EVERYTHING YOU ALWAYS WANTED TO KNOW ABOUT CERTIFICATE TRANSPARENCY

(BUT WERE AFRAID TO ASK)

MARTIN SCHMIEDECKER

#8167

Everything you always wanted to know about Certificate Transparency

(but were afraid to ask)

SBA Research

Martin who?

$whoami:

- member c^{3}wien
- online privacy, network security & digital forensics
- researcher at SBA Research
- @Fr333k

Agenda

State of the Foo

The Big Picture

Under the hood

Show me the data!

Agenda

State of the Foo

The Big Picture

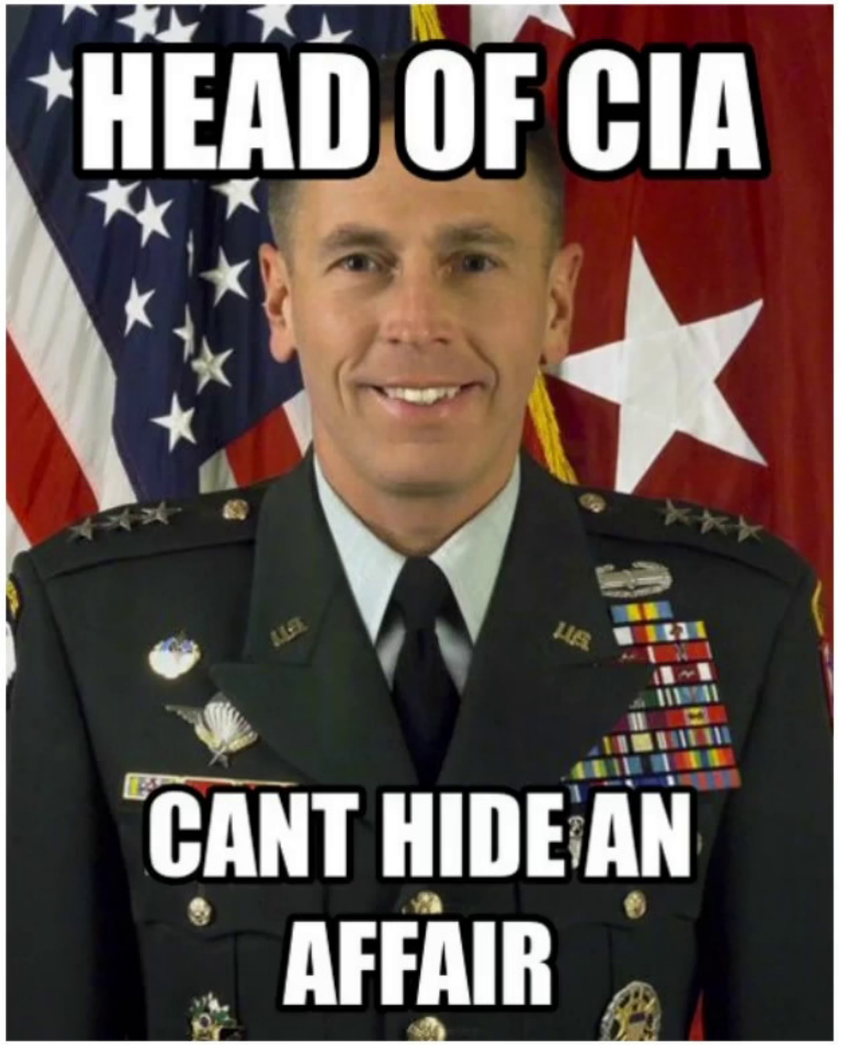
Under the hood

Show me the data!

Disclaimer

Keep in mind:

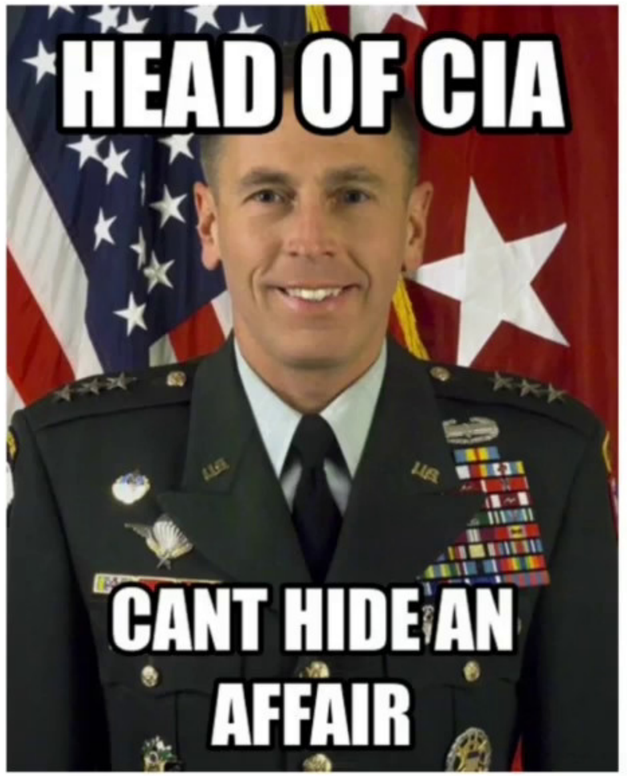
- this is a serious topic
- memes & cat pics are just means to an end
- people literally depend on decent HTTPS

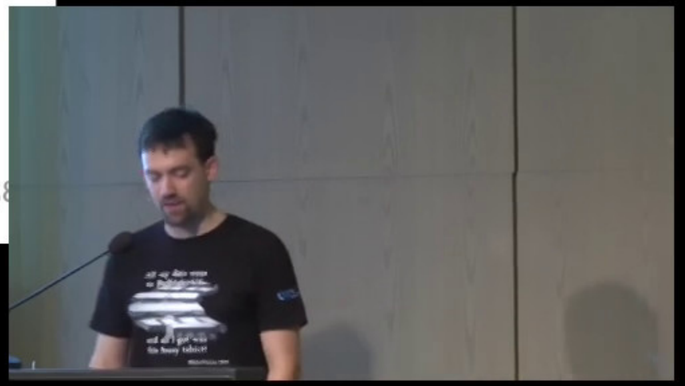


Disclaimer

Keep in mind:

- this is a serious topic
- memes & cat pics are just means to an end
- people literally depend on decent HTTPS





DigiNotar

It all started with a hack:

- July 10th-20th, 2011
- CA DigiNotar pwned
- 531 fraudulent certificates issued
- among them: *.google.com, *.windowsupdate.com, *.mozilla.com, *.torproject.org ...

DigiNotar

It all started with a hack:

- July 10th-20th, 2011
- CA DigiNotar pwned
- 531 fraudulent certificates issued
- among them: *.google.com, *.windowsupdate.com, *.mozilla.com, *.torproject.org ...

DigiNotar

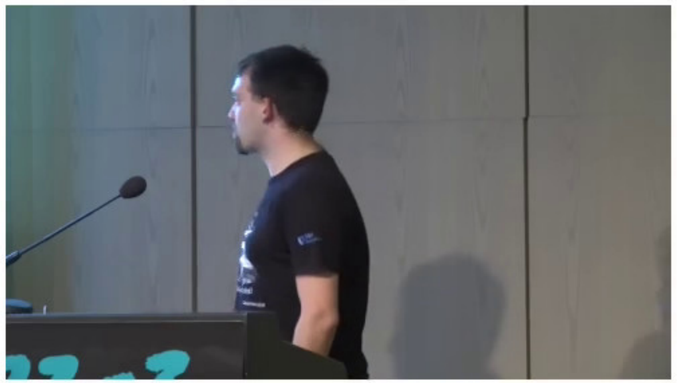
Who got MitM'd:

- at least 300.000 unique IPs
- $>$ 99% from Iran
- identified using OCSP requests
- others: Tor, VPN, proxies ...

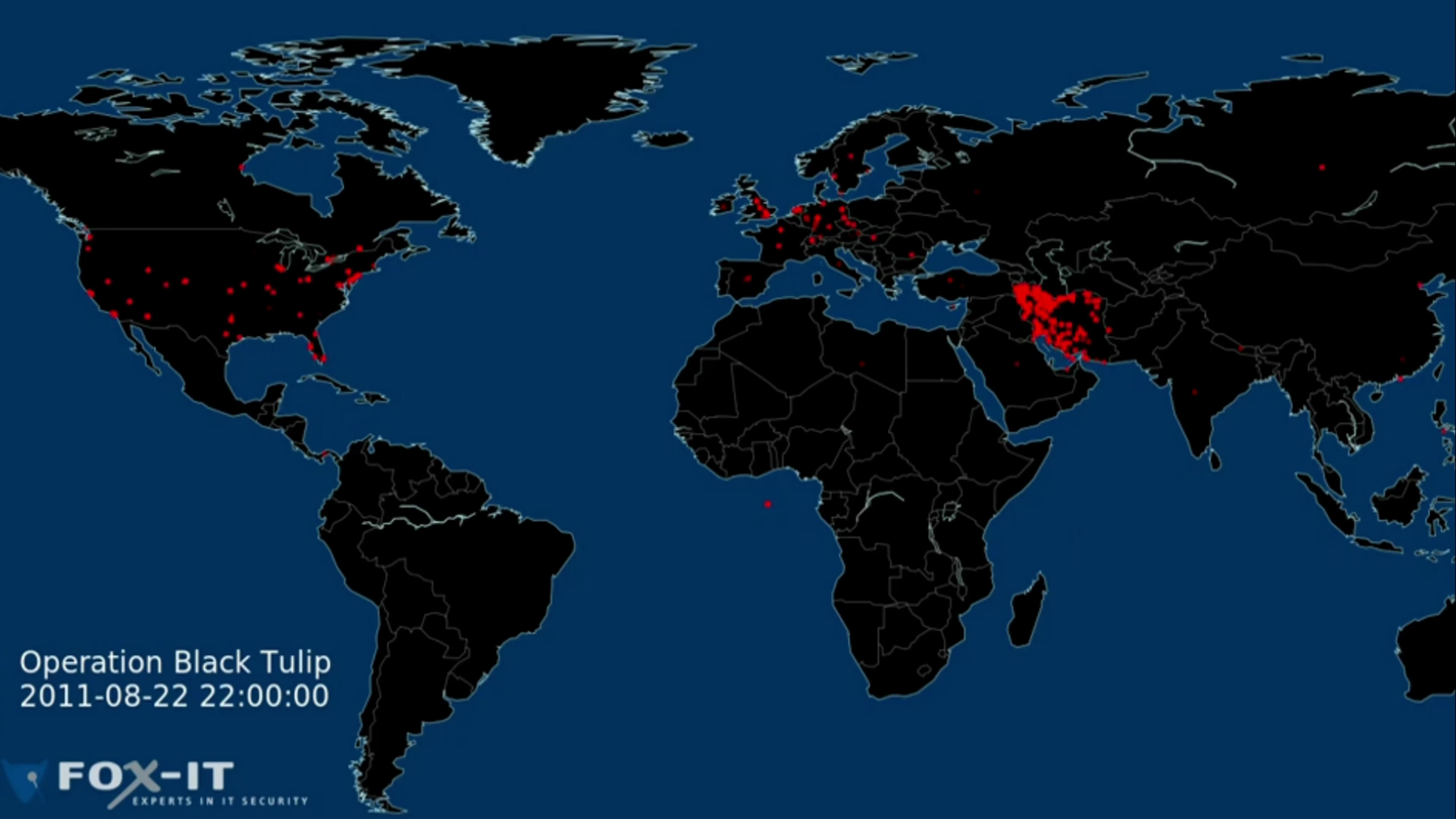
DigiNotar

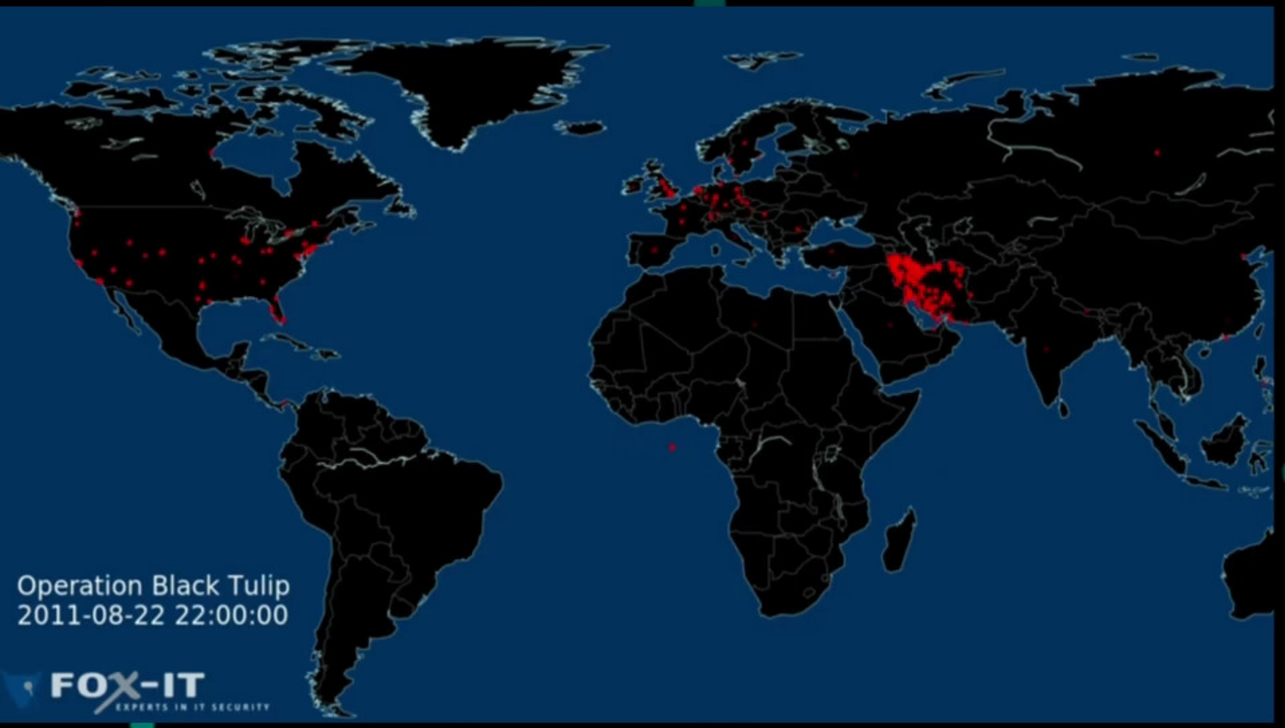
Who got MitM'd:

- at least 300.000 unique IPs
- $>$ 99% from Iran
- identified using OCSP requests
- others: Tor, VPN, proxies ...




Operation Black Tulip
2011-08-22 22:00:00
FOX-IT
EXPERTS IN IT SECURITY


Operation Black Tulip
2011-08-22 22:00:00
FOX-IT
EXPERTS IN IT SECURITY


Operation Black Tulip
2011-08-22 22:00:00
FOX-IT
EXPERTS IN IT SECURITY


33c3
EM ROF SKROW

DigiNotar

Lessons learned (for CAs):

- patch your software!
- use antivirus!
- strong passwords for admin accounts!
- not all eggs in one basket (domain)
- report incidents

DigiNotar

Lessons learned (for CAs):

- patch your software!
- use antivirus!
- strong passwords for admin accounts!
- not all eggs in one basket (domain)
- report incidents

Other Incidents

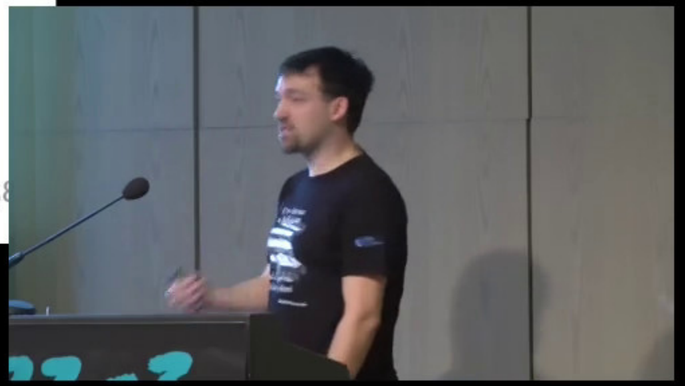
Fraudulent CAs:

- Trustwave 2011: sub-CA for introspection
- Lenovo Superfish 2015: local MitM-CA
- CNNIC 2015: sub-CA for introspection
- Symantec 2016: test certificates (with CT)
- ...

Other Incidents

Fraudulent CAs:

- Trustwave 2011: sub-CA for introspection
- Lenovo Superfish 2015: local MitM-CA
- CNNIC 2015: sub-CA for introspection
- Symantec 2016: test certificates (with CT)
- ...



Other Incidents

Fraudulent CAs:

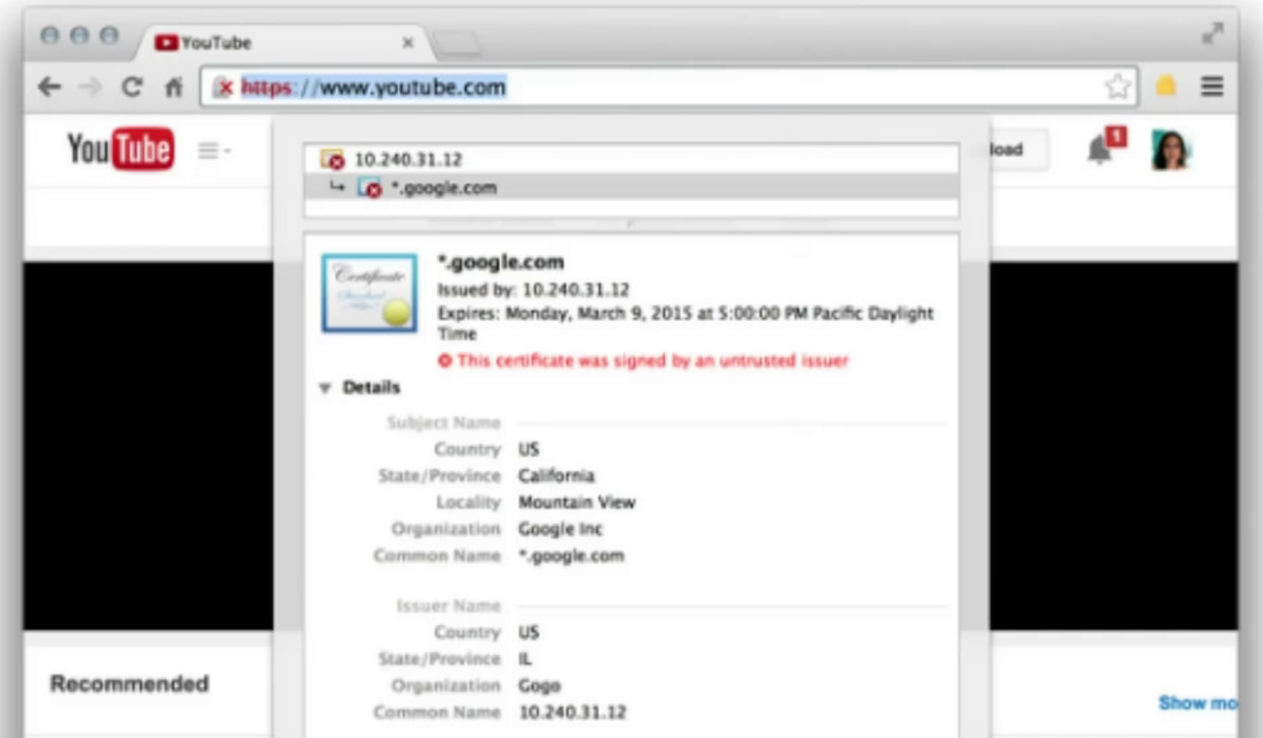
- Trustwave 2011: sub-CA for introspection
- Lenovo Superfish 2015: local MitM-CA
- CNNIC 2015: sub-CA for introspection
- Symantec 2016: test certificates (with CT)
- …

Gogo inflight wifi

Adrienne Porter Felt ✓
@__apf__

Follow

hey @Gogo, why are you issuing *.google.com certificates on your planes?



More Problems

(Some) weaknesses of TLS:

- certificate revocation is tricky
- all CAs for all CommonNames
- 1800+ CAs and sub-CAs (in 2013) [1]
- 1/3 never used for issuing HTTPS certificate (in 2014) [2]

More Problems

(Some) weaknesses of TLS:

- certificate revocation is tricky
- all CAs for all CommonNames
- 1800+ CAs and sub-CAs (in 2013) [1]
- 1/3 never used for issuing HTTPS certificate (in 2014) [2]

More Problems

Implementation issues:

- different trust stores per OS/browser
- low entropy during key generation
- “goto fail;”

Deployment issues:

- SSLv2, SHA-1, CipherSuites, …
- STARTTLS, no PFS, …

More Problems

Implementation issues:

- different trust stores per OS/browser
- low entropy during key generation
- “goto fail;”

Deployment issues:

- SSLv2, SHA-1, CipherSuites, ...
- STARTTLS, no PFS, ...

More Problems

Implementation issues:

- different trust stores per OS/browser
- low entropy during key generation
- “goto fail;”

Deployment issues:

- SSLv2, SHA-1, CipherSuites, …
- STARTTLS, no PFS, …

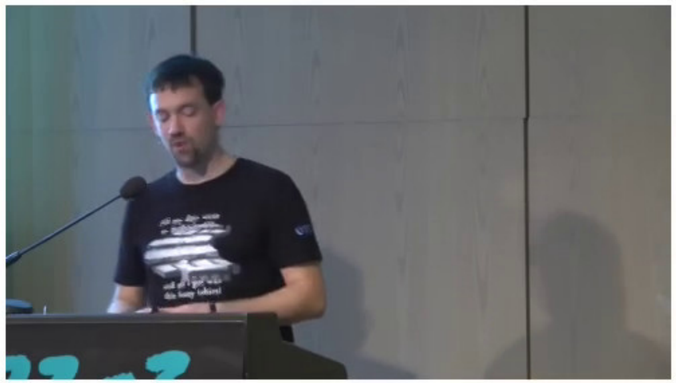
More Problems

Implementation issues:

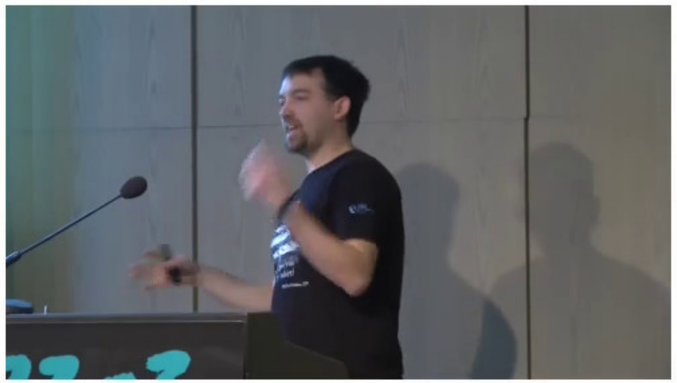
- different trust stores per OS/browser
- low entropy during key generation
- “goto fail;”

Deployment issues:

- SSLv2, SHA-1, CipherSuites, …
- STARTTLS, no PFS, …



More Problems



More Problems

More Problems

Symantec

BlueCoat

More Problems

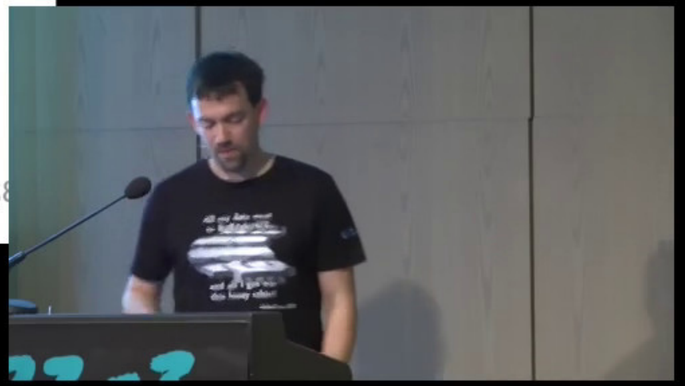
More Problems


CERTIFICATE TRANSPARENCY
TO THE RESCUE
memecrunch.com

Basic Idea of CT

Wouldn’t it be nice, if …

- CAs would publish all their business?
- problems could be detected upon issuance?
- there was punishment for misbehaving CAs?



Google is like ...

Why Google?

Uniquely positioned:

- control over client-run software
- pinned their certs
- $>$ 50% market share
- also, common target

Why Google?

Uniquely positioned:

- control over client-run software
- pinned their certs
- $>$ 50% market share
- also, common target

Solution

RFC 6962:

- public, append-only cert logging
- cryptographically assured
- open for all

Goals:

- detect misbehaving CAs
- quickly identify fraudulent certs

Solution

RFC 6962:

- public, append-only cert logging
- cryptographically assured
- open for all

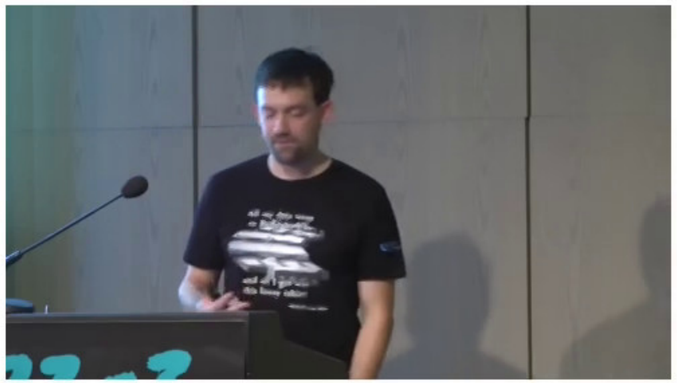
Goals:

- detect misbehaving CAs
- quickly identify fraudulent certs

RFC 6962

CT Entities:

- *Logs*: collect certificates
- *Monitors*: identify suspicious certs
- *Auditors*: identify misbehaving logs



RFC 6962

Monitors:

- periodically fetch all logged certs
- look for suspicious certs or permissions
- e.g. sub-CAs, submitted cert not visible, …
- most commonly CAs
- also, identify misbehaving log operators

RFC 6962

Auditors:

- verify log integrity
- e.g. no old certs removed, back-dated certs, …
- query logs with signed cert timestamp (SCT)
- verify log proofs
- most commonly browsers

RFC 6962

Auditors:

- verify log integrity
- e.g. no old certs removed, back-dated certs, …
- query logs with signed cert timestamp (SCT)
- verify log proofs
- most commonly browsers

RFC 6962

CT openess:

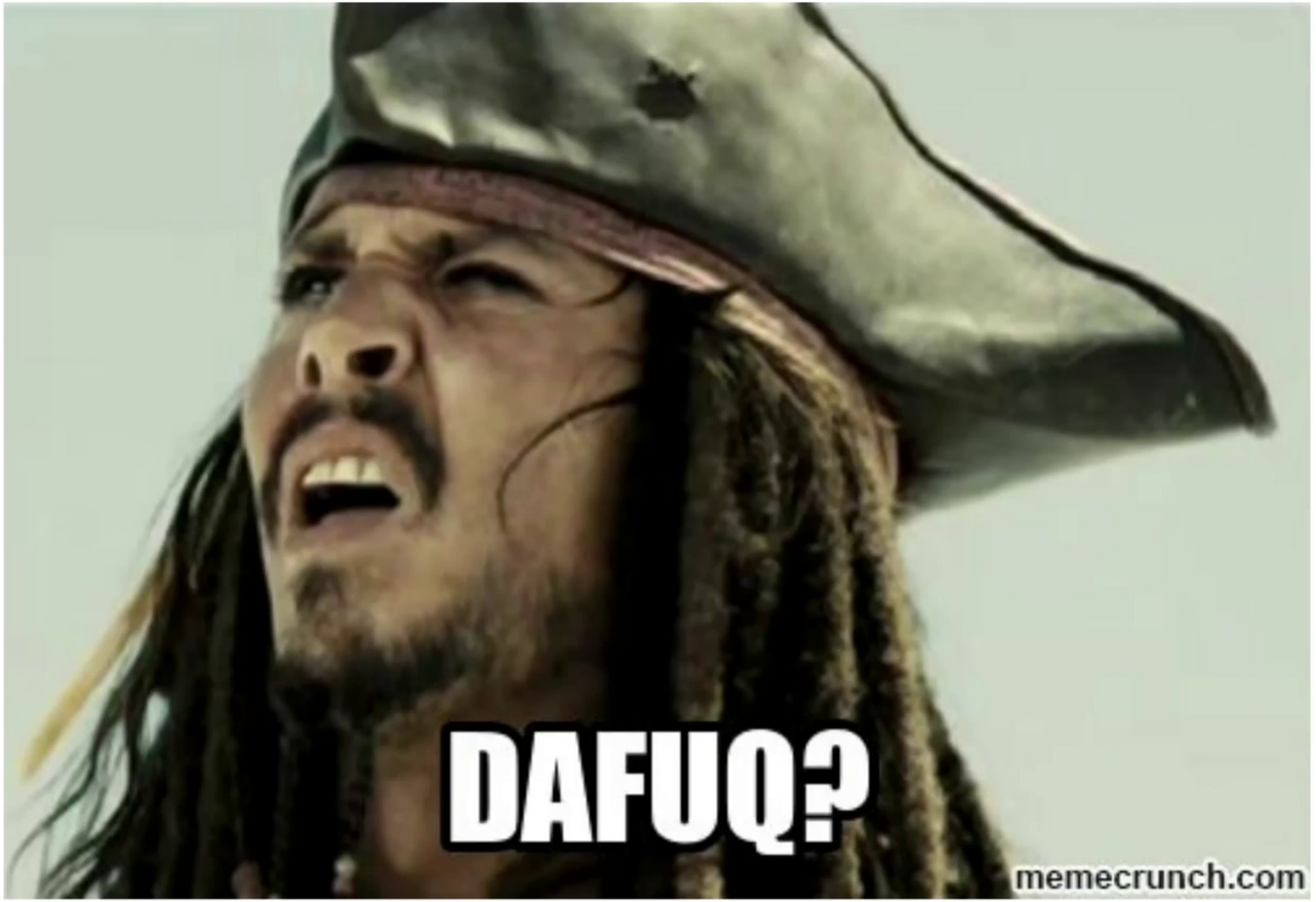
- anyone can run any software
- e.g. CA can run all three:
  - log, monitor & auditor
  - also for other CAs and logs
- ideally, all gossip with each other
- difficulty: mostly availability, and log size

Under the Hood

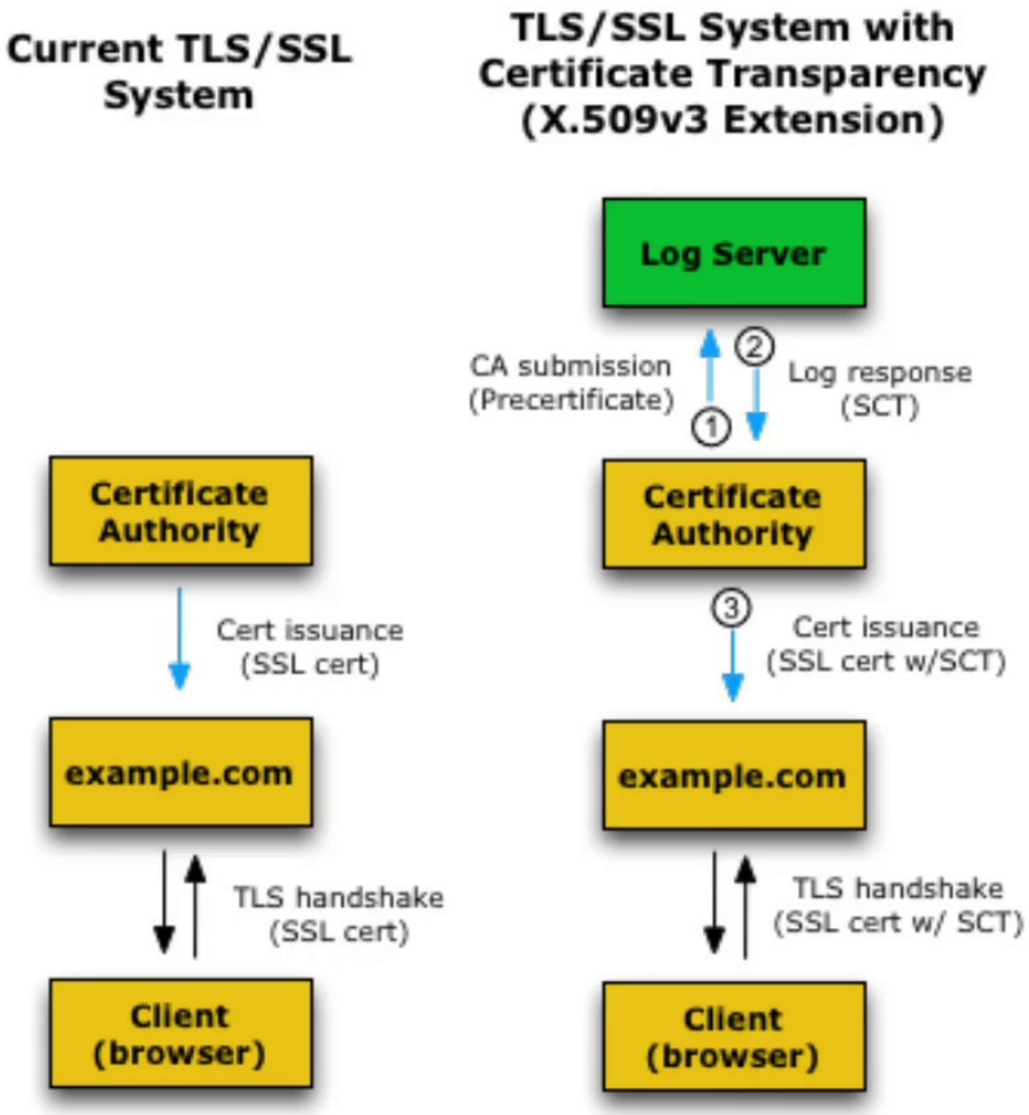
But how does it work?

- CAs send (pre-)cert to log
- immediately get a signed SCT back
- log promises to add the cert
- servers deliver SCT with cert

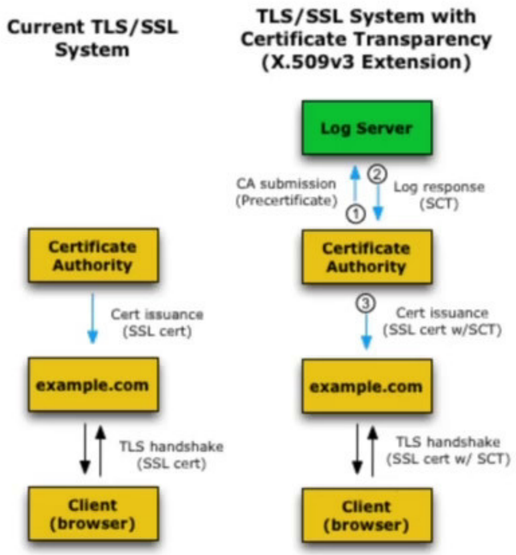
Under the Hood



Under the Hood



Under the Hood



Under the Hood

Signed Certificate Timestamp (SCT):

- contains timestamp and cert
- LogID
- signed by log
- 3 methods available for clients

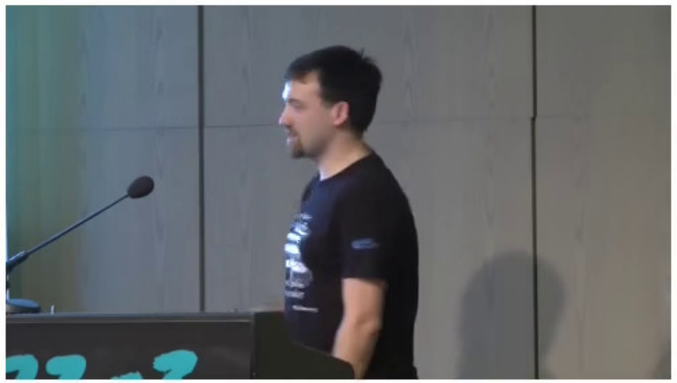
non-exclusive, a cert may have multiple SCT

Under the Hood

Signed Certificate Timestamp (SCT):

- contains timestamp and cert
- LogID
- signed by log
- 3 methods available for clients

non-exclusive, a cert may have multiple SCT



Under the Hood

X.509v3 extensions:

- send pre-certificate to log
- get SCT valid for cert
- obtain certificate from CA
- SCT is part of certificate
- works on all current servers

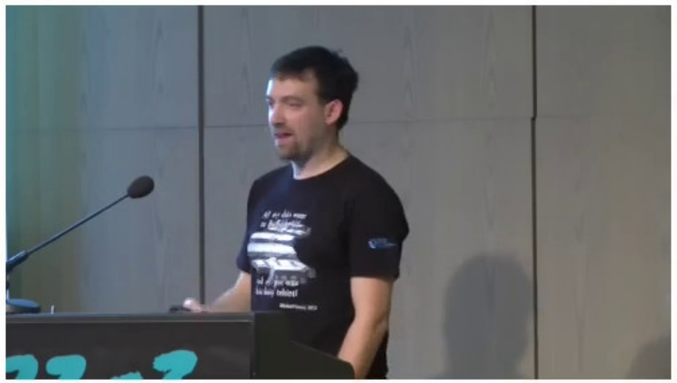
Under the Hood

OCSP stapling:

- part of the OCSP information

OR as part of the TLS handshake:

- as TLS extension
- part of the ClientHello



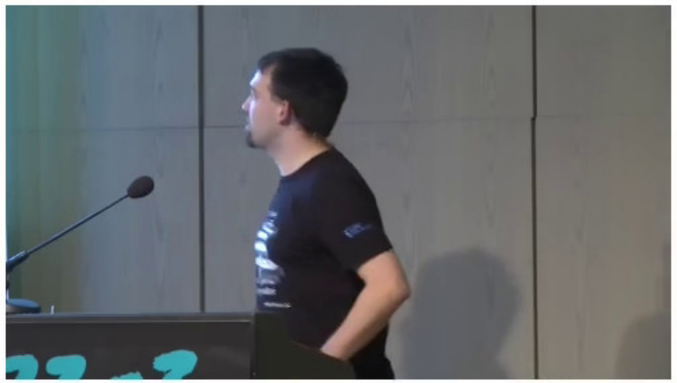
Merkle Tree

Merkle Hash Tree:

- foundation for CT logs
- binary tree
- hash of a node depends on all children
- CT uses SHA-256

More funky terms:

- *maximum merge delay*, usually 24h
- *signed tree head* (STH)



Merkle Tree

Merkle Hash Tree:

- foundation for CT logs
- binary tree
- hash of a node depends on all children
- CT uses SHA-256

More funky terms:

- *maximum merge delay*, usually 24h
- *signed tree head* (STH)

Merkle Tree

Merkle Hash Tree:

- foundation for CT logs
- binary tree
- hash of a node depends on all children
- CT uses SHA-256

More funky terms:

- *maximum merge delay*, usually 24h
- *signed tree head* (STH)

Merkle Tree

Why MHT:

- order of included elements important
- signed tree hash == all elements
- proofs are hashes of inner nodes
- number is small

not possible to unnoticeably:

- back-date elements
- remove elements
- add elements

Merkle Tree

Merkle Hash Tree:

- foundation for CT logs
- binary tree
- hash of a node depends on all children
- CT uses SHA-256

More funky terms:

- *maximum merge delay*, usually 24h
- *signed tree head* (STH)

Merkle Tree

Why MHT:

- order of included elements important
- signed tree hash == all elements
- proofs are hashes of inner nodes
- number is small

not possible to unnoticeably:

- back-date elements
- remove elements
- add elements

Merkle Tree

Growing trees:

- logs add new certs e.g. every hour
- build a separate tree
- merge it with main tree
- all previous elements still there
- minimal hashes needed for verification

Merkle Tree

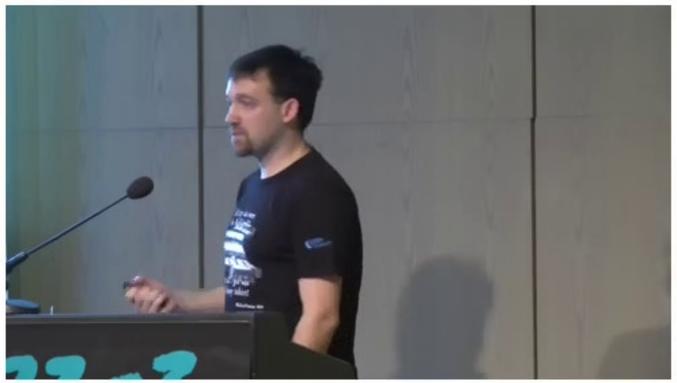
Merkle Consistency Proof:

- a.k.a “Hey log, u be cheating?”
- get STH, certs, inner nodes
- have: old STH
- verify STH and signature

Merkle Tree

Merkle Consistency Proof:

- a.k.a “Hey log, u be cheating?”
- get STH, certs, inner nodes
- have: old STH
- verify STH and signature



Merkle Tree

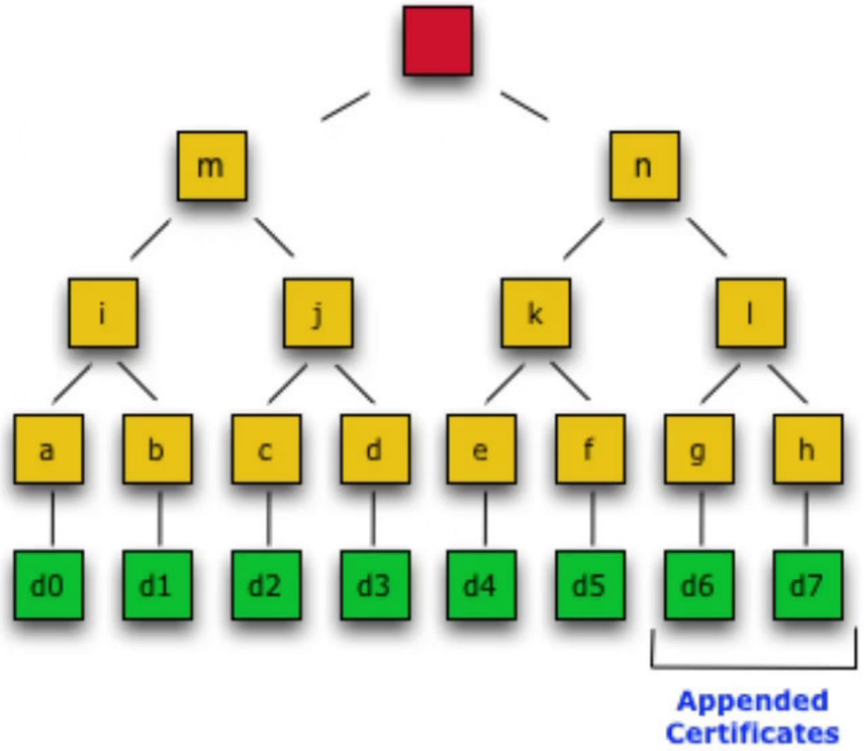


Figure 3

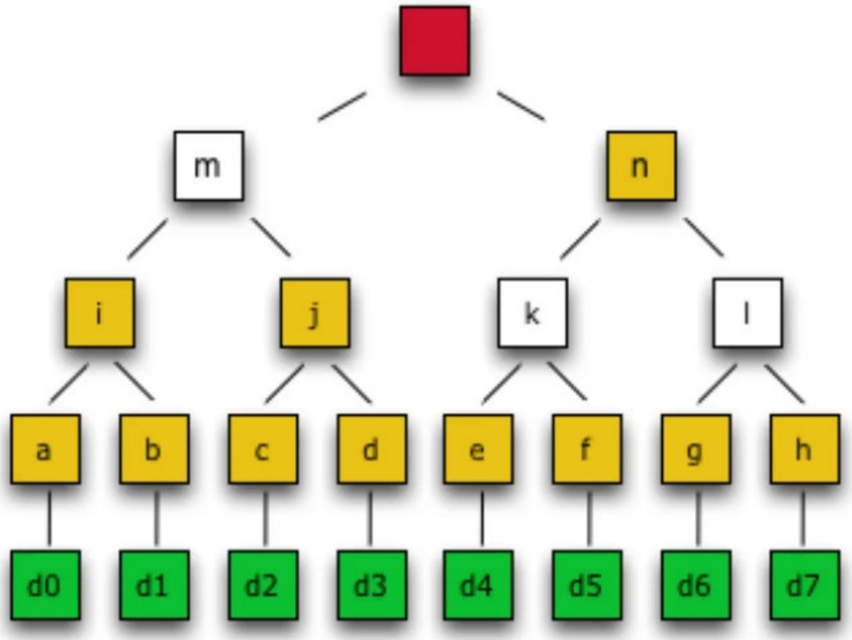


Figure 4

Merkle Tree

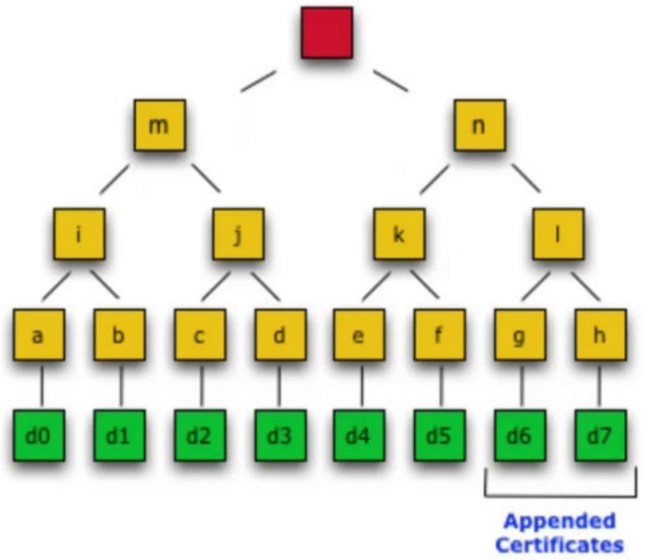


Figure 3

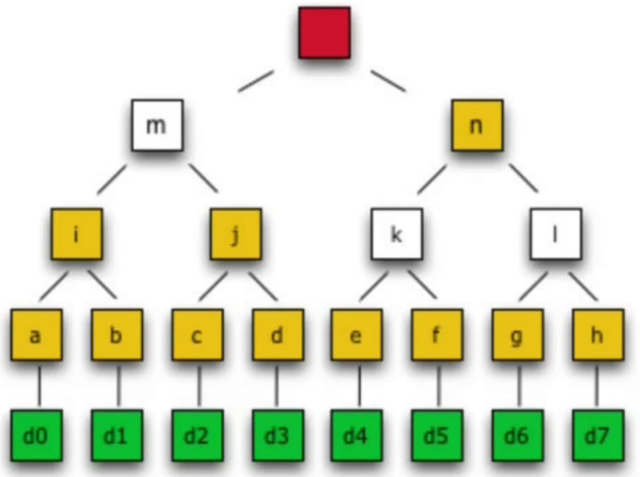


Figure 4

Merkle Tree

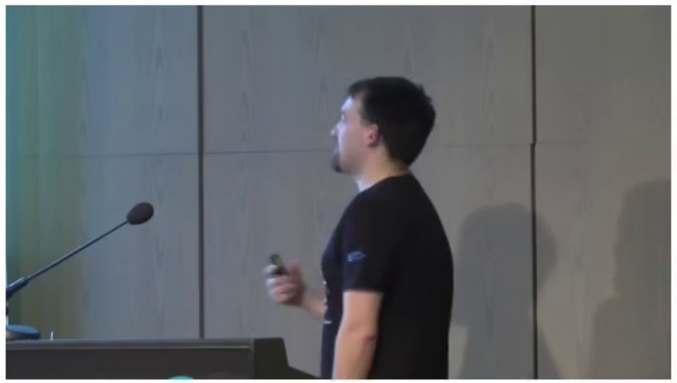
Audit proofs:

- specific certificate is in the log?
- no need to obtain all certificates
- only (few) inner node hash values
- reconstruct STH

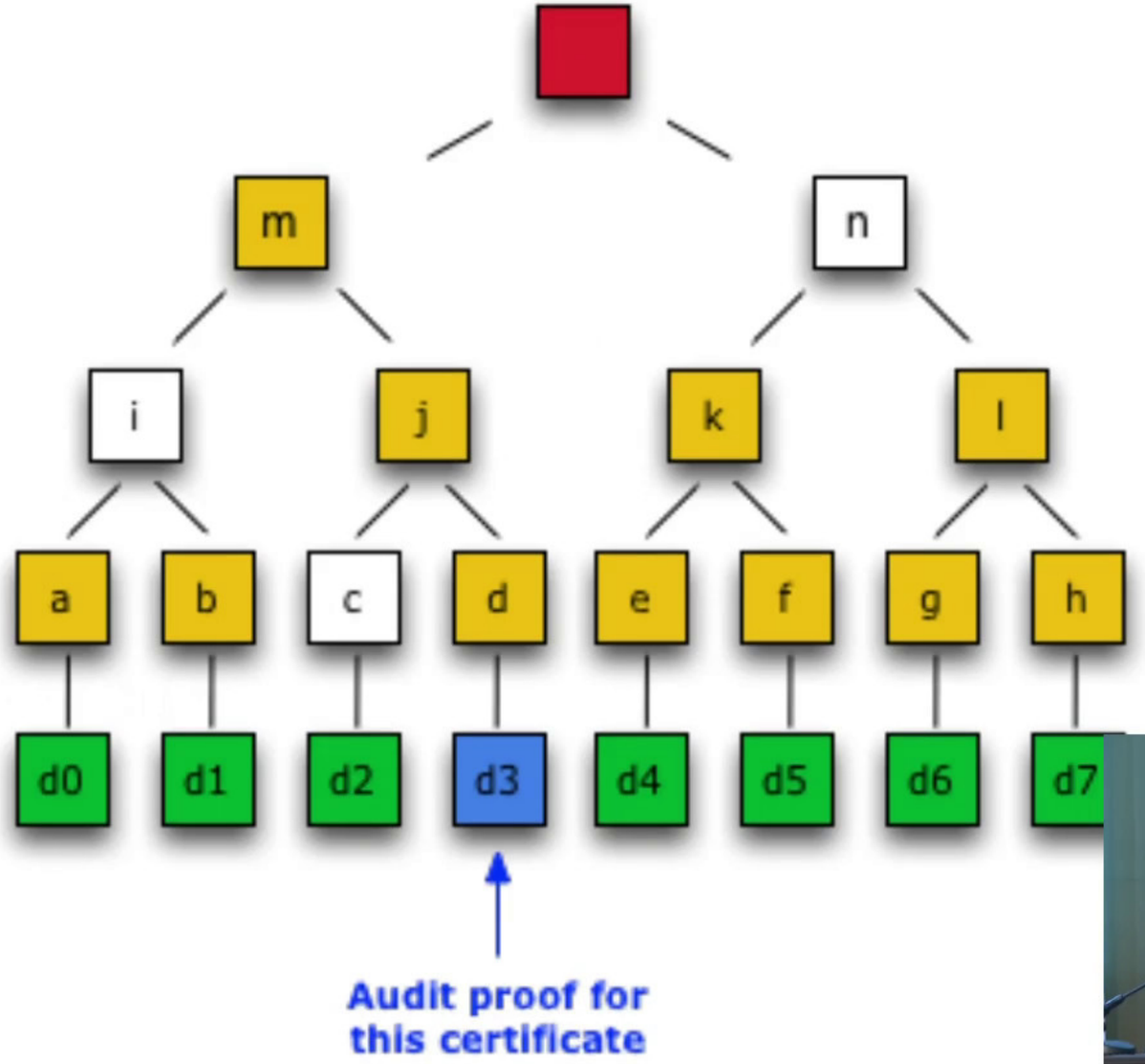
Merkle Tree

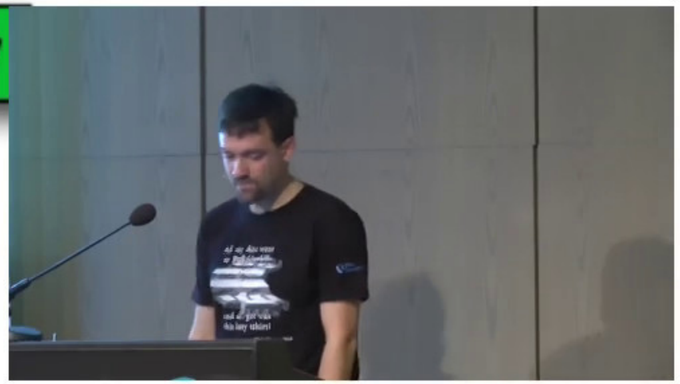
Audit proofs:

- specific certificate is in the log?
- no need to obtain all certificates
- only (few) inner node hash values
- reconstruct STH

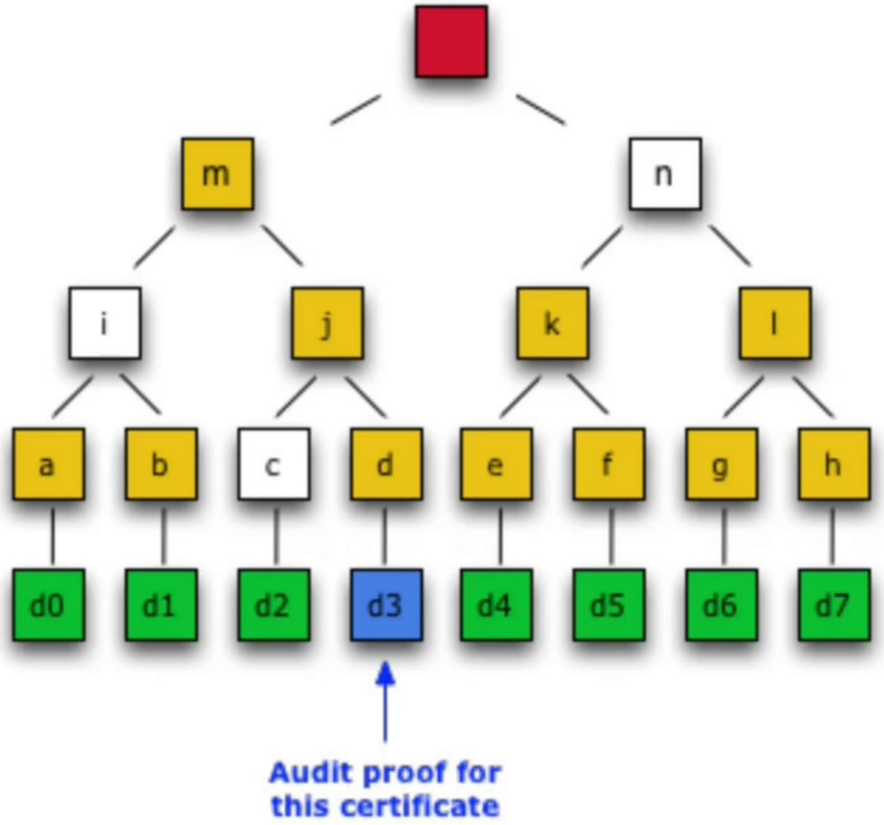


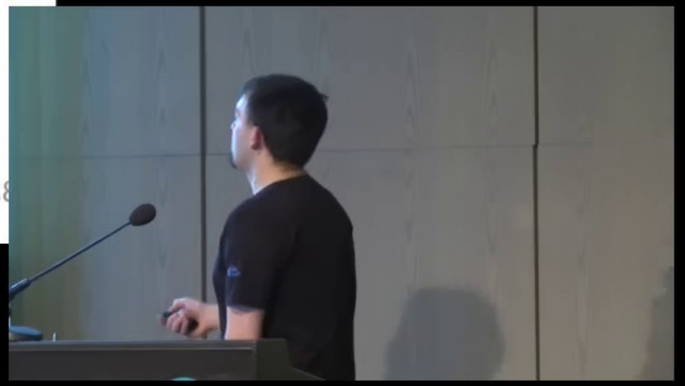
Merkle Tree


m
n
i
j
k
l
a
b
c
d
e
f
g
h
d0
d1
d2
d3
d4
d5
d6
d7
Audit proof for
this certificate

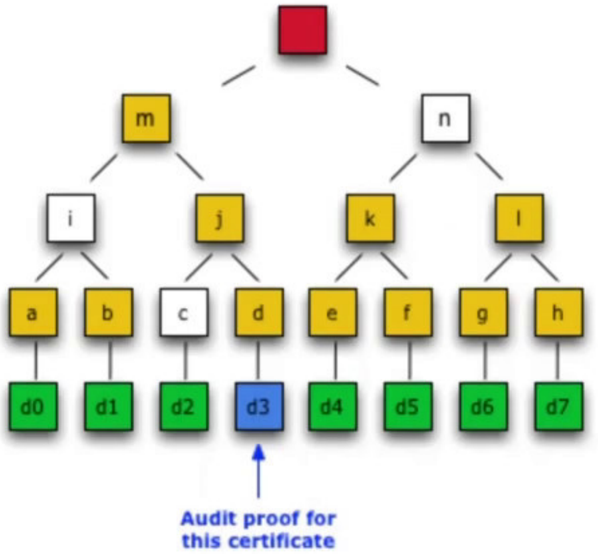


Merkle Tree


m
n
i
j
k
l
a
b
c
d
e
f
g
h
d0
d1
d2
d3
d4
d5
d6
d7
Audit proof for
this certificate



Merkle Tree


m
n
i
j
k
l
a
b
c
d
e
f
g
h
d0
d1
d2
d3
d4
d5
d6
d7
Audit proof for
this certificate


33c3
EM ROF SKROW

Merkle Tree

Ever-growing logs:

- nothing is forever
- need to rotate the logs
- old logs get “frozen”
- e.g. aviator, 46M certs
- needs to remain online until last cert expires

Merkle Tree

Ever-growing logs:

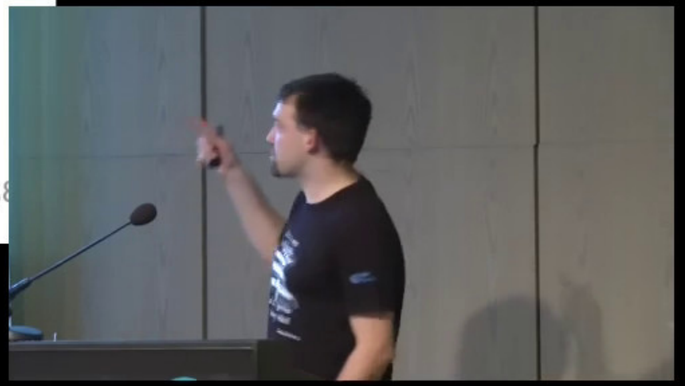
- nothing is forever
- need to rotate the logs
- old logs get “frozen”
- e.g. aviator, 46M certs
- needs to remain online until last cert expires

Gossip

Information exchange:

- logs should chatter
- exchange STH
- detect malicious logs
- split-world attack e.g. gouvernments
- piggybacked in handshake [3]

Gossip



Gossip

Who is logging

Who runs the logs:

- Google: 5 logs
  - 3 open for all
  - 1 let's encrypt
  - 1 non-let's encrypt
- Digicert: among the first
- Symantec, WoSign, CNNIC: caught cheating
- some smaller ones

In Browsers

Support by browsers:

- Google mandates 2 SCT for EV certs
- also checks it chrome://net-internals
- Firefox will gradually include

In Browsers

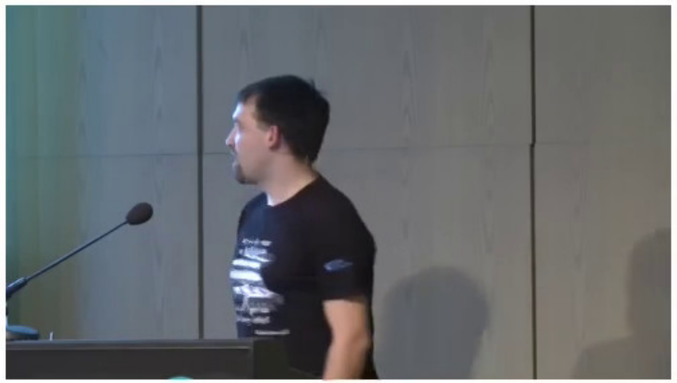
Support by browsers:

- Google mandates 2 SCT for EV certs
- also checks it chrome://net-internals
- Firefox will gradually include

Does it work?

Symantec incident:

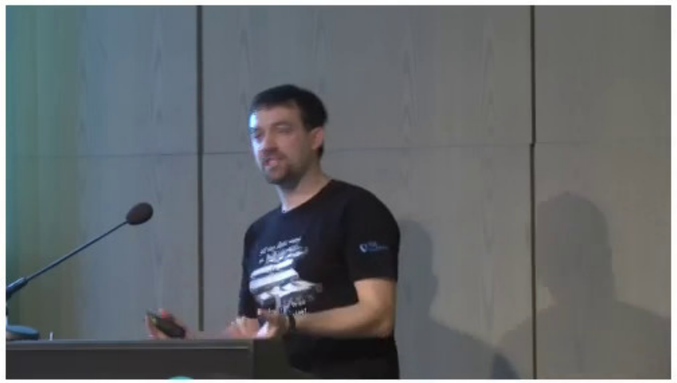
- issued google.com
- 23 “test certificates”
- CT logs had another 164 certs
- another 2.5k certs for non-existing domains



Downsides

Privacy:

- people can learn your internal hosts
- great for reconaissance!
- popular: Let’s encrypt



Downsides

Log entries must contain entire chain up to root, thus:

- excludes self-signed
- exludes DANE

“… until some mechanism to control spam is found. The authors welcome suggestions.”

Show me the data!

Show me the data!

Show me the Data

For all logs:

- https://URL/ct/v1/get-sth
- gives no. of certs, timestamp, root hash and signature

Show me the Data


```
{"tree_size":46466472,
"timestamp":1480512258330,
"sha256_root_hash":"LcGcZRsm+LGYmrlyC5LXhV1T6OD8iH5dNlb0sEJl9bA=",
"tree_head_signature":"BAMASDBGAiEA/M0Nvt77aNe
+9eYbKsv6rRpTzFTKa5CGqb56ea4hnt8CIQCJDE7pL6xgAewMd5i3G1lrBWgFooT2kd3+zliEz5Rw8w==}
```

Show me the Data

Other proofs:

- https://URL/ct/v1/get-sth-consistency
- https://URL/ct/v1/get-proof-by-hash

Push certs:

- POST https://URL/ct/v1/add-chain

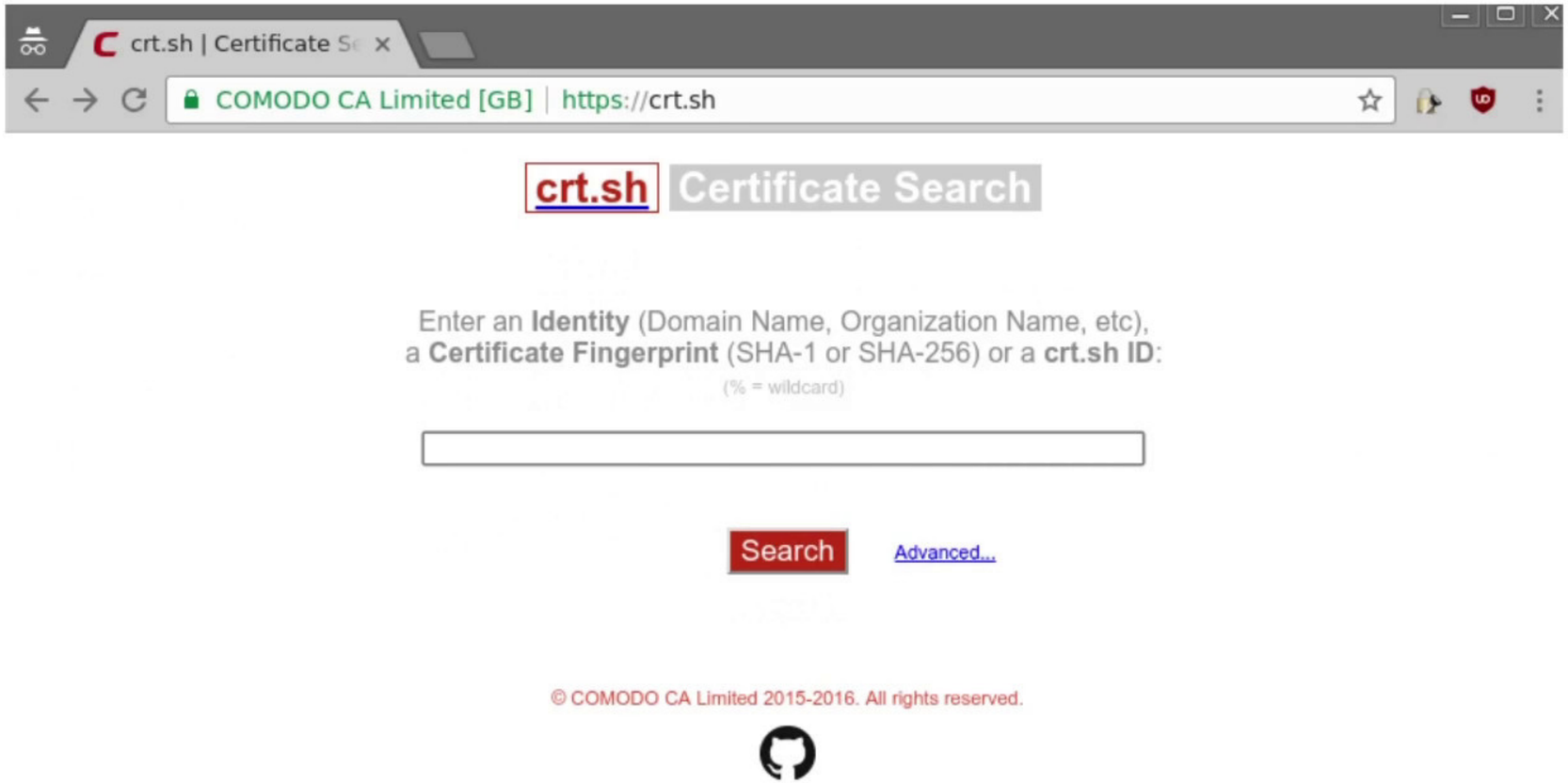
Show me the Data

Chrome net-internals:

```
t=4690 [st=148]        SIGNED_CERTIFICATE_TIMESTAMPS_RECEIVED
                       --> embedded_scts = "APEAdgDd6x0reg1PpiCLga2BaHB+Lo6dAdVciI09EcT
                       --> scts_from_ocsp_response = ""
                       --> scts_from_tls_extension = ""
t=4690 [st=148]        SIGNED_CERTIFICATE_TIMESTAMPS_CHECKED
                       --> scts = [{"extensions":"","hash_algorithm":"SHA-256","log_id"
t=4690 [st=148]        EV_CERT_CT_COMPLIANCE_CHECKED
                       --> certificate =
                             -----BEGIN CERTIFICATE-----
                             MIIGdDCCBVygAwIBAgIQat1vXCh8QJJNXRO5v+zigjANBgkqhkiG9w0BA
                             MQswCQYDVQQGEwJVUzEdMBsGA1UEChMUU3ltYW50ZWMgQ29vcG9yYXRpb
```

Show me the Data

https://crt.sh

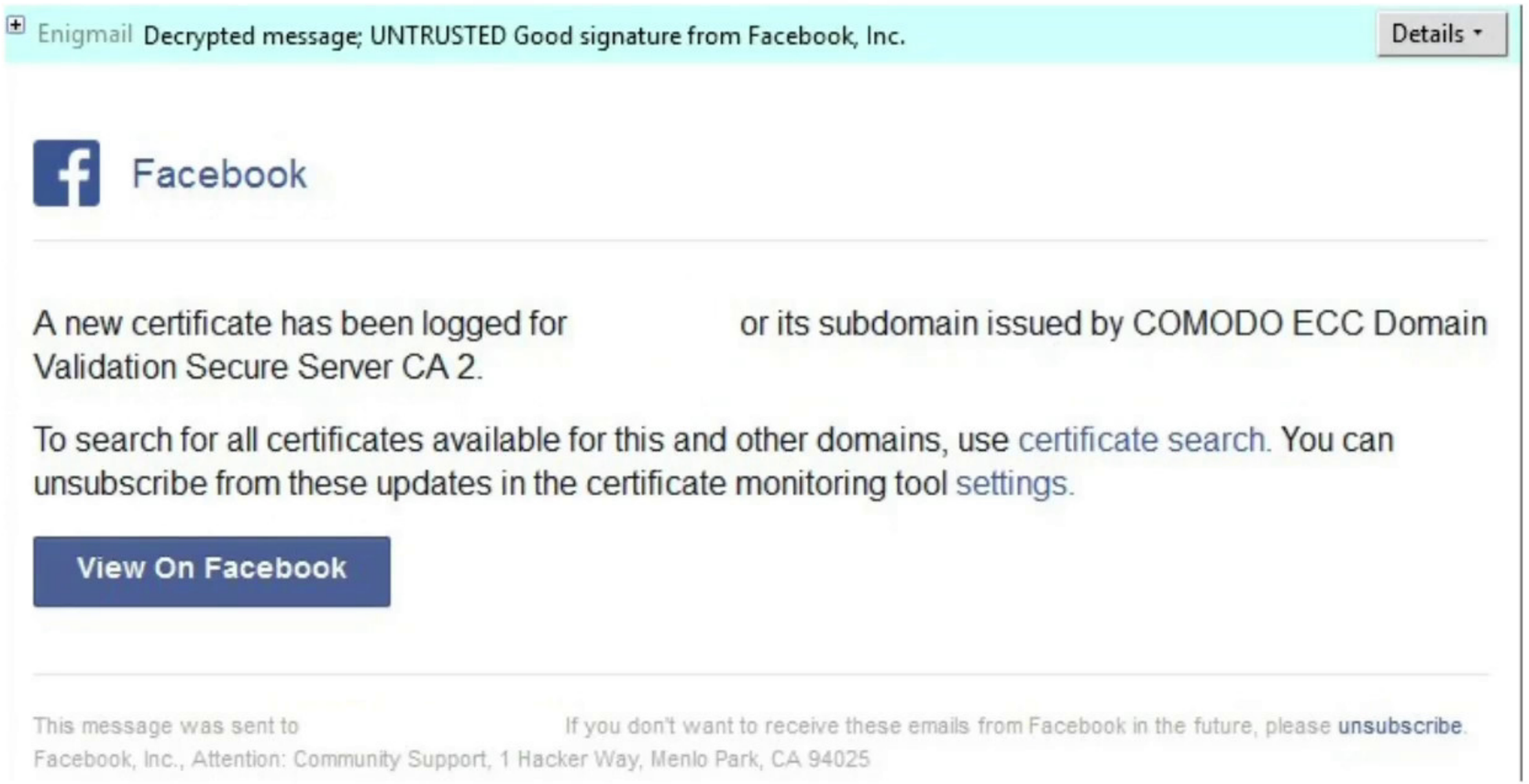


Show me the Data

Facebook Monitor:

- allows to monitor domains
- get email on cert update
- based on CT data

Facebook Notification



Future of CT

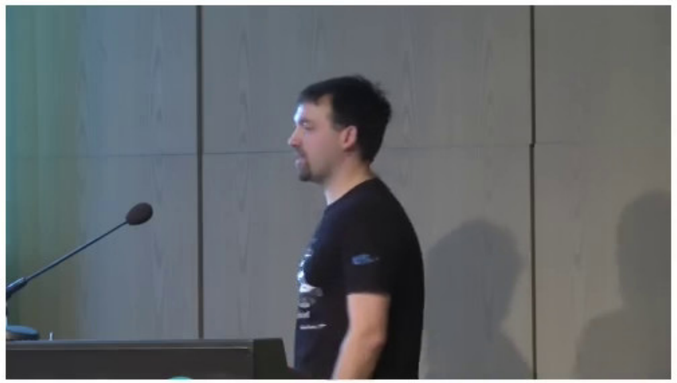
Whats next?

- mandatory from October 2017 on!
- moar logs and certs
- many moar auditors
- creating incentives for running it?

Future of CT

Whats next?

- mandatory from October 2017 on!
- moar logs and certs
- many moar auditors
- creating incentives for running it?



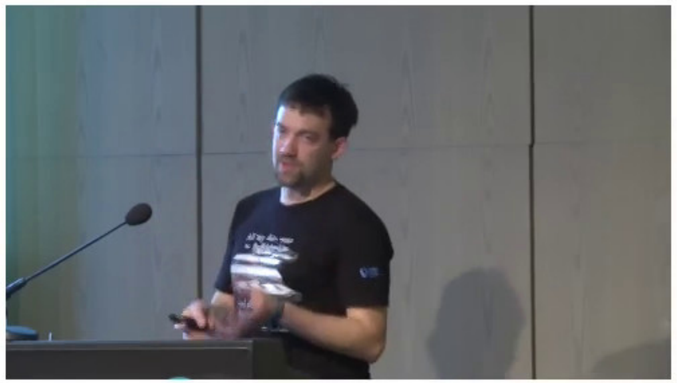
Future of CT

Far future:

- software releases?
- key management?
- alternatives to blockchains?

Generalize:

- “Verifiable Data Structures”
- *Trillian*



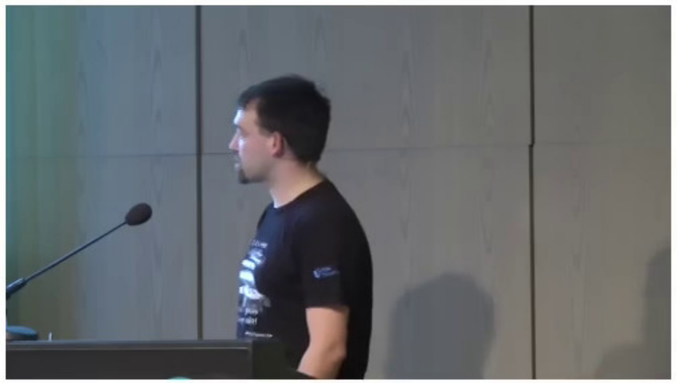
Future of CT

Far future:

- software releases?
- key management?
- alternatives to blockchains?

Generalize:

- “Verifiable Data Structures”
- *Trillian*



Future of CT

Thx for the attention!

CREATIVE COMMONS

ATTRIBUTION 4.0 INTERNATIONAL

http://creativecommons.org/licenses/by/4.0/

RECORDED BY

TOGETHER WITH

ags

ags – Wissenschaftliche Arbeitsgemeinschaft
für Studio- und Senderfragen
an der TU Braunschweig e.V.

FEM

Forschungsgemeinschaft
elektronische Medien e.V.

iSystems

VISUALS & SOUND

VEITH YÄGER
ARNE BENSE

FOR MORE TALKS AND
CONFERENCE RECORDINGS
VISIT

MEDIA.CCC.DE