LogPicker

Strengthening Certificate Transparency Against Covert Adversaries

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(In)Secure Web Communication

https://

Secure Communication on the Web

- HTTPS $\rightarrow$ default nowadays [4]

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- Guidelines by CA/Browser Forum [7]
- Increasing number of illicit certificate creations [10]

A Tale of Illicit Certificate Creations

[14]

[12]

[12]

[15]

[9]

HTTPS Interception Attempts by Governments

[1]

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Kazakhstan Considers a Plan to Snoop on all Internet Traffic

DEEPLINKS BLOG

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[1] Kazakhstan: [16], Mauritius: [3], Syria: [8], Iran: [17]

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Why should attacker stop here?

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A Strong Attack Scenario

Covert Adversary [5][2]

[2]Aumann & Lindell, 2007
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Compelled Certificate Creation [18][3]

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A Strong Attack Scenario

Covert Adversary [5][2]

Compelled Certificate Creation [18][3]

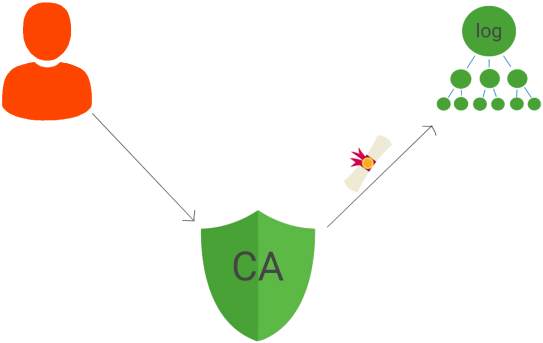
Attacker succeeds if he can create a rogue certificate that remains unnoticed by domain owner!

[2] Aumann & Lindell, 2007
[3] Soghoian & Stamm, 2010

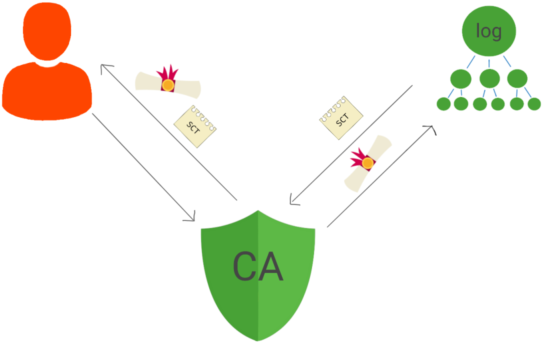
Public Certificate Creation[4]

[4] Laurie, 2012

Certificate Transparency



Certificate Transparency



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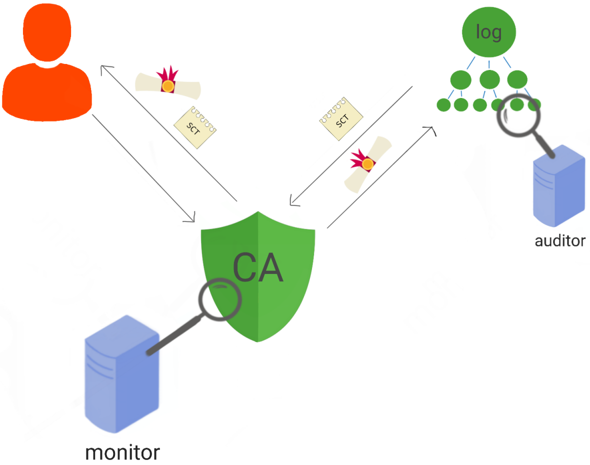

Certificate Transparency is still vulnerable

[5] June, 2021
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  - Low probability, but high impact [6][6]

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Certificate Transparency is still vulnerable

- All logs belong to CA vendors[1][5]
- First compromise of a CT log in 2020[2]
- CT is vulnerable to collaboration attacks[11]
  - Low probability, but high impact [6][6]
  - Split View attacks possible

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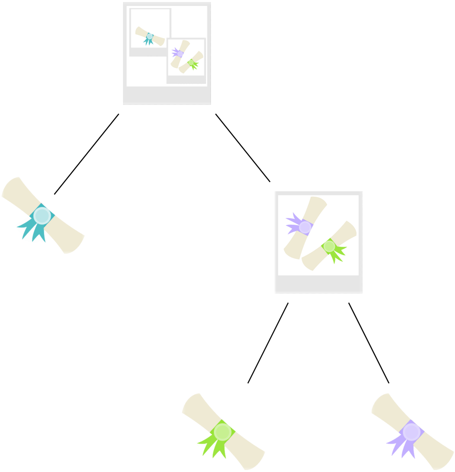
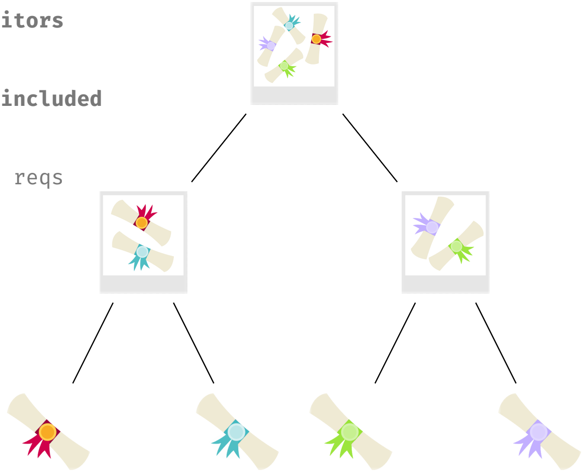
Split View Attack



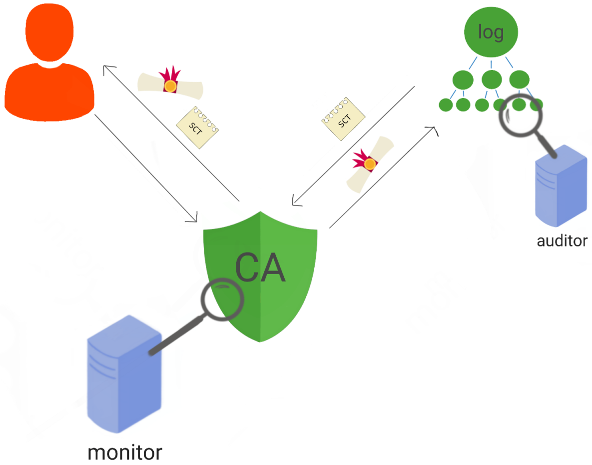
- View served to **monitors**
- Rogue certificate **excluded**
- Attack remains undetected

Split View Attack

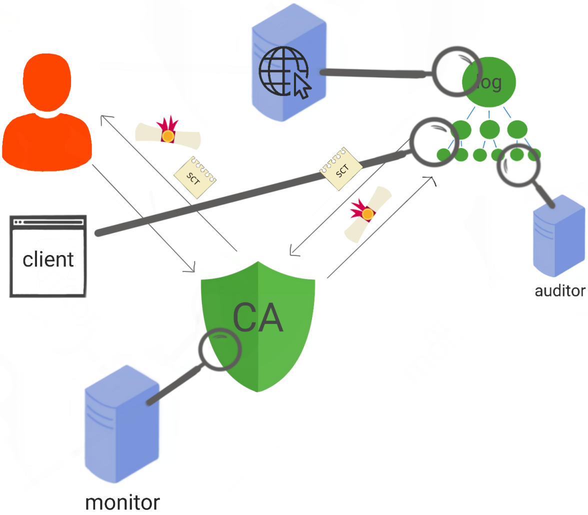
- View served to **auditors**
- Rogue certificate **included**
- Violations of CA/B reqs remain undetected



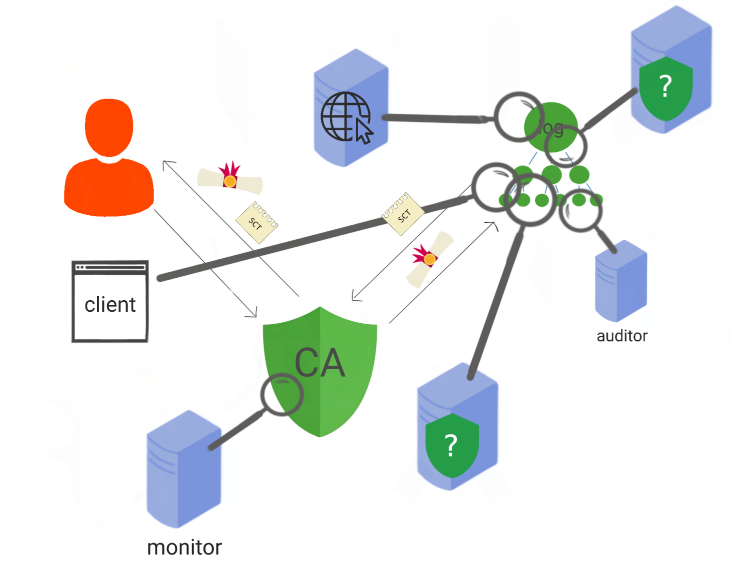
Certificate Transparency - Reminder on CT



Certificate Transparency - Gossip



Further Trusted Parties?



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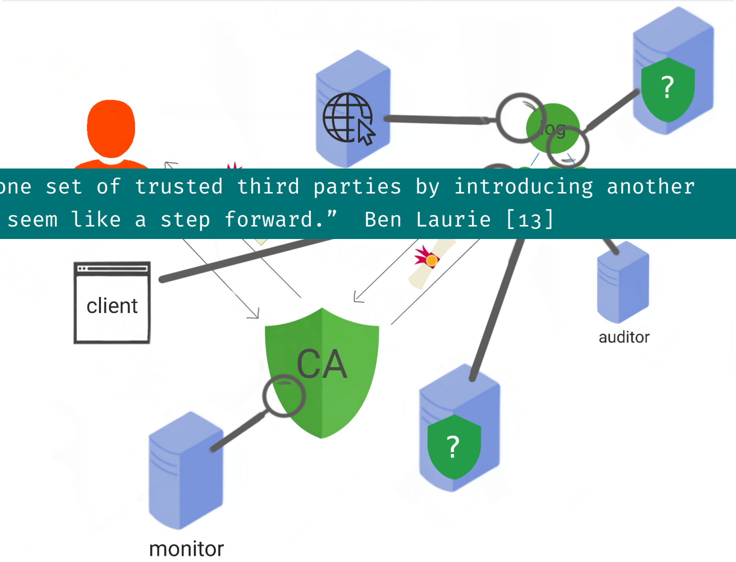
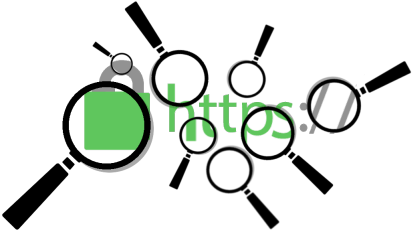


"fixing one set of trusted third parties by introducing another "doesn't seem like a step forward." Ben Laurie [13]

LogPicker: A Decentralized Approach



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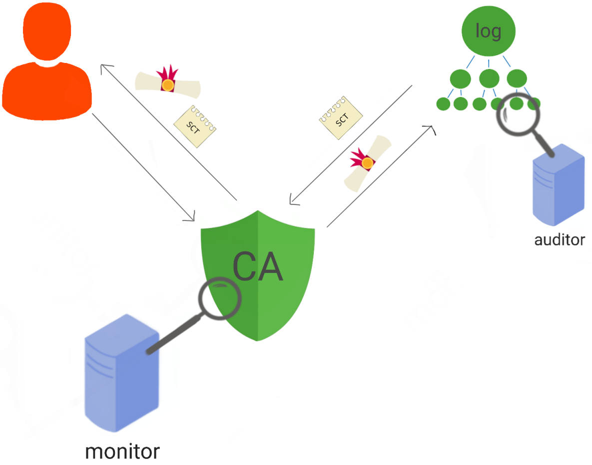
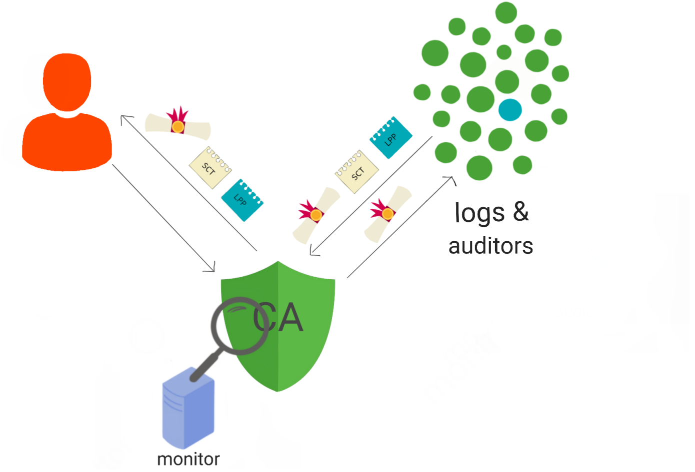


LogPicker - High Level Overview



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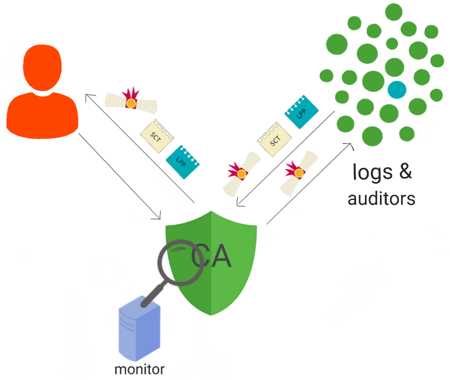

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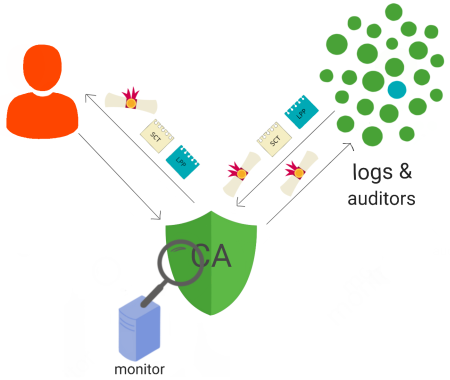

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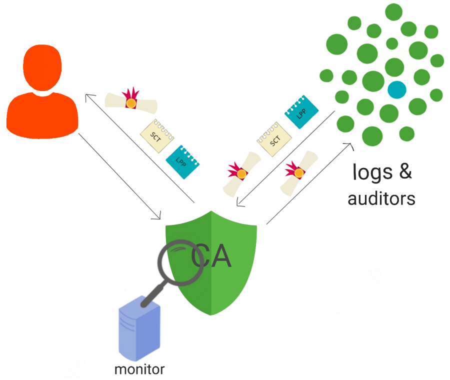

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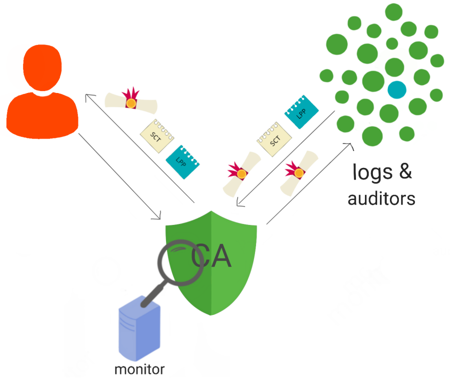

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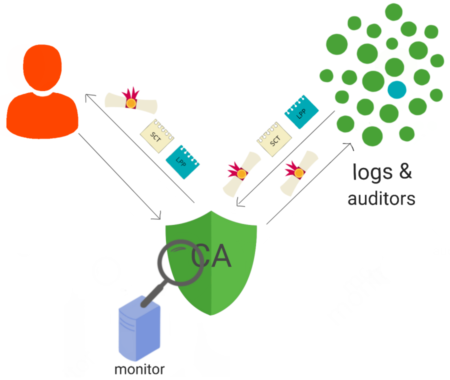

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5. Proof is aggregated & attached to cert

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Additional paper contribution

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- Protocol goals and crypto primitives

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- Protocol goals and crypto primitives
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- Probabilistic analysis of correctness
- Discussion on the policies of CT and LP based PKI
- Prototyped simulation of LogPicker protocol [7]

[7] https://logpicker.github.io/

Outlook

- ? Inclusion of monitors
- ? Interlog auditing
- ? Handling protocol aborts
- ? Revocation's still a nightmare

References

[1] Certificate transparency - known logs.
https://www.gstatic.com/ct/log_list/v3/log_list.json.

[2] Ct2 log compromised via salt vulnerability, 2020.
https://groups.google.com/a/chromium.org/forum/#!topic/ct-policy/aKNbZuJzwfM.

[3] Consultation paper on proposed amendments to the ict act for regulating the use and addressing the abuse and misuse of social media in mauritius.
Information & Communication Technologies Authority, Apr 2021.

[4] Transparency report: Https encryption on the web (2023-24-03), 2023.
https://transparencyreport.google.com/https/overview?hl=en.

[5] Y. Aumann and Y. Lindell.
Security against covert adversaries: Efficient protocols for realistic adversaries.
Journal of Cryptology, 2007.

[6] M. Bussiere and M. Fratzscher.
Low probability, high impact: Policy making and extreme events.
Journal of Policy Modeling, 30(1):111–121, 2008.

[7] CA/Browser Forum.
Baseline Requirements for the Issuance and Management of Publicly-Trusted Certificates, Mar. 2020.
https://cabforum.org/wp-content/uploads/CA-Browser-Forum-BR-1.6.8.pdf.

[8] P. Eckersley.
A syrian man-in-the-middle attack against facebook, May 2011.

[9] E. Galperin, S. Schoen, and P. Eckersley.
A post mortem on the iranian diginotar attack, Sep 2011.
https://www.eff.org/de/deeplinks/2011/09/post-mortem-iranian-diginotar-attack.

[10] R. Housley and K. O'Donoghue.
Problems with the Public Key Infrastructure (PKI) for the World Wide Web.
IETF Draft, 2017.

[11] S. Kent.
Attack and threat model for certificate transparency.
Internet Engineering Task Force, 2018.

[12] A. Langley.
Fraudulent digital certificates could allow spoofing, Jan 2013.
https://security.googleblog.com/2013/01/enhancing-digital-certificate-security.html.

[13] B. Laurie.
Certificate Transparency.
ACM Queue, (8), 2014.

[14] G. Markham.
Incidents involving the ca wosign, Aug 2016.
https://groups.google.com/forum/#!topic/mozilla.dev.security.policy/k9PBmyLCi8I%5B1-25%5D.

[15] J. Nightingale.
Revoking trust in digicert sdn. bhd intermediate certificate authority, Mar 2011.
.

[16] R. S. Raman, L. Evdokimov, E. Wurstrow, J. A. Halderman, and R. Ensafi.
Investigating large scale https interception in kazakhstan.
In Proceedings of the ACM Internet Measurement Conference, pages 125–132, 2020.

[17] E. G. Seth Schoen.
Iranian man-in-the-middle attack against google demonstrates dangerous weakness of certificate authorities, Aug 2011.

[18] C. Soghoian and S. Stamm.
Certified lies: Detecting and defeating government interception attacks against ssl.
In Proceedings of ACM Symposium on Operating Systems Principles, pages 1–18, 2010.

[19] T. Zimmermann, J. Ruth, B. Wolters, and O. Hohlfeld.
How HTTP/2 pushes the web: An empirical study of HTTP/2 server push.
In 2017 IFIP Networking Conference, IFIP Networking 2017 and Workshops, 2017.

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