Certificate Pinning

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Objective

To teach you *why* you should be doing certificate pinning

First, a little crypto introduction.

Prerequisite Knowledge

- Hashing (MD5, SHA1, SHA256, etc)
- Symmetric Encryption (AES, 3DES, etc)
- Asymmetric Encryption aka Public Key Crypto (RSA, ECC)
- Digital Signatures

Hashing

- Cryptographic function that takes a string of bytes of any length and produces a *unique* fixed length string known as a “hash” no matter how large the string of bytes are.
- Example:
  - MD5 hash of “**t**est”
    - 098F6BCD4621D373CADE4E832627B4F6
  - MD5 hash of “**T**est”
    - 0CBC6611F5540BD0809A388DC95A615B
  - SHA1 hash of “**t**est”
    - A94A8FE5CCB19BA61C4C0873D391E987982FBBD3
  - SHA1 hash of “**T**est”
    - 640AB2BAE07BEDC4C163F679A746F7AB7FB5D1FA

“t” and “T” are represented by different bytes
e.g. ASCII lowercase t is 0x74 uppercase is T is 0x54

Hashing cont.

- Hashing is perfect for taking a “signature” of a stream of bytes. You are *guaranteed* to receive the same hash every single time if absolutely ***none*** of the bytes have changed in your input.

- When you download a Linux distro or some software, you will sometimes see them include a MD5 hash of the .ISO (or some file) you downloaded.

- Why?

Hashing cont.

- So you can verify the *integrity* of the download.
- Remember, the same sequence of bytes will produce the same hash. If someone tampered with your download or it was corrupt, *some* bytes will be missing/changed. This will result in a *different* hash produced and therefore your download is no bueno.

From Ubuntu's dl page

md5 Hash	Version
119cb63b48c9a18f31f417f09655efbd	ubuntu-14.04.1-desktop-amd64.iso
a4fc15313ef2a516bfbf83ce44281535	ubuntu-14.04.1-desktop-i386.iso
ca2531b8cd79ea5b778ede3a524779b9	ubuntu-14.04.1-server-amd64.iso
3aa14ca13d52df070870d39306f4a4eb	ubuntu-14.04.1-server-i386.iso
b31731ea6cdbebe1d02f8193db420886	wubi.exe

Hashing cont.

- How to?
  - Mac terminal
    - md5 <yourFile>
    - shasum <yourFile>
  - Linux terminal
    - md5sum <yourFile>
    - shasum <yourFile>
  - Windows
    - shutdown -s

ProTip: Hashing is *not* encryption. Hashing is a one way street. You can go down it (produce a hash from stream of bytes), but you cannot reverse down the street (reverse the stream from hash).

Symmetric Encryption

- *Same* key is used to encrypt and decrypt (hence symmetric)
- Different types of symmetric encryption
  - Block Ciphers
    - AES, 3DES, etc
  - Stream Ciphers
    - RC4, Salsa20, etc
- Block ciphers are *very* fast, but there's an inherent problem.
- The **same** key is used by both parties. You can't just pass that across the network…

Asymmetric Encryption

aka Public Key Crypto

- Public Key Crypto addresses the symmetric encryption problem of using the same key to encrypt as decrypt
- Not getting into the details of how it all works, but a high level description is below.
  - No pre-shared secret (the key) needed to talk securely
  - Typically generate a *public* and *private* key pair
- Do *NOT* use public key crypto to encrypt large datasets. It's not designed to do this. SSL/TLS uses a hybrid approach.

Asymmetric Encryption Cont.

Public and Private keys

You've gotta understand the differences and their respective uses!!!

- Public Key
  - You can give this to anyone!
  - They can use it to encrypt a message and ONLY *you* will be able to decrypt it!

- Private Key
  - KEEP *PRIVATE*! DO NOT GIVE TO ANYONE!
  - *You* can use it to encrypt something and ANYONE who has your public key will be able to decrypt this!
  - ^^^That's important to understand digital signatures

Hashing Recap

- Function that takes stream of bytes and produces unique fixed length output

ab7777148236ac6314b17837591fd9be

Symmetric Recap

- Same key is used to encrypt and decrypt
- Problem? You have to share this key in plain text with the party you want to communicate with
- Fast. Use this to encrypt *large* datasets

Asymmetric Recap

- Public and Private Keys
- *You keep your private key PRIVATE*
- Public key can be given to the public
- Public key can decrypt data that was encrypted with private key
    - Therefore this isn't really secure if your goal is secure communication.
- Private key allows *you and only* you to decrypt because YOU have the private key.

Digital Signatures

- What is it?
  - The idea of *signing* something digital and you trusting that it was in fact me that signed it and it hasn't been tampered with.
  - Think buying an SSL certificate…
    - You're paying for "trust" or "their digital signature" to let other people know you're who you say you are!
    - They don't have some fancy crypto algorithm that you're paying for..everything's about trust.

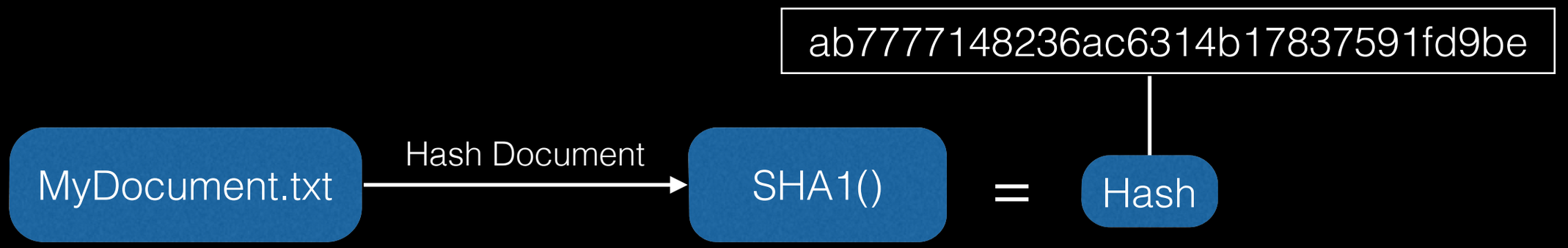
- How does it work?
  - Remember hashing and public key crypto?
  - Let's combine these two…

Digital Signature Scenario

I create document and want to digitally sign it so you know it is from me *and* hasn't been tampered.

Step 1: Fingerprint

1) Create the “fingerprint” of the document

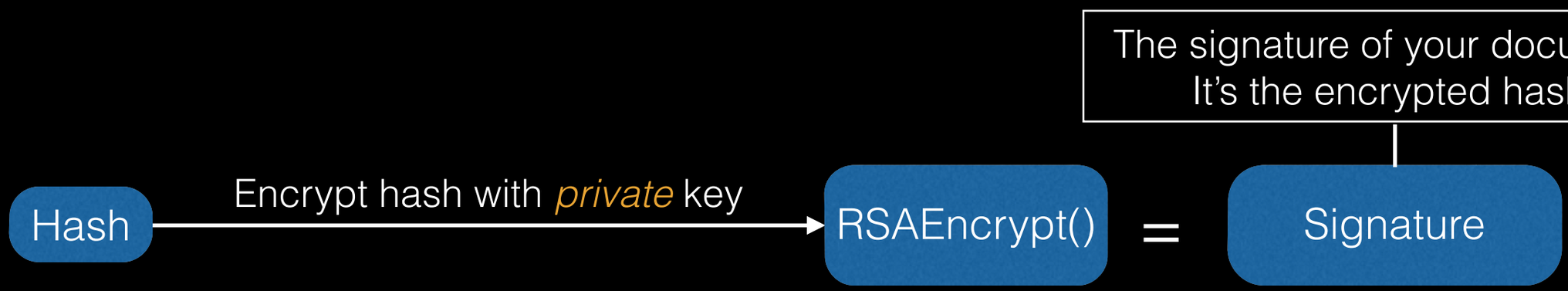


If I sent the document and hash across network at this point, we’re vulnerable.

Can easily intercept this document, change document, and rehash.

Step 2: Encrypt Fingerprint

2) Sign the document with your private key

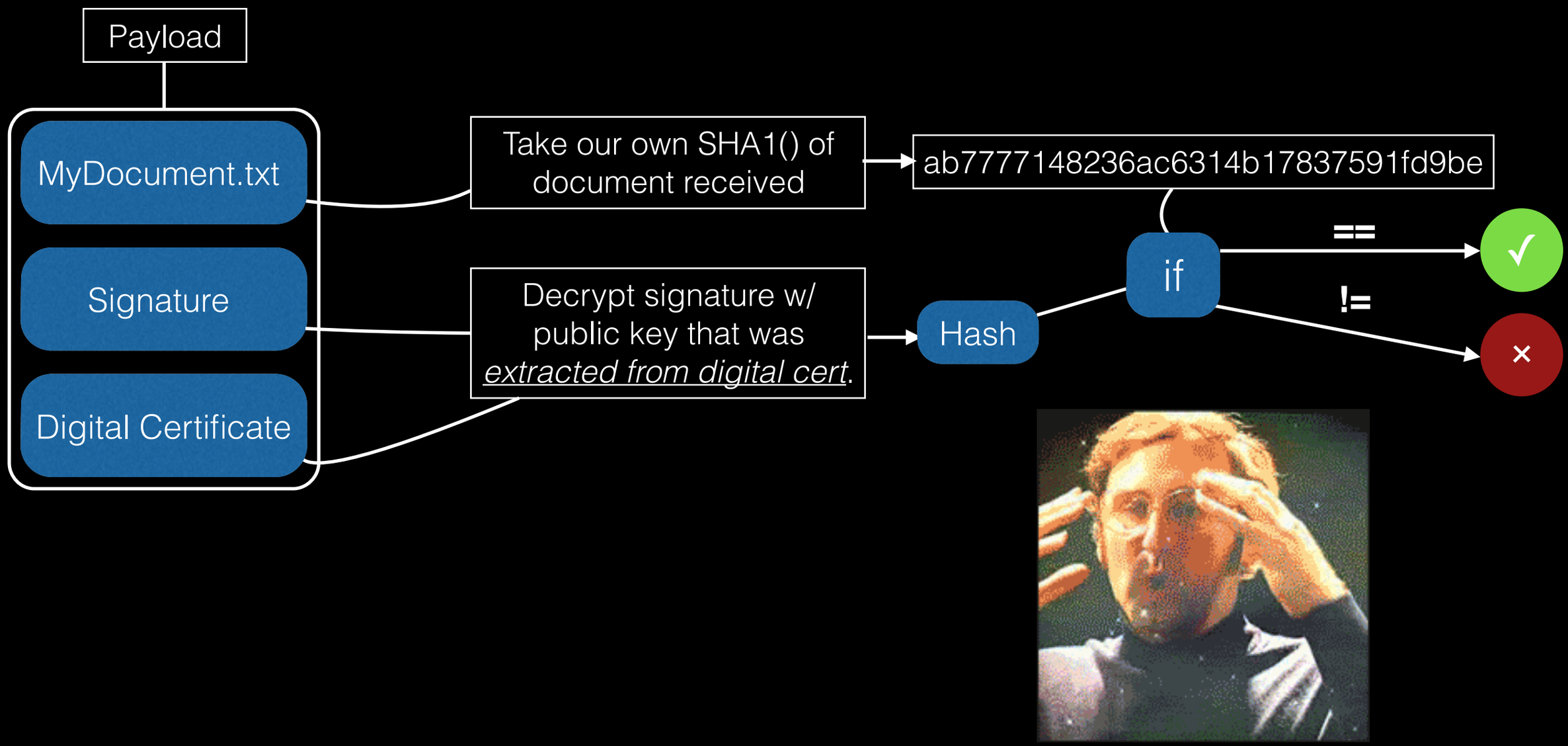


Remember, your public and private key identify you. The *public key* is part your *digital certificate* that identifies you.

Knowing that, let's see how to verify.

Step 3:Verification

3) Sent across network at this point..time to verify



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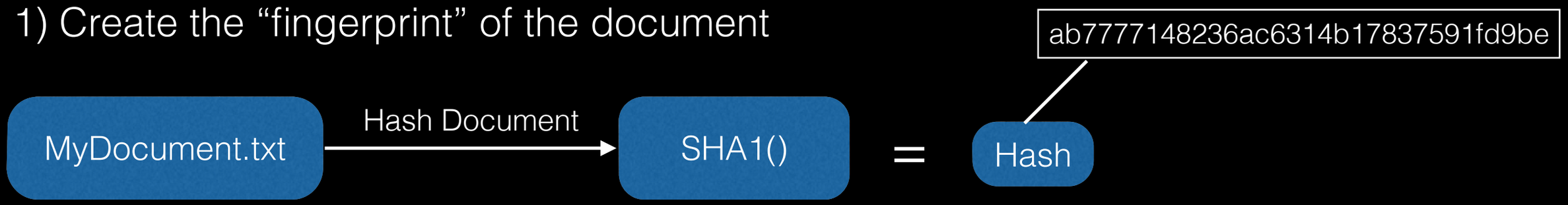

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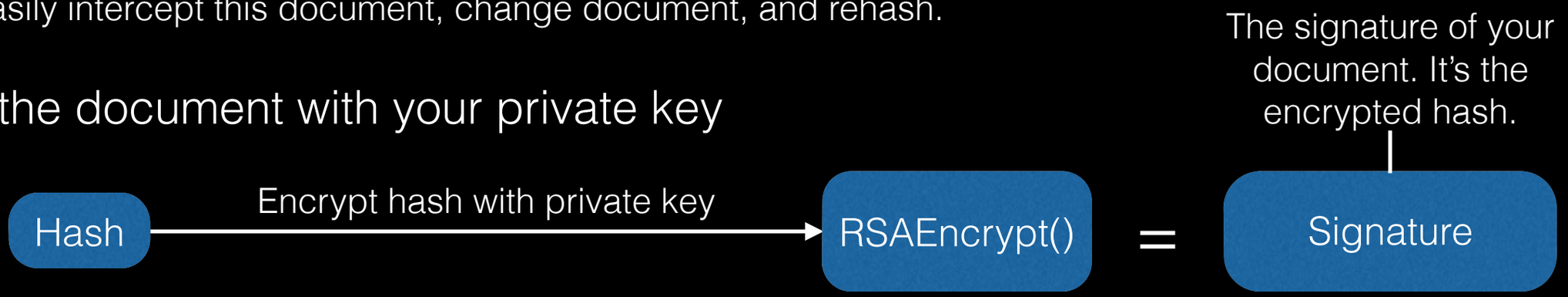

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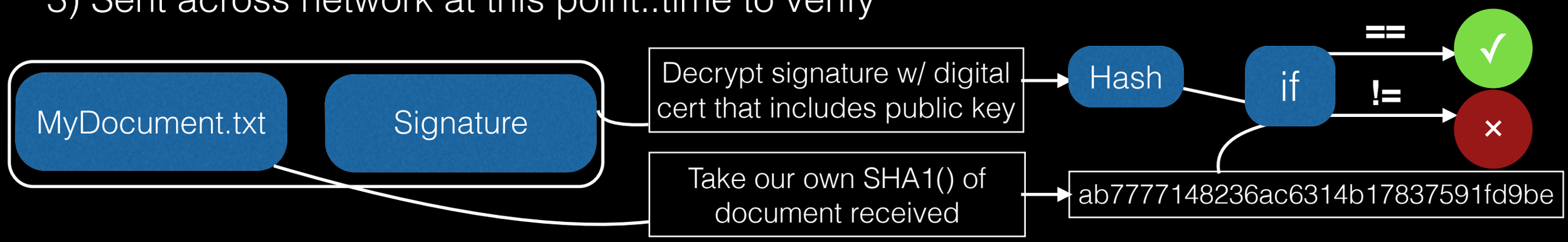
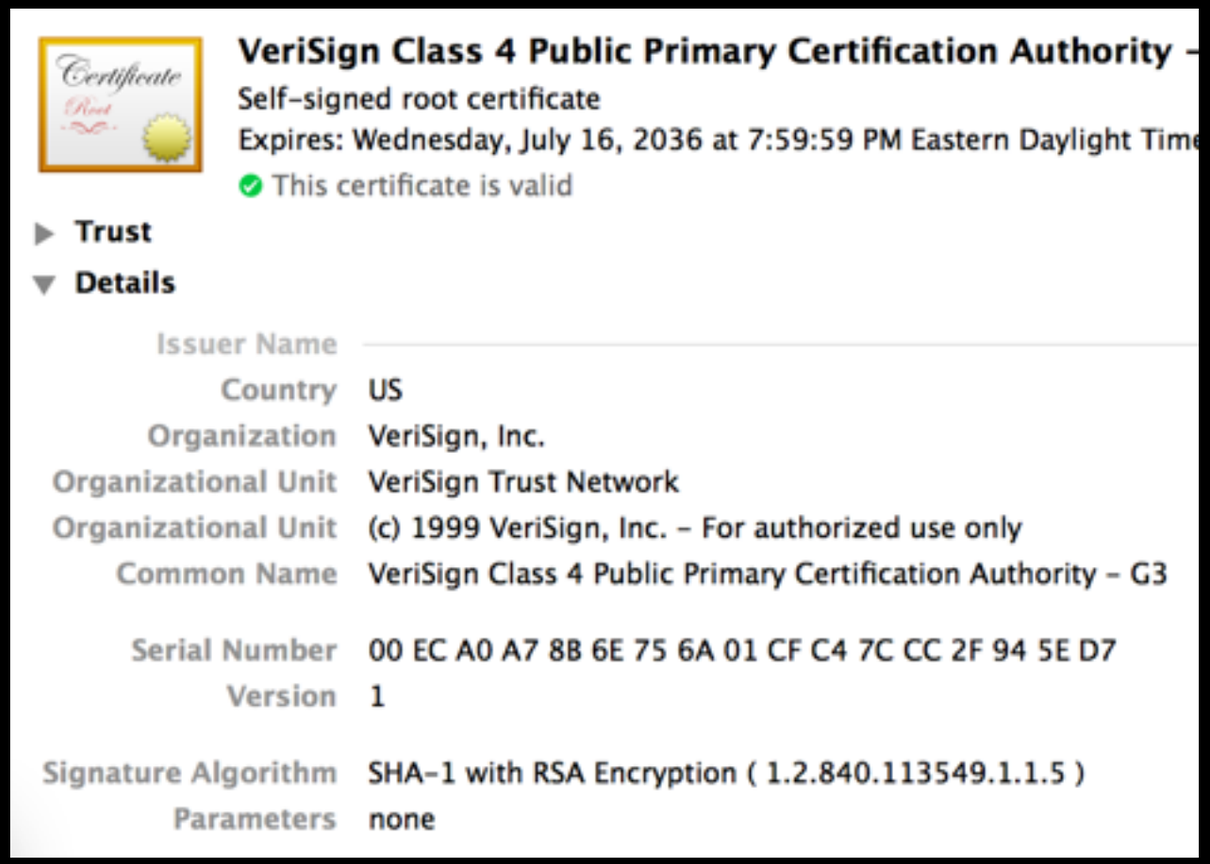


Digital Certificates

- This is what helps identify you!
- Typically a X.509 certificate..just a format that contains certain information about you and your certificate. Read Apple's crypto services guide.

CryptoServices Link



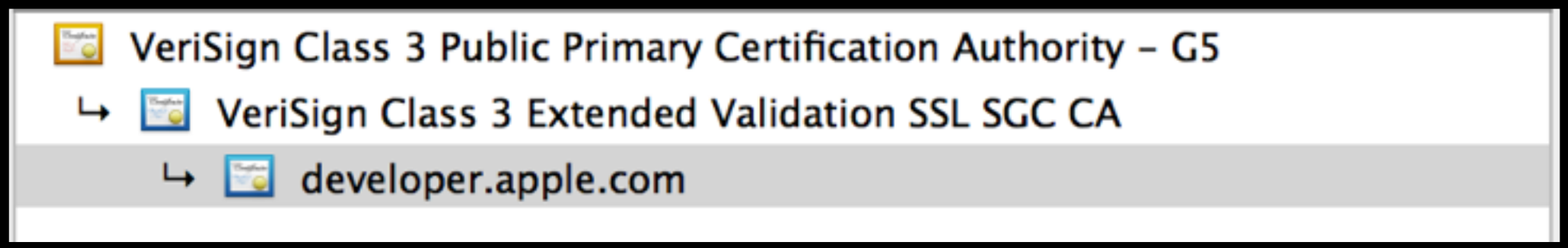
X.509

- Version, Serial Number, Message Digest (hash), etc
- A *digital signature* from a CA (someone who issued this certificate)
- Info about certificate owner (name, email, company, public key, etc)
- How long cert is valid for
- And other things…

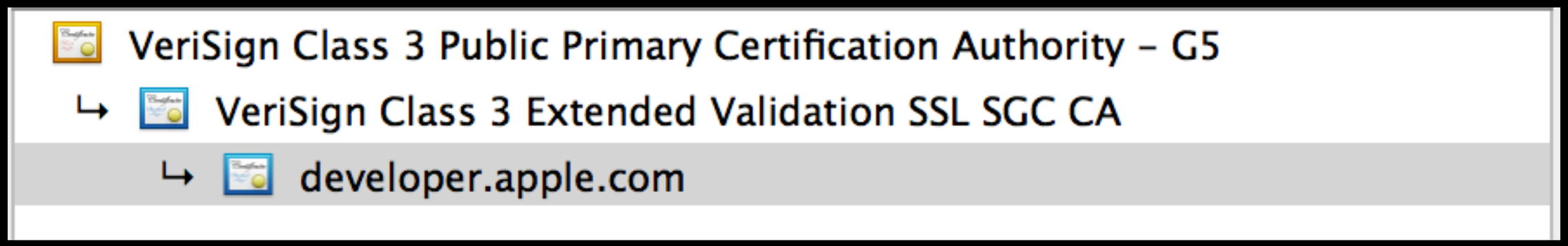
Remember, digital signatures contains a digital certificate! So a X.509 cert contains another X.509 cert that was used to digitally sign it! Like a chain…or a *certificate chain.*

Certificate Chain

- As we said, a certificate is usually digitally signed by some other CA and that process is recursive all the way until you hit a root CA (or the final cert in the chain).
- What then?
- Root certificates are *self-signed* meaning they were created by themselves..
- The chain stops here..



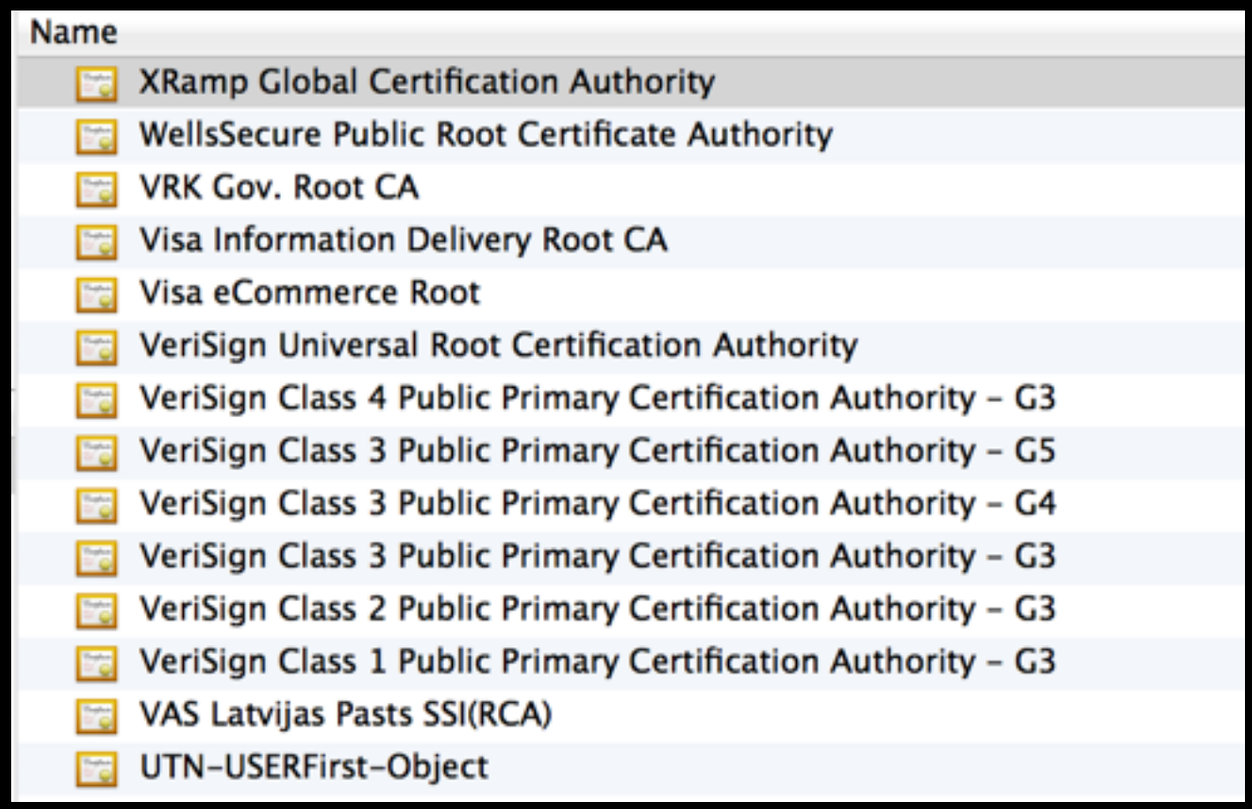
Certificate Chain cont.



- How is the certificate chain verified? Easy…
- 1) *developer.apple.com* contains signature from verisign.
- 2) Hash *developer.apple.com* cert
- 3) Decrypt signature embedded within *developer.apple.com* with public key of Verisign Class 3 Extended
- 4) Compare hashes
- 5) If match, go up the chain to VeriSign Class 3 and repeat process.
- 6) Once you get to root certificate, what happens then?

The root certificate

- How to verify the root certificate that is self-signed?
- How do I know to trust this?
- *All of your devices comes preinstalled with a list of trusted root certificates.*
- Look in your keychain on the Mac, there's 100s (System Roots Key chain)



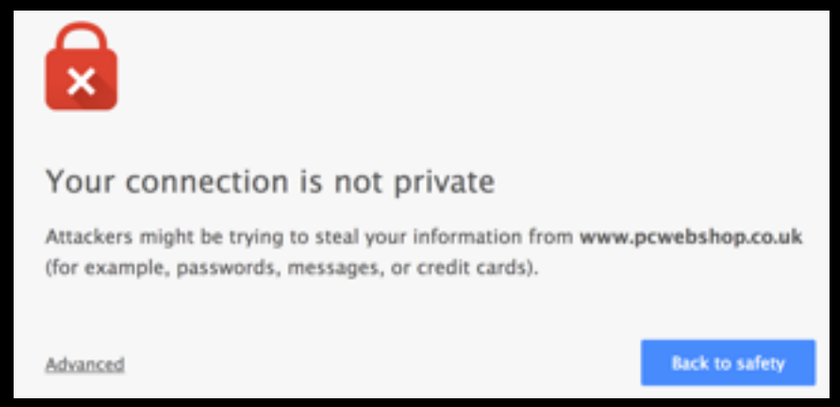
Root cert cont.

- When the certificate chain evaluates a root certificate, it will look at these preinstalled certs and if they match, it's trusted!!!
- Sounds good right? No. No. No.
- Why?

Google Attack

- Let's say I hack one of these certificate authorities that's trusted on the device.
- I create a certificate issued for *.google.com and digitally sign it with this compromised CA.
- I can now MITM you, setup fake google site, and your browser will have no idea that you're not talking to the *real* google because I'm supposedly trusted..

This actually happened…



Certificate Pinning

What is it?

- It's all about *trust*..
- In short, you take a servers certificate or a certificate in their certificate chain, store it locally on your device, when connection is initiated, you compare the certs returned from the server against this "pinned" cert in your app.
- Pinned is just a fancy term that means "compare my certificate to the one the server presented."

Note: You can compare public keys of the certs (typically embedded in the cert itself), but this presentation is about comparing the actual certs. Also you don't have to just compare against one cert, you can pin a set of certs.

When to use it?

- Simple: when *you* know *exactly* who you're going to be talking to on the backend, use certificate pinning.
  - e.g. Twitter iOS app will hit a web service that provides all of the tweets. There's no need for them to trust anyone else (Certificate Authorities in particular). Only person you need to trust, is your self.

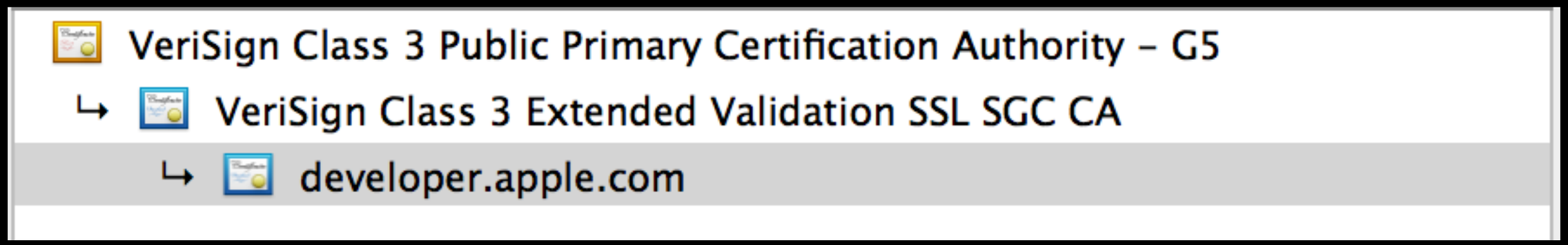
How does this help me?

- Take the google attack for example
- Instead of trusting hundreds of the “trusted” certs on the device, limit it to one or a subset of CAs to trust..this is pinning..
- You can specify the certs to trust in code..

Code Examples

- This means there's no need to go waste money on buying an SSL cert from one of these "trusted" CAs.
- This actually could open you up to more attacks if you don't pin against the CA your purchased the cert from..
- Trust in yourself, create your own certs..

Which certs to pin?



If we pin against the *developer.apple.com*, this is fine, but if the cert changes, your app will break and you will need to update.

If we pin against the root cert *VeriSign Class 3 Public Primary Certification Authority - G5*, the cert on the server *can* change as long as the certificate chain still has the same root CA.

But what if…

- You have physical access to the device and swap out the certificate that stored in the bundle (using iExplorer)
  - Good point. Swap out cert in bundle with cert of your choice. MITM the device - present your cert to the device and your good to go.
- You could get creative, store it in db that ships with app that's encrypted, or whatever else you can think of to obfuscate it.
- Maybe hardcode a hash and hash the cert before pinning it? If different, it's been tampered with…
  - Still not gonna stop someones that's determined. You can easily reverse the binary and patch it with the hash of your choice.
- So…once you have physical access to *any* device, the party is over. There will be a way to compromise the app/device/etc.

Questions?

Resources

- WWDC 2014 - Session 704 - 27 minute mark for implementation

- https://www.owasp.org/index.php/Certificate_and_Public_Key_Pinning

- http://www.thoughtcrime.org/blog/authenticity-is-broken-in-ssl-but-your-app-ha/

Anonymous Request

- Spoofing your MAC address
- sudo ifconfig <interface> lladdr 00:11:33:44:55:66
- Not persistent between boots
- Have a nice day ;)

Thanks

@bartcone