On TLS/SSL: Research and Practice

Devdatta Akhawe
At CA/Browser Forum

About Me

- Engineer in Product Security team at Dropbox
  - Opinions expressed today are my own and do not necessarily represent the views of my employer
- Previously, grad student at UC Berkeley
  - Working on web security, SSL, usability etc
- Also, editor of specs at W3C
  - Sub-resource Integrity and Sub-origins

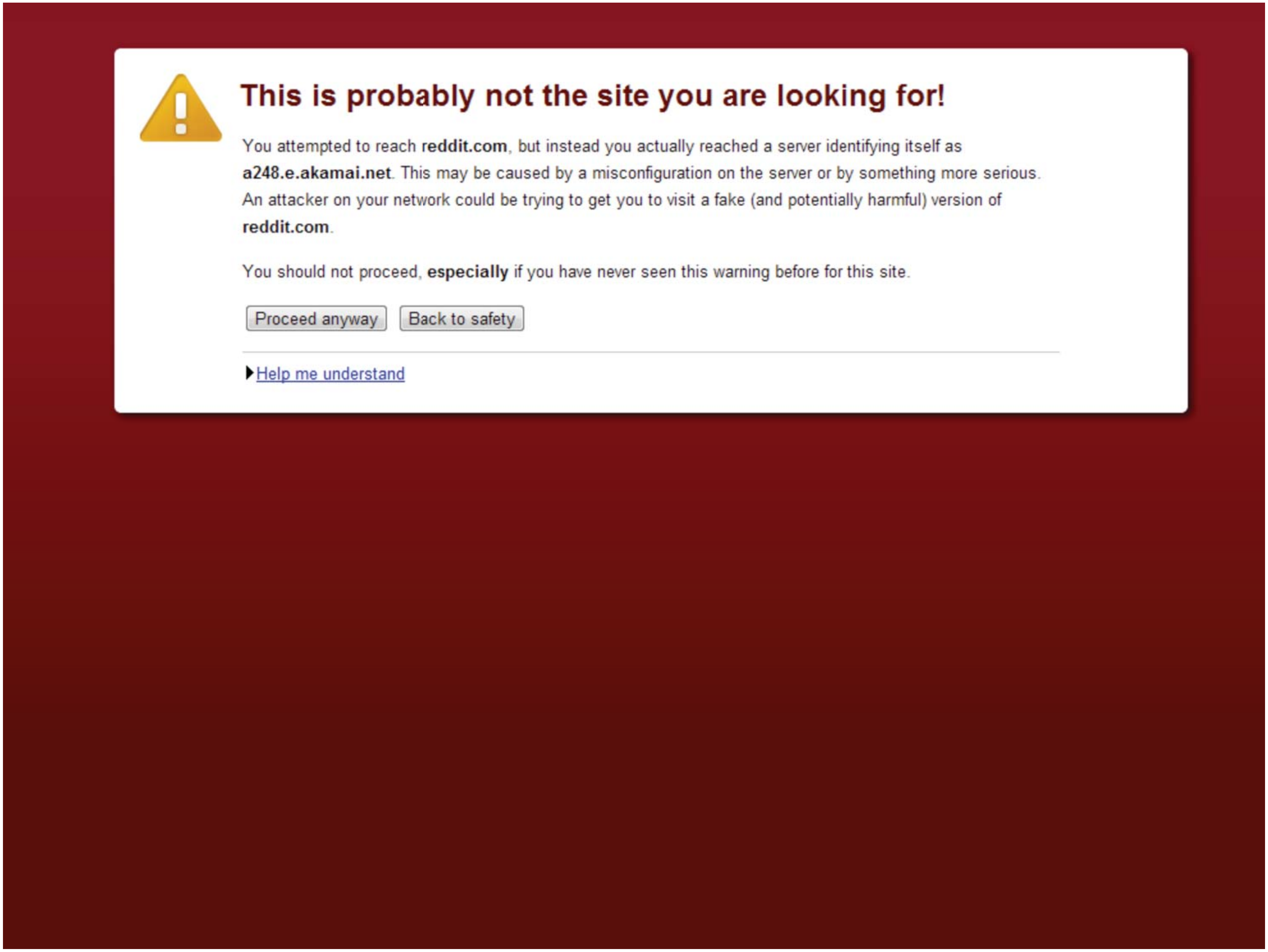
Today

- Research on SSL Warnings and Errors
  - Large scale study of source of SSL errors in the wild
  - Proposals and ideas on how to mitigate these issues
- Experience deploying advanced SSL features at Dropbox

Part 1

Large Scale study of SSL errors

Let’s talk about TLS warnings



This is probably not the site you are looking for!

You attempted to reach **reddit.com**, but instead you actually reached a server identifying itself as **a248.e.akamai.net**. This may be caused by a misconfiguration on the server or by something more serious. An attacker on your network could be trying to get you to visit a fake (and potentially harmful) version of **reddit.com**.

You should not proceed, **especially** if you have never seen this warning before for this site.

The “bypass this certificate error” button … is a UI disaster.

Those buttons are clicked 60% of the time by Chrome users.

Adam Langley
Google, Inc.

One Explanation:
Too many false warnings due to misconfigurations!

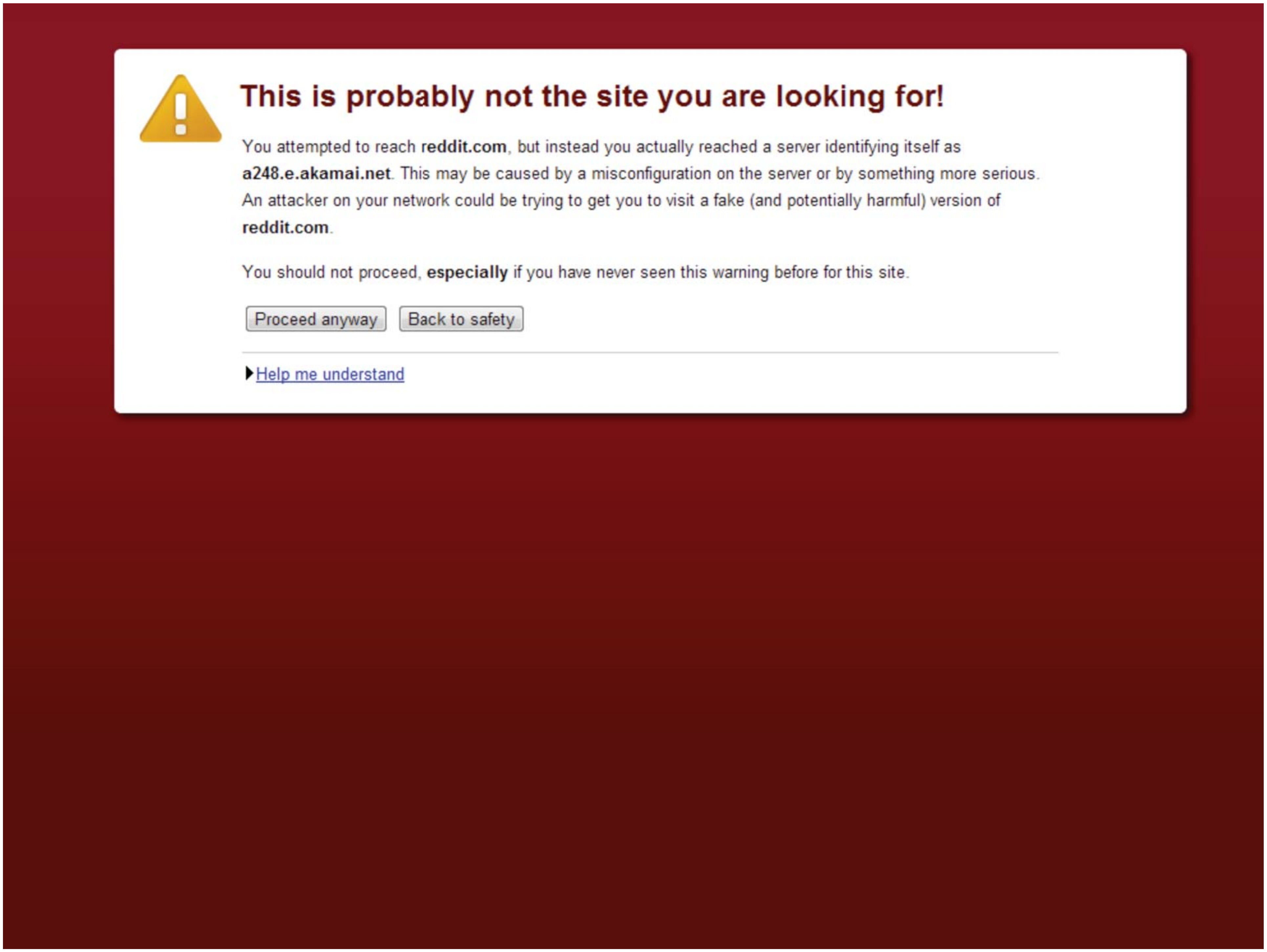
Hypothesis: Tragedy of the Commons with TLS Warnings

shared resource? user attention

Consumers?
browsers, servers, proxies

The Lump of Attention Model

Shared resource: Attention



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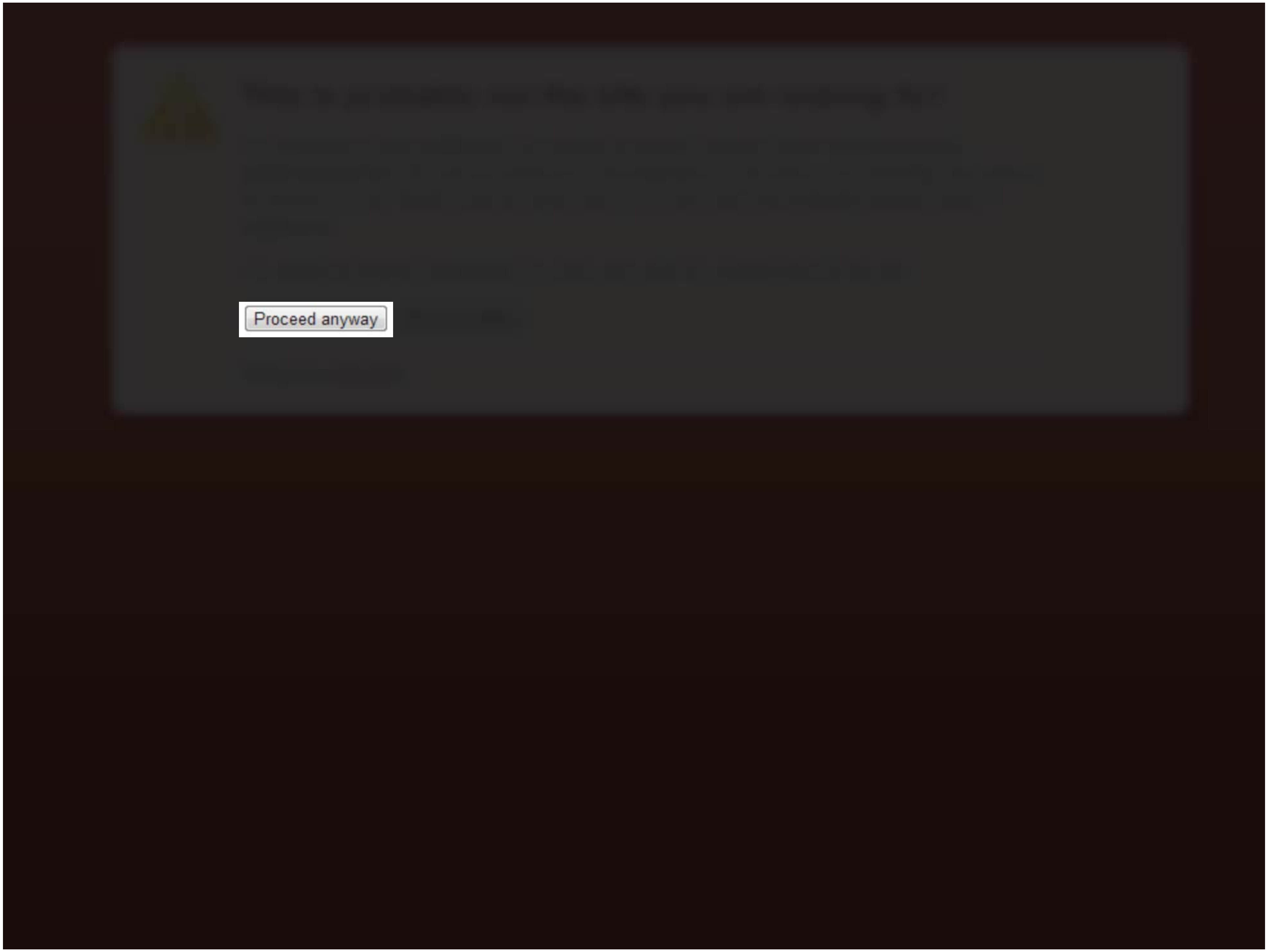
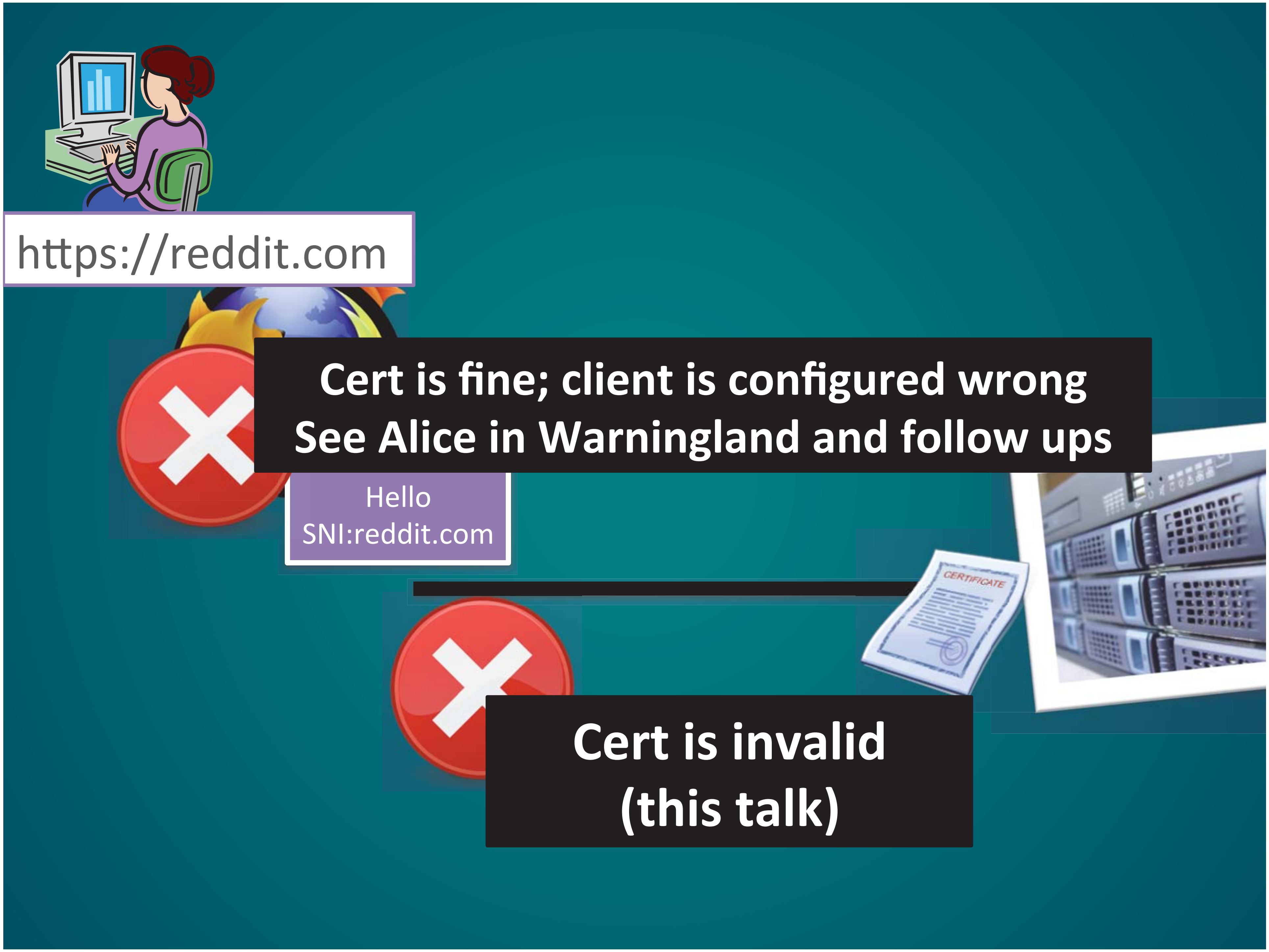

Proceed anyway

Nothing new

While warnings can be improved,
a better approach may be to minimize
the use of SSL warnings altogether

Sunshine et al.
Crying Wolf :...
Usenix Security **2009**

Where do we warnings come from?



Cert is fine; client is configured wrong
See Alice in Warningland and follow ups

Cert is invalid
(this talk)

Research not in this talk

- Alice in Warningland: A Large-Scale Field Study of Browser Security Warning Effectiveness
  - Me and Adrienne Porter Felt (Google)
  - Study from inside browsers on what are the warning click through rates and what sort of SSL errors are really common

Research not in this talk

See Adrienne’s talk at AppSecCali to see the follow on work on all sources of errors in client side and work on improving warning adherence

That supersedes work in this paper.

Today

A large scale measurement of TLS certificate errors to look for opportunities to *conserve* user attention

Here's My Cert, So Trust Me, Maybe? Understanding TLS Errors on the Web

Devdatta Akhawe / Bernhard Amann / Matthias Vallentin / Robin Sommer

UC Berkeley and International Computer Science Institute

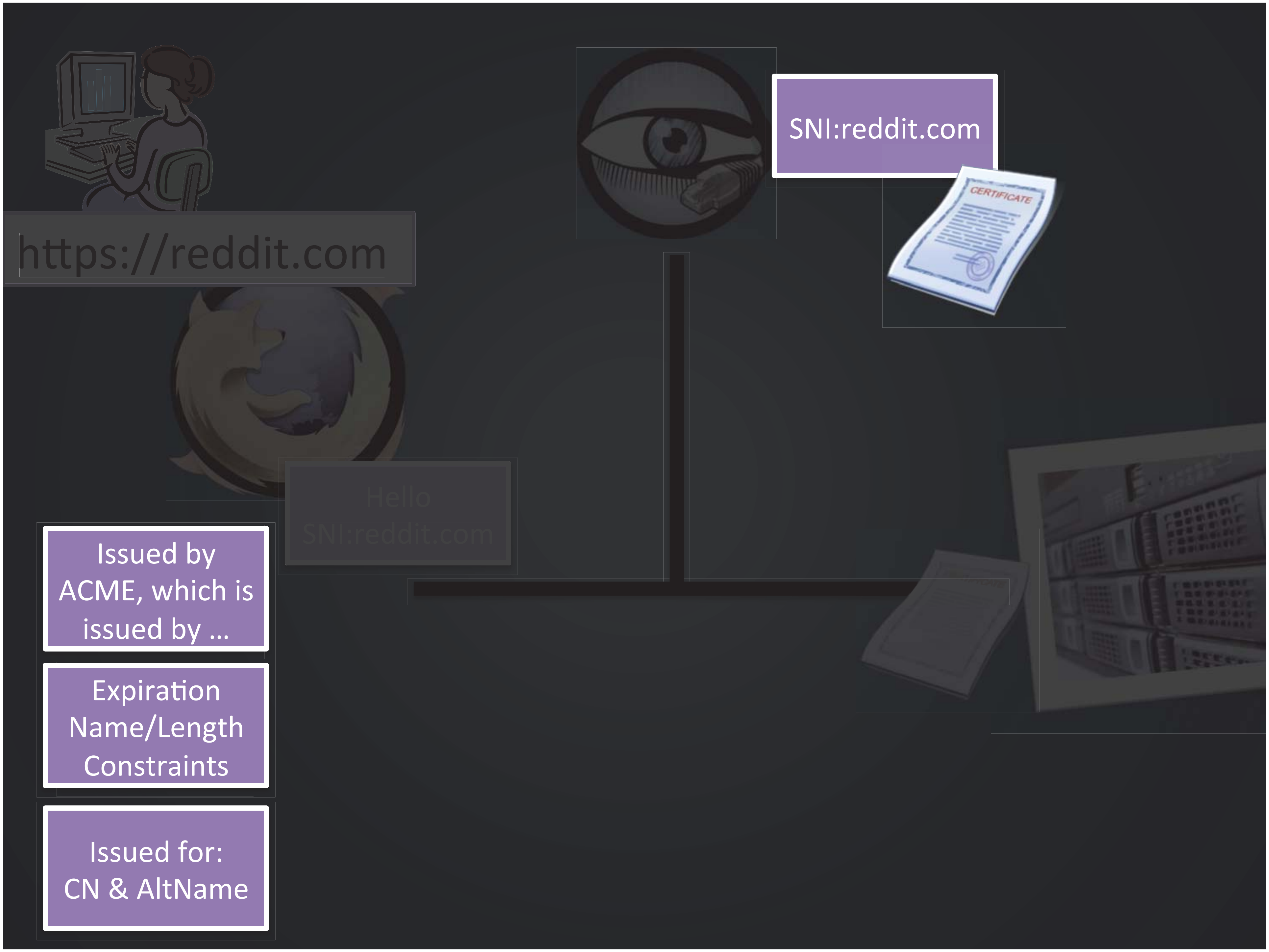
(Published in 2013)

Outline

Data Collection

Methodology

Results



Issued by ACME, which is issued by …

Expiration Name/Length Constraints

Issued for: CN & AltName

10 networks running the Bro network monitor

300K users

9 Months of data

3.9B connections to port 443

Outline

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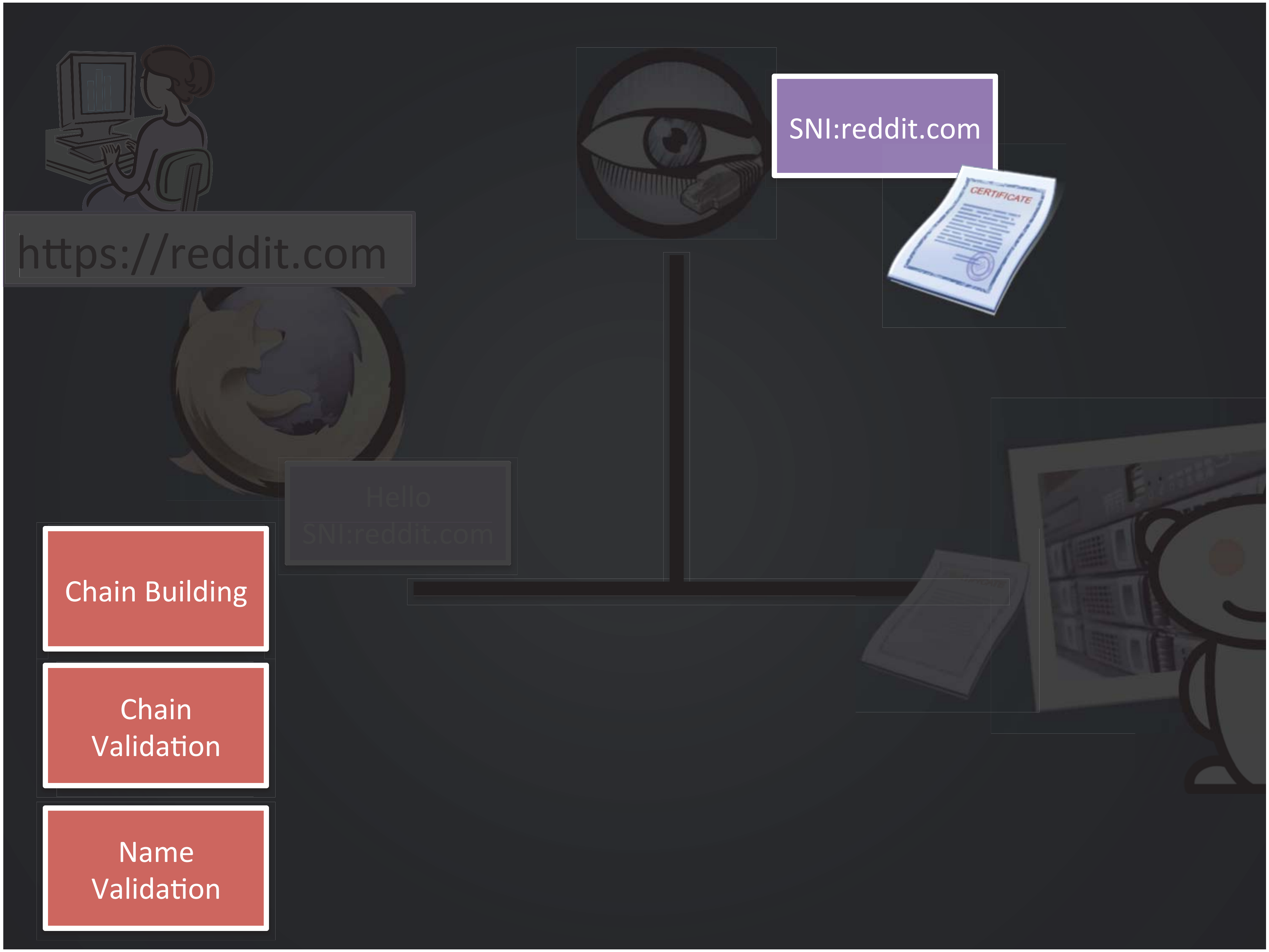
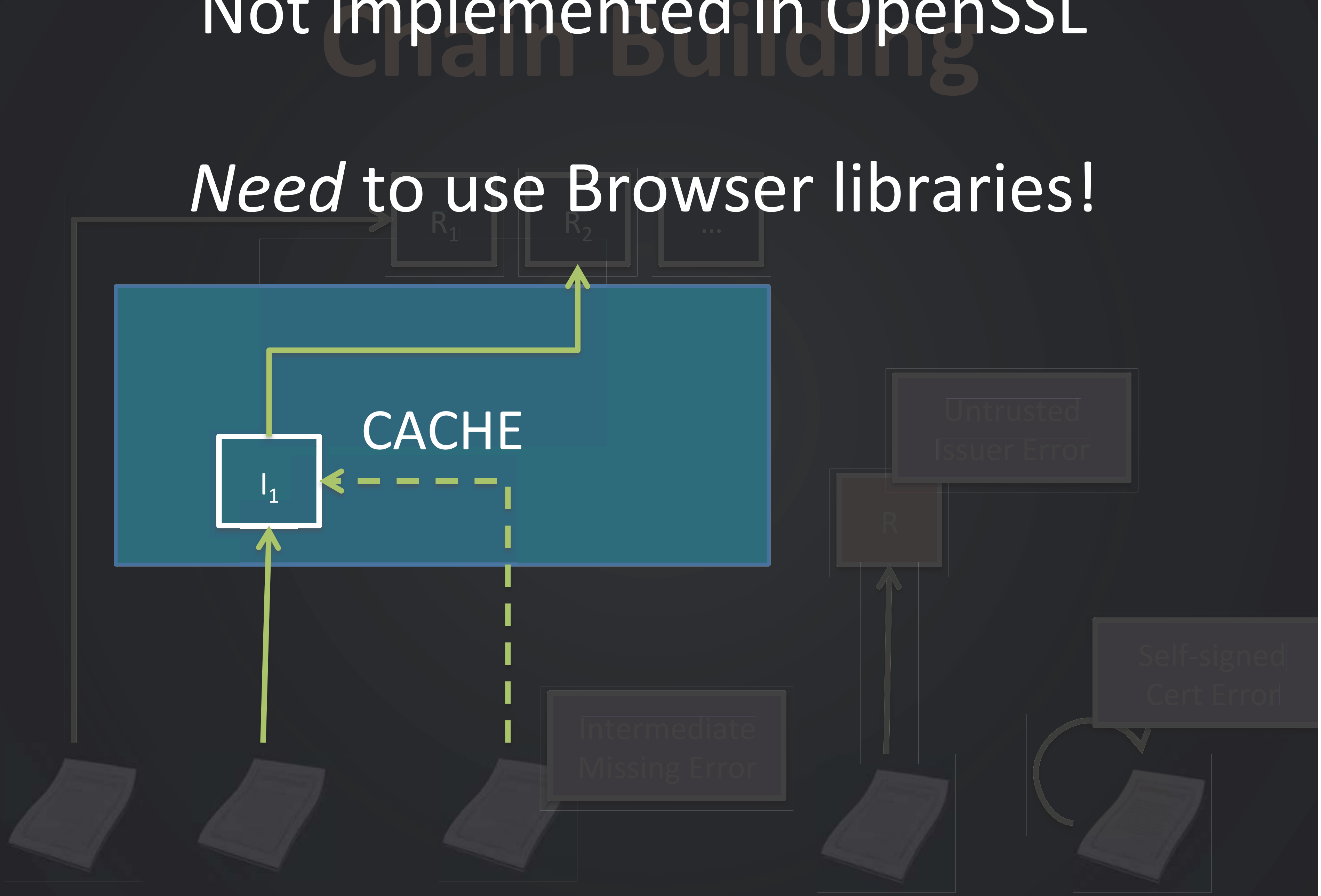
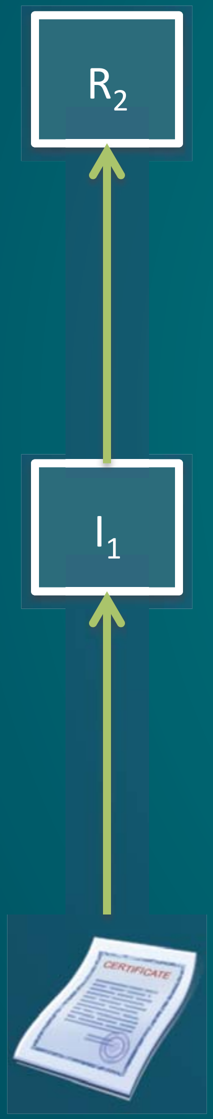

https://reddit.com
Hello
SNI:reddit.com
SNI:reddit.com
CERTIFICATE
Chain Building
Chain Validation
Name Validation

Not Implemented in OpenSSL

Need to use Browser libraries!



Chain Validation



For each certificate in chain:

- Is cert expired? Expired Cert Error
- Is cert revoked? Revoked Cert Error
- Name/length con Constraints Violation Error ?

Name Validation

- Is the Cert really for intended website?
    - Attacker can always get cert for attacker.com
- Reuse the browser code
    - Compare saved SNI with the certificate
- OpenSSL introduced a name match function in 2013!

Outline

Data Collection

Methodology

Results

1.54%

connections with errors, presumably false warnings

If an actual attack occurs once in a million connections, 15400 false warnings for 1 real warning

99.994%

false warnings

Assuming no client-side config errors, which would make this number even worse

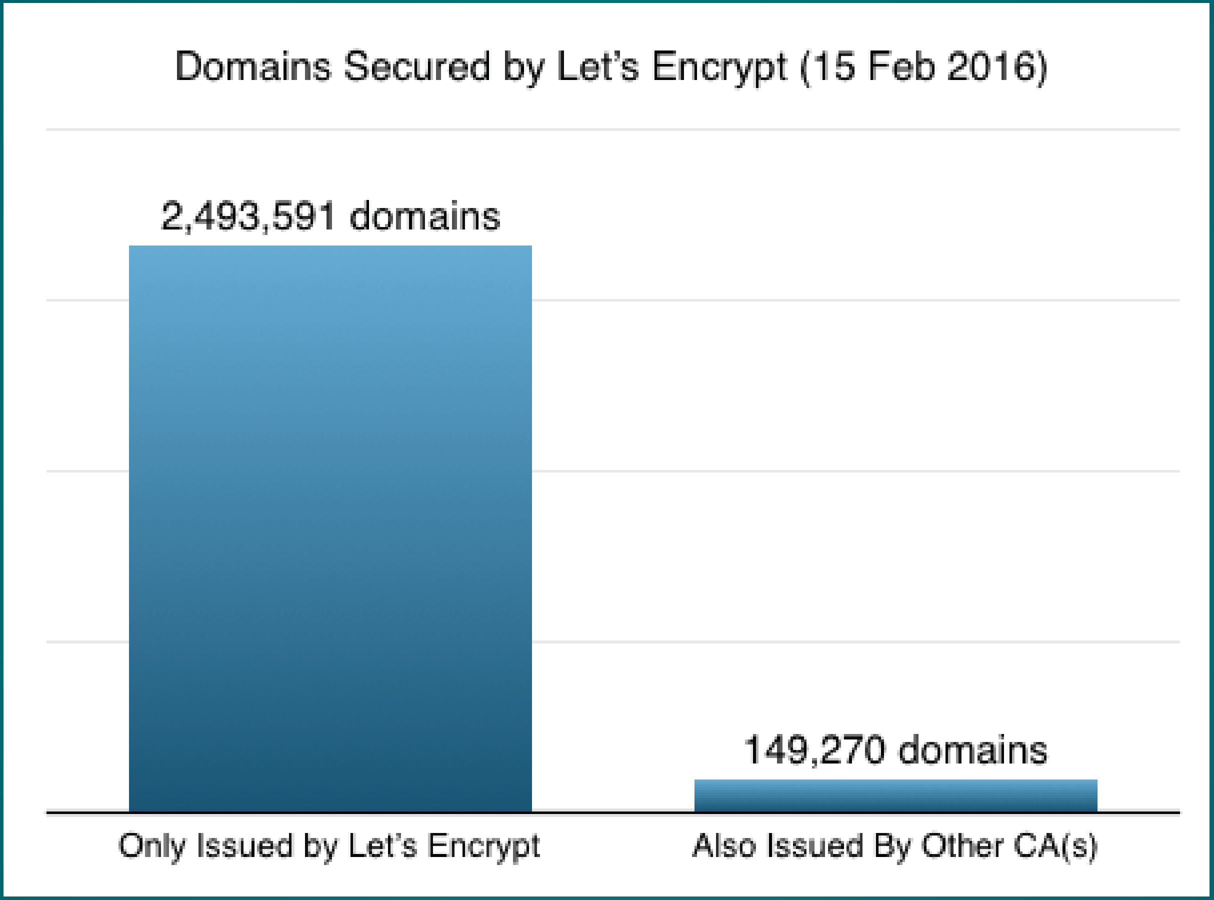
Error Breakdown

Error	Connections	Unique Certificates
Unknown Issuer	70.51%	5,027
Self Signed Certificates	2.99%	6,126
Expired Certificates	7.65%	21,522
Name Validation Errors	18.82%	12,146

Untrusted issuers remain a big problem.

1 Free and easy certificates offered by CAs such as StartSSL, Lets Encrypt are valuable.

2 Mechanisms such as DANE & Convergence have value due to tremendous usability benefits.


Domains Secured by Let's Encrypt (15 Feb 2016)
2,493,591 domains
149,270 domains
Only Issued by Let's Encrypt
Also Issued By Other CA(s)

Error Breakdown

A majority of certificates used in erroneous certificates correspond to expired and name validation errors

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Expired Certificates

- Expired Certs common in the long tail
  - 50% of expired certs used only 4 times
  - 75% of expired certs used only 12 times

- 25% of all expired certificates accessed only for a week after expiry
  - Presumably, renewed after that

3

Use a non-blocking infobar
to warn for certificates
expired in the last week.

Name Validation Errors

Name Validation Errors

Error	Connections	Unique Certificates
WWW Mismatches	1.17%	7.92%
Multiple Names	1.21%	0.03%
Relaxed Match	50.40%	7.24%
Relaxed Match with WWW	51.54%	13.87%
TLD Match	56.93%	29.73%

Name Validation Errors

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User wants to connect to paypal.com and cert says www.paypal.com

4

Tolerate WWW mismatches or show a different “low-risk” warning.

Name Validation Errors

User wants to connect to foo.bar.test.com and cert is for *.test.com

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Move to a relaxed matching algorithm that accepts multiple levels for an asterisk.

Name Validation Errors

User wants to connect to foo.bar. com and cert is for www.bar.com

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6

Use a low-risk warning for sub-domain mismatch to help focus user attention on the high-risk scenarios.

- We started off with 15400 false warnings.
- We first need to fix chain errors > 70%
  - Convergence or TOFU can help
- IF we do, then using our other tricks, the number of false warnings, in our data, drops off to 213 per million
  - Still 99.5% false warnings! ☹
  - But browser vendors can make these stronger

A clear opportunity exists to reduce unnecessary consumption of user attention budget and help focus attention on high risk scenarios

Part 2

Deploying TLS at Scale

Case Studies

HSTS includeSubDomains

OCSP Stapling

HSTS on UserContent

The Problem:

How to deploy HSTS includeSubDomains on dropbox.com?

- https://carousel.dropbox.com
- https://photos.dropbox.com
- https://www.dropbox.com
- https://block.dropbox.com
- … all public sites support SSL …
- http://cafemenu.corp.dropbox.com
- http://busschedules.corp.dropbox.com

- https://carousel.dropbox.com
- https://photos.dropbox.com
- https://www.dropbox.com
- https://block.dropbox.com
- … all public sites support SSL …
- http://cafemenu.corp.dropbox.com
- http://busschedules.corp.dropbox.com

dropbox.com

HSTS: 3 years,

includeSubDomains

corp.dropbox.com

HSTS: 3 years,

~~includeSubDomains~~

foo.corp.dropbox.com

HSTS policy?

Not an exception

A lot of sites don’t set includeSubDomains on root URI

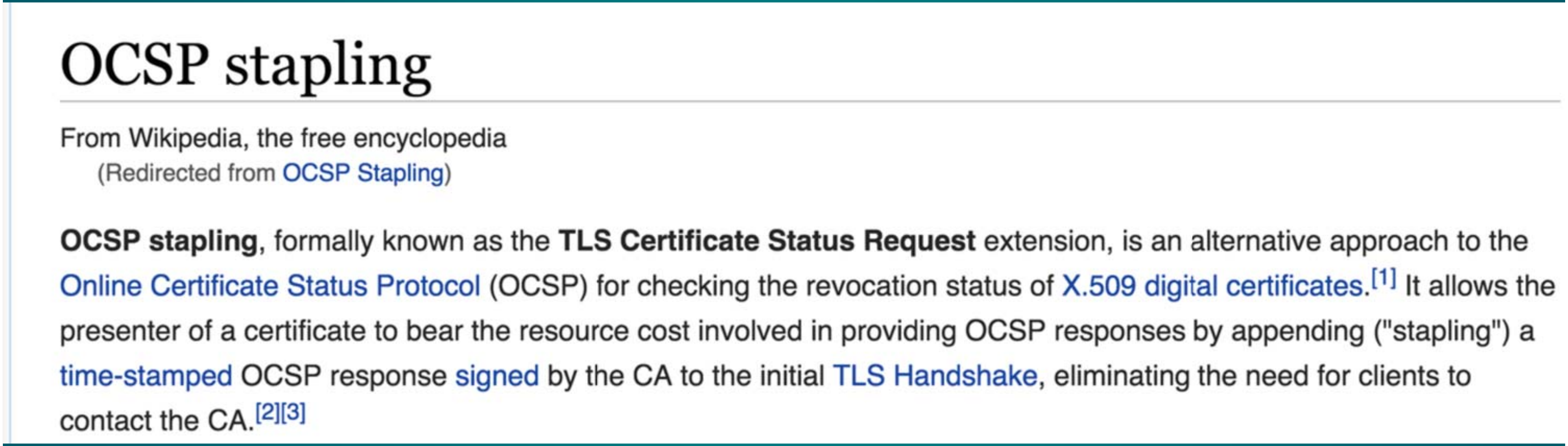
Allowing HSTS overrides with enterprise policy or some config would help massively

Case Studies

HSTS includeSubDomains

OCSP Stapling

HSTS on UserContent



OCSP stapling

From Wikipedia, the free encyclopedia
(Redirected from OCSP Stapling)

OCSP stapling, formally known as the **TLS Certificate Status Request** extension, is an alternative approach to the Online Certificate Status Protocol (OCSP) for checking the revocation status of X.509 digital certificates.[1] It allows the presenter of a certificate to bear the resource cost involved in providing OCSP responses by appending ("stapling") a time-stamped OCSP response signed by the CA to the initial TLS Handshake, eliminating the need for clients to contact the CA.[2][3]

A Good OCSP implementation

- Robust against CA responder failures
- Should not DoS the responder by mistake
- Check for invalid responses and alert
- Support arbitrary certificates and arbitrary responder URIs
- Robust against network failures and other failures

Implementing OCSP Stapling

- The core idea is simple: write a script that fetches the response and tells nginx about it
- And then you worry about all the problems in the previous slide

Implementing OCSP Stapling

- The core idea is simple: write a script that fetches the response and tells nginx about it

Using OpenSSL

- ocsp command returns non-zero even with success sometimes
- ocsp command is sensitive to argument ordering
- ocsp verification command returns with 0 whether or not the response is valid
  - We have to manually scan for “OK” in output!

This is not tenable for large scale deployments

Agreeing to must-staple with this foundation is too risky

Better OCSP stapling services, examples, packages would help. Default nginx support not ok.

Need “Report only mode” in browsers

Case Studies

HSTS includeSubDomains

OCSP Stapling

HSTS on UserContent

The Problem:

Sites host untrusted user content on a separate domain

Can we turn on HSTS ?

Common: googleusercontent.com, *.github.io, and so on

Sites only link to it as https:

But users could directly link to it

Turning on HSTS will just break the user's page if any fetch is over http

Thanks for listening!

evil@berkeley.edu
devd.me