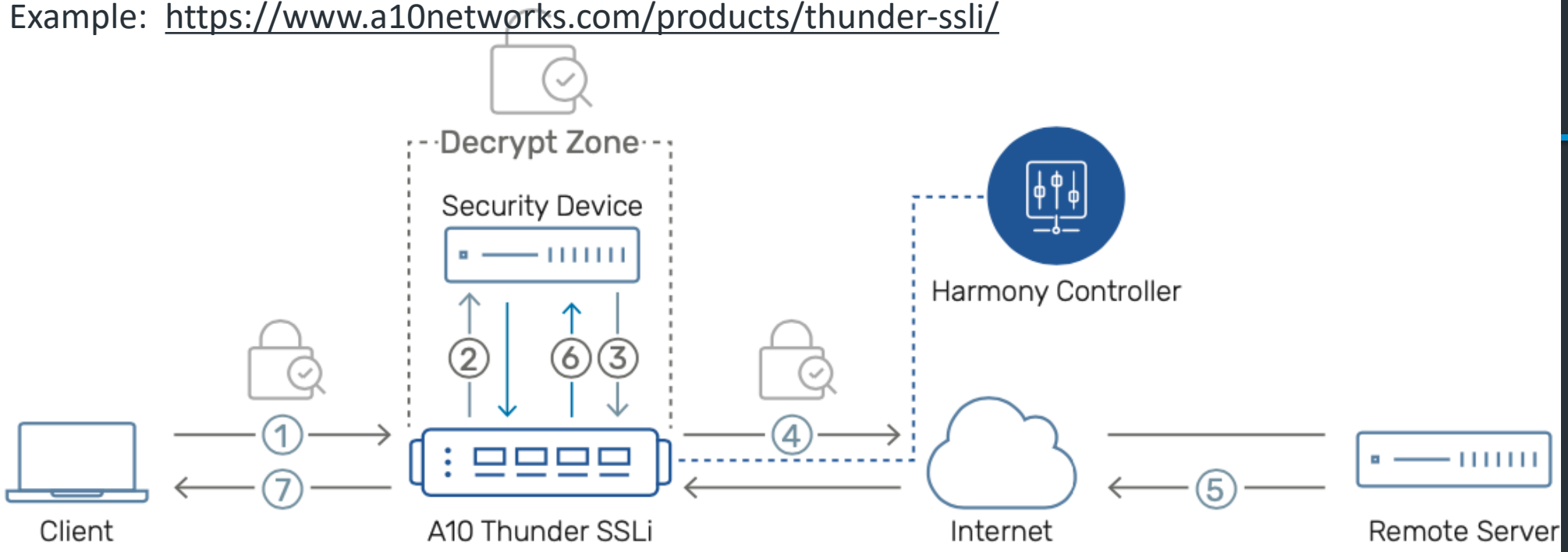
- Onion routing service: build encrypted circuit on tor relay network
- Network of relays, mainly operated by volunteers
- Started in 1990s from Naval Research Lab, now maintained by The Tor Project (a non-profit)

Onion Routing

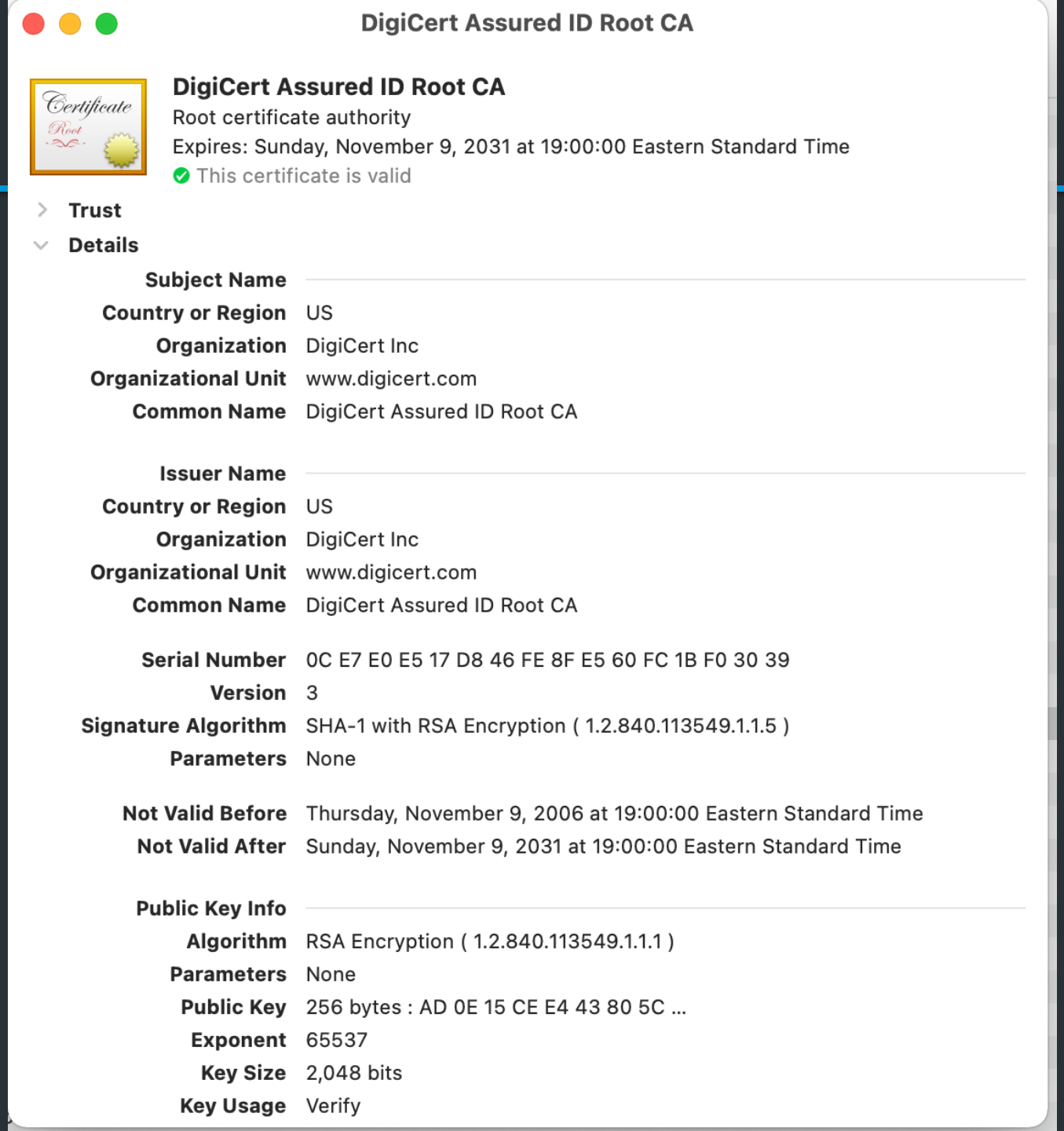
- Layered encryption
  - Build onion inside out
- Routing
  - Peel onion outside in
- Each router knows only previous and next



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.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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