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On the Effective Prevention of TLS Man-In-The-Middle Attacks in Web Applications

Nikos Karapanos and Srdjan Čapkun, ETH Zurich

USENIX Security 2014

Server authentication is problematic

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- Compromised CAs

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- Compromised server keys

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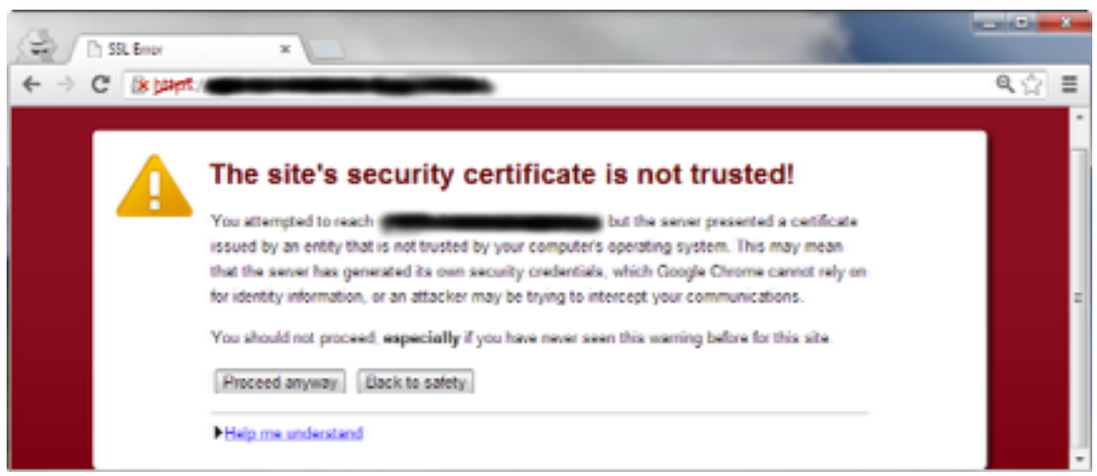
- Users click through warnings



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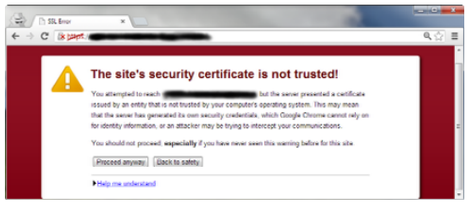
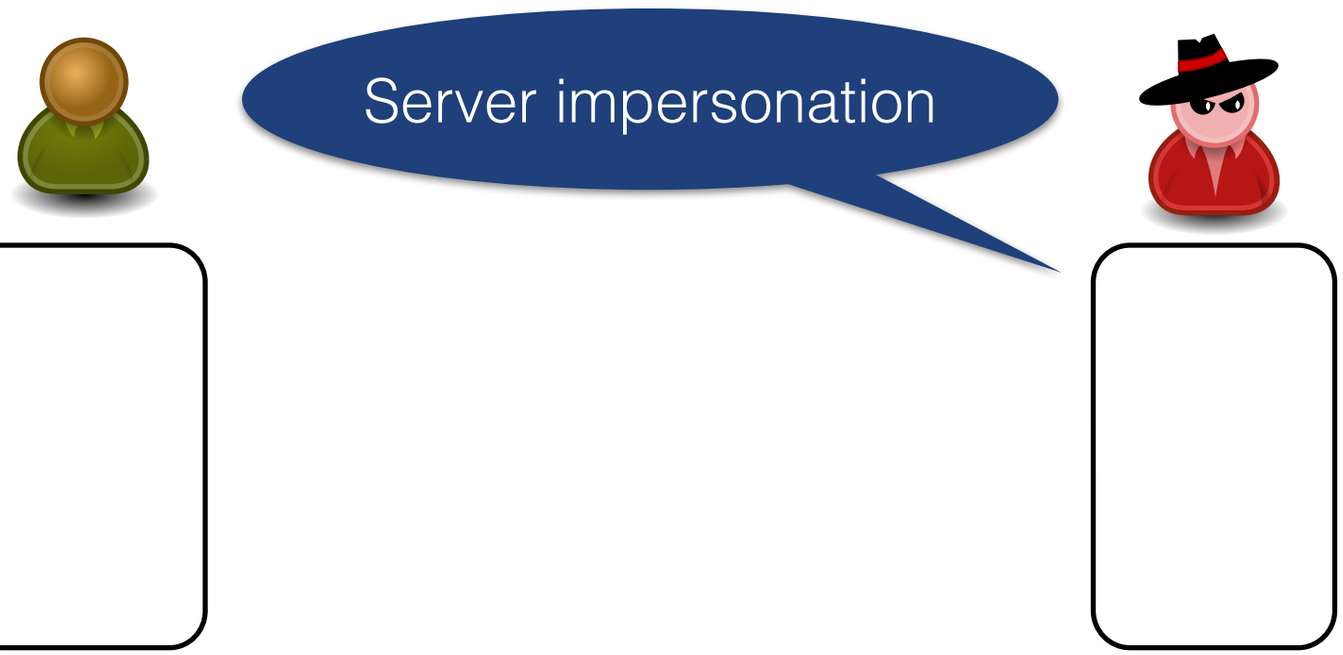
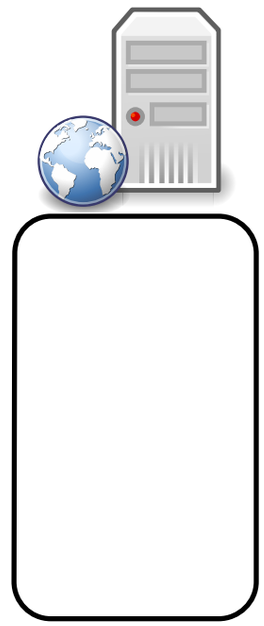
Goal: Compromise user account







**Some of the icons used in this presentation were taken and adapted from opensecurityarchitecture.org*

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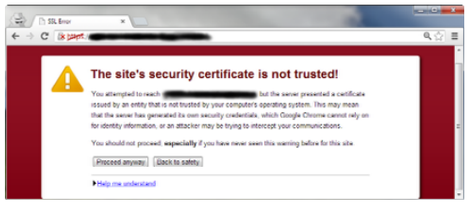

Server impersonation

TLS

TLS

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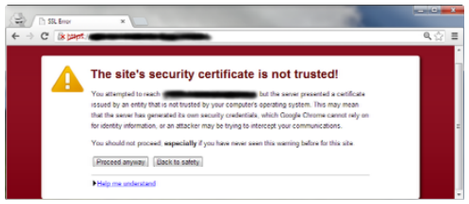

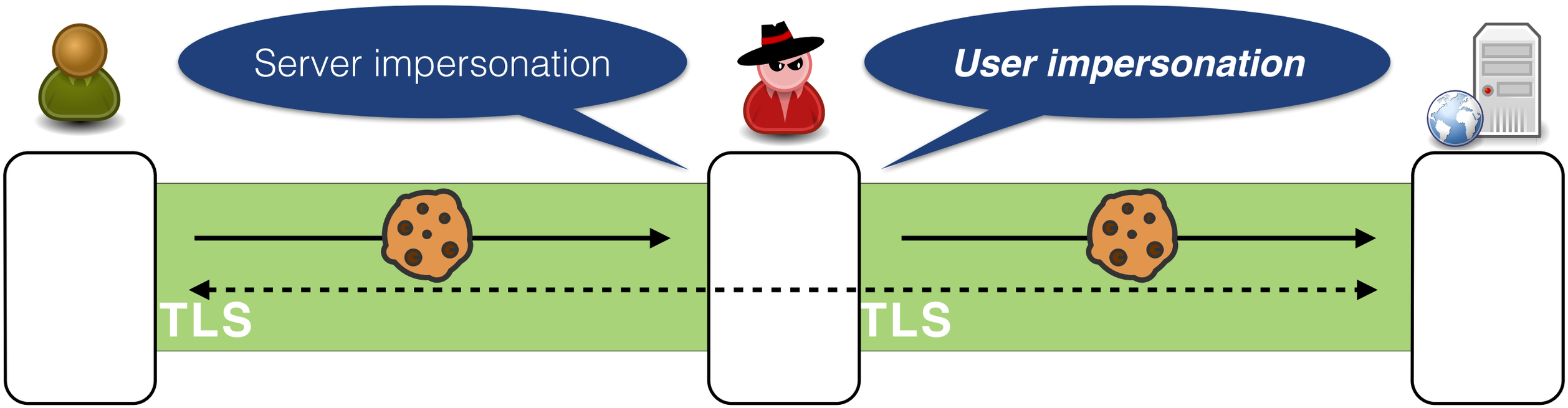

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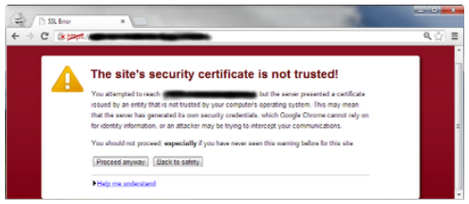

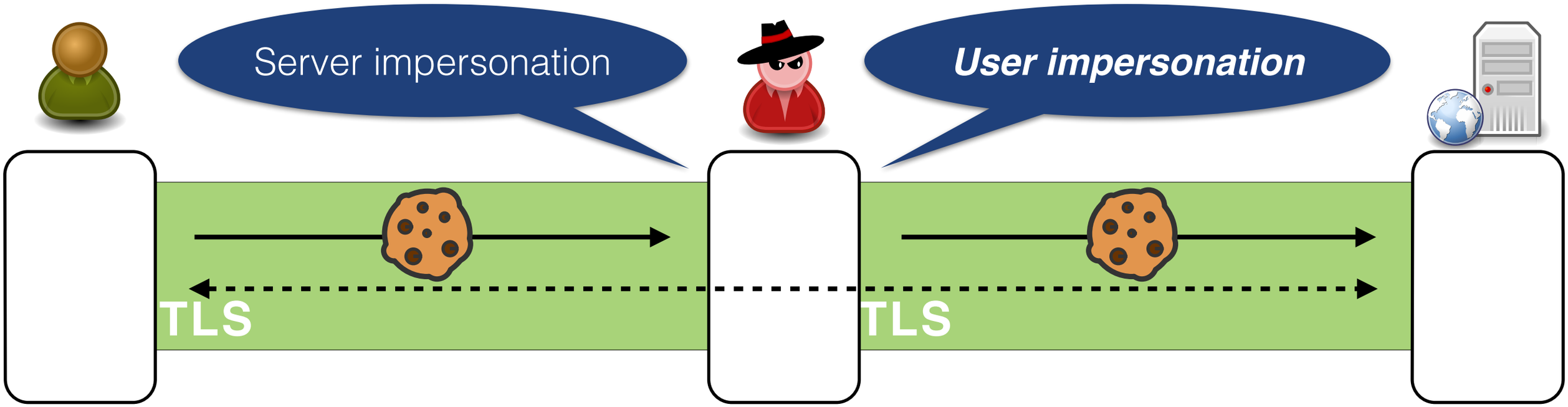

TLS Channel IDs (Balfanz et al., IETF Internet Draft) proposed as a solution

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Main Contributions

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1. We show an attack against TLS Channel IDs
   - extends usually considered attacker models
   - implemented and tested

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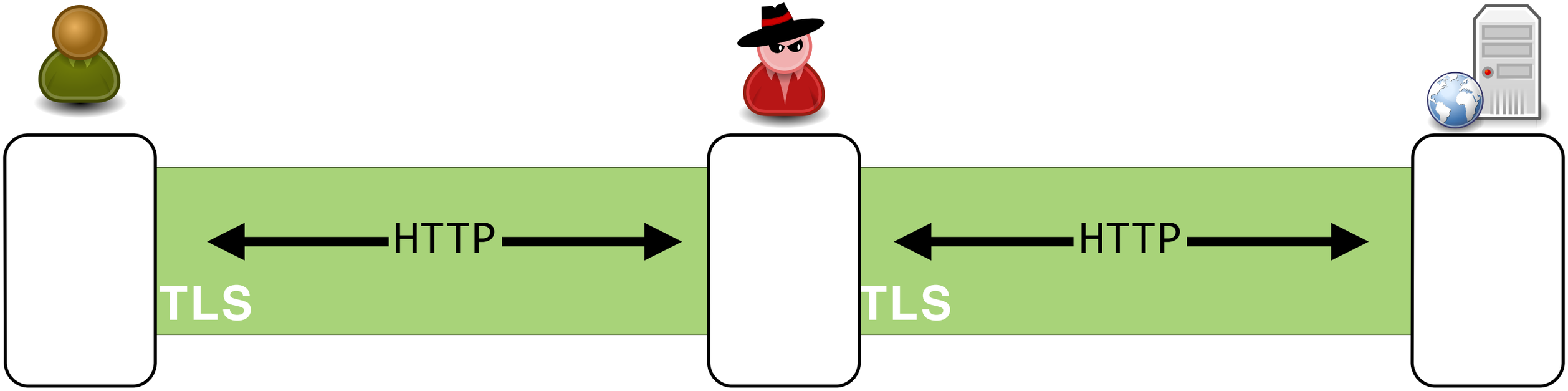
1. We show an attack against TLS Channel IDs
   - extends usually considered attacker models
   - implemented and tested
2. We propose a new solution: SISCA (Server Invariance with Strong Client Authentication)
   - prevents MITM attacks **even under server impersonation**
   - prototype implemented

Solutions focus on either endpoint



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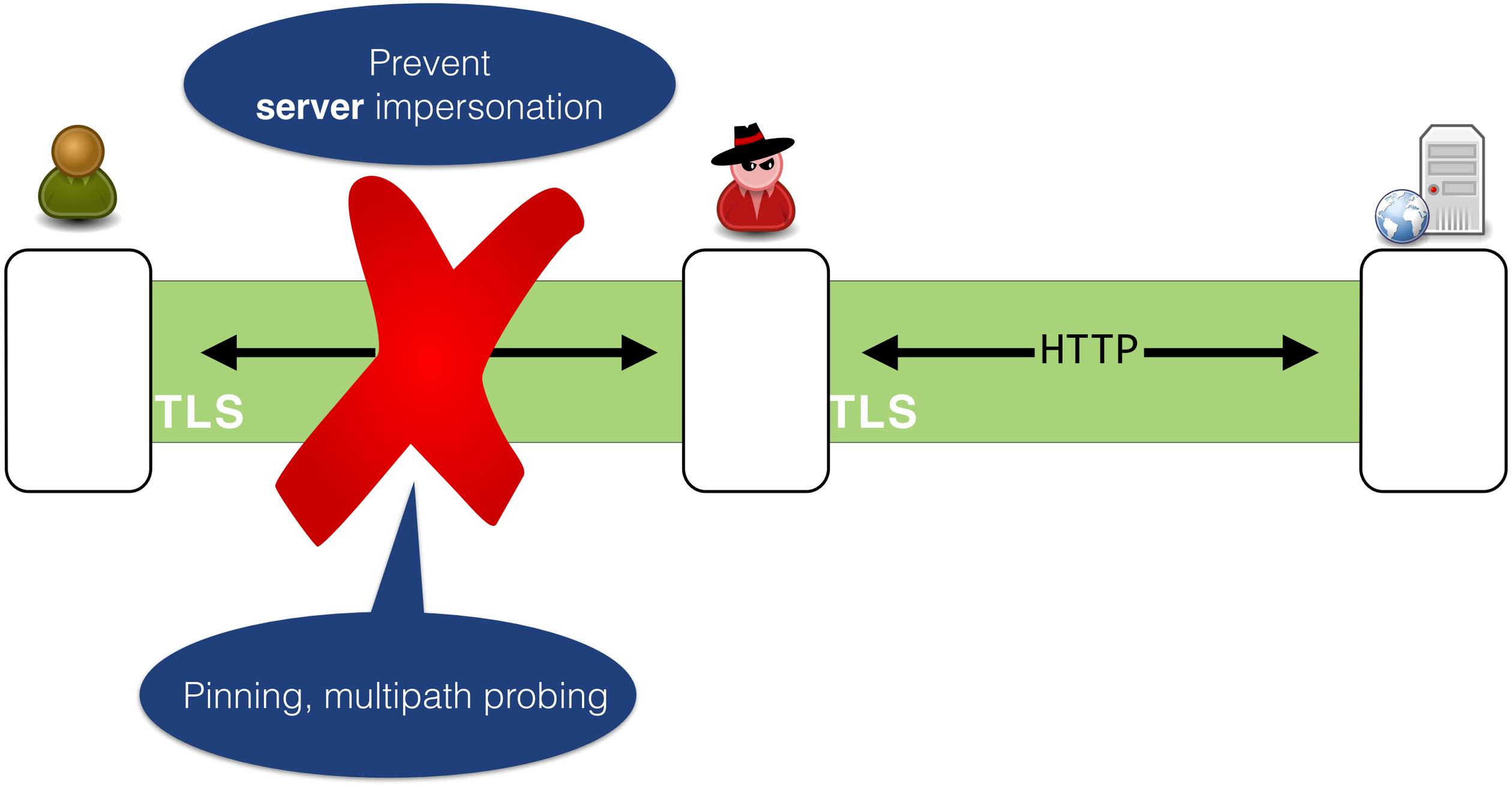

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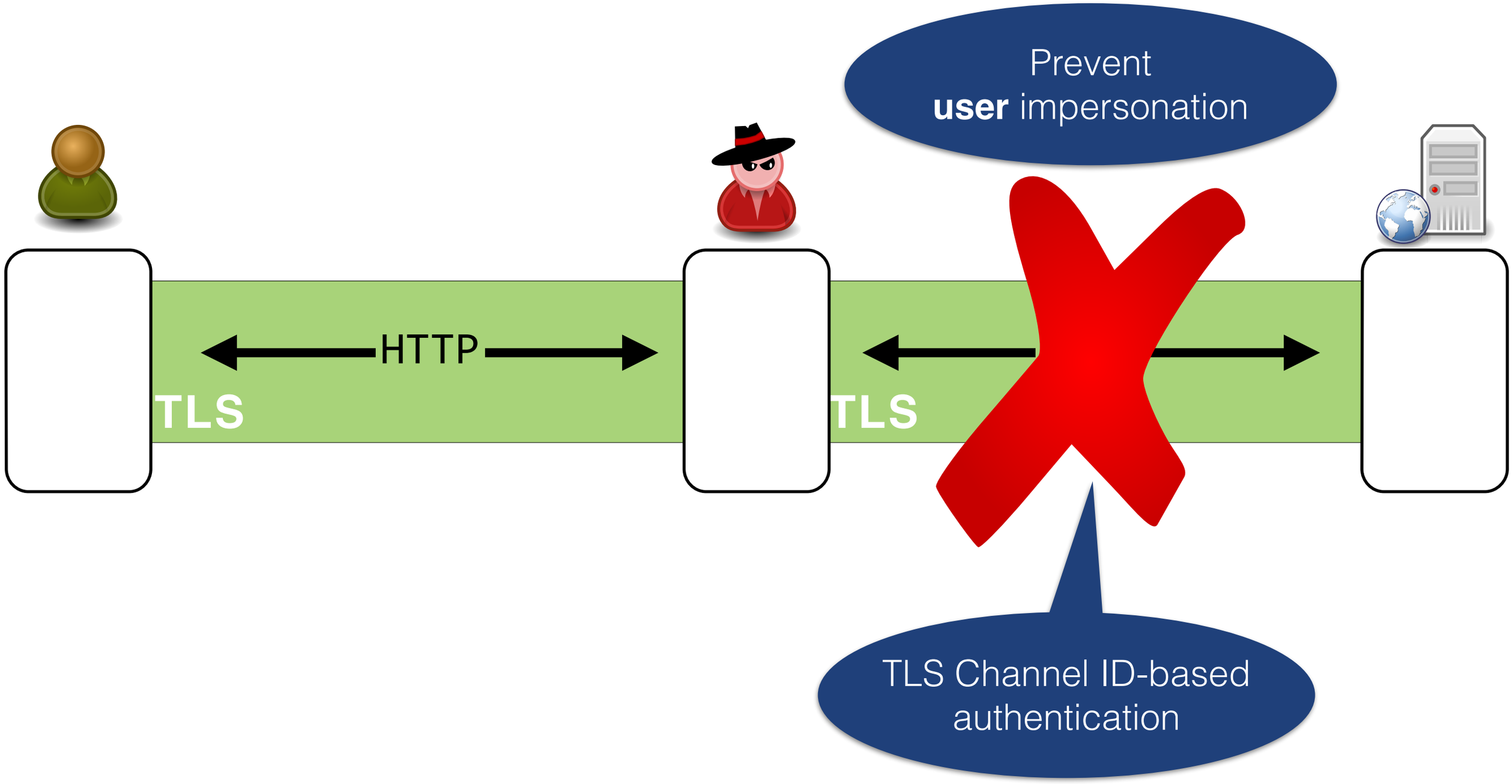
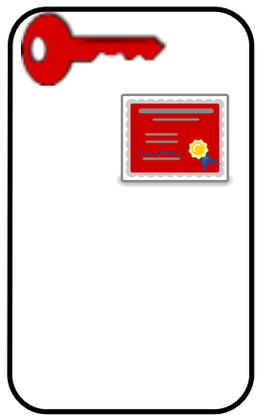
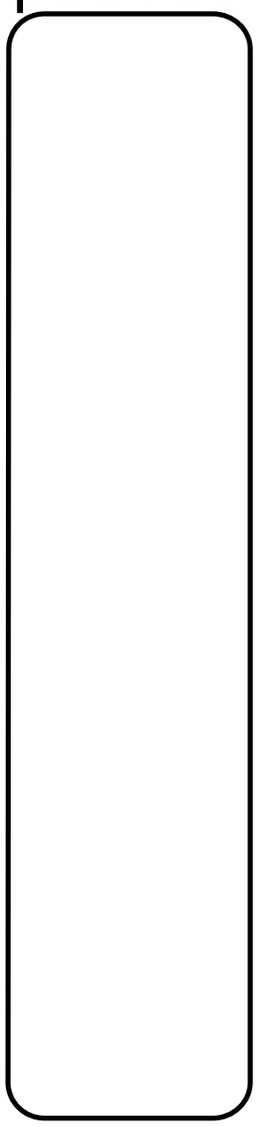


Channel ID = public key of a private/public key pair



www.example.com



 ,  : **TLS Channel IDs**

Channel ID = public key of a private/public key pair

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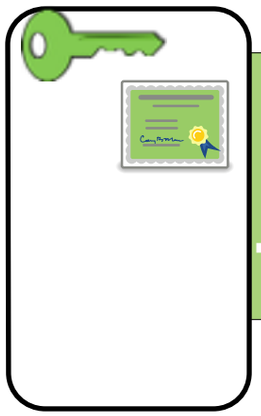
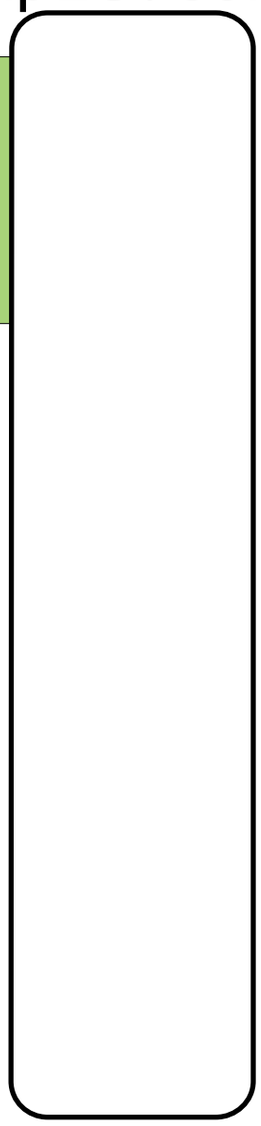
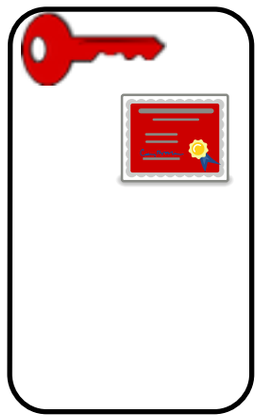


Here is my channel ID  , signed with the corresponding private key

TLS





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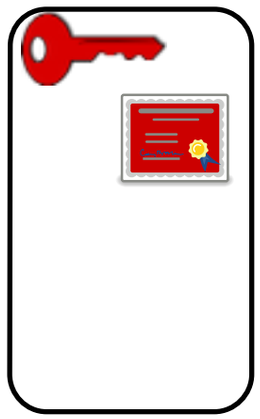

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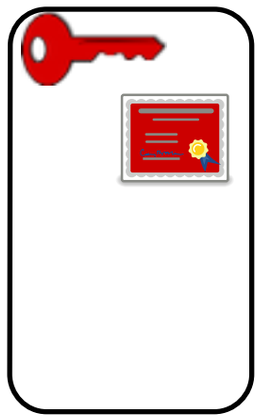

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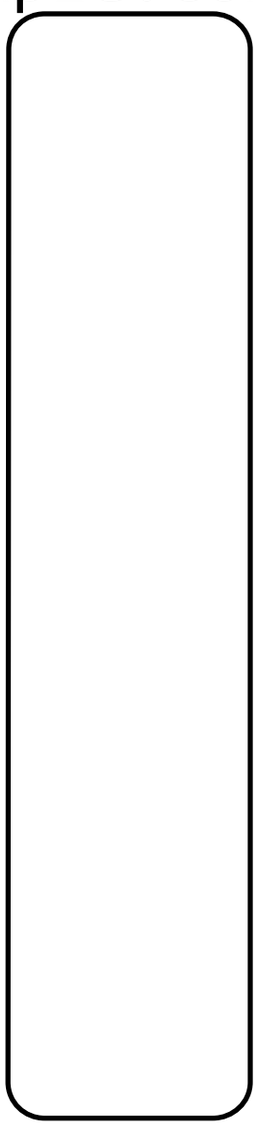

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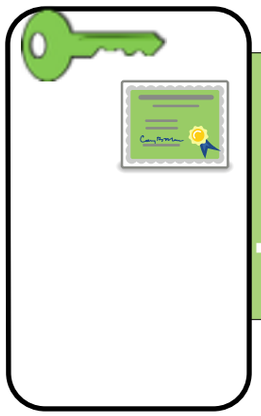

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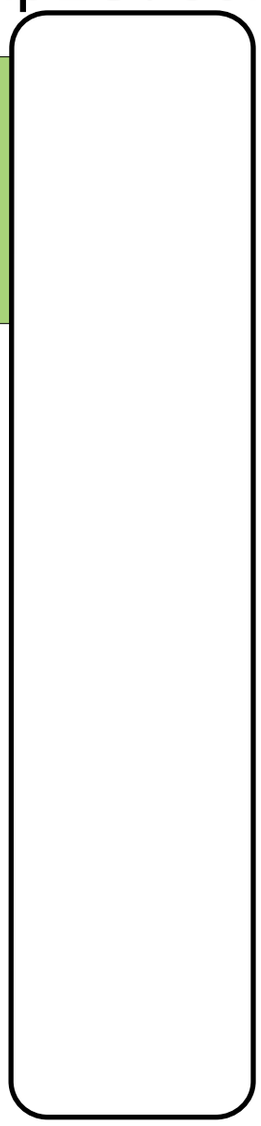

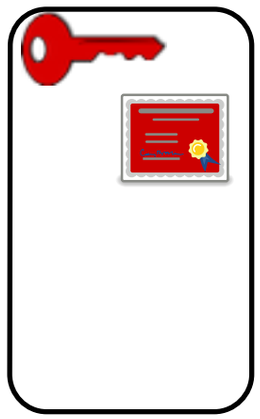

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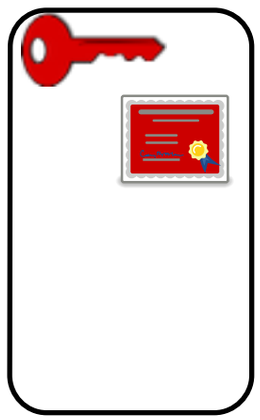
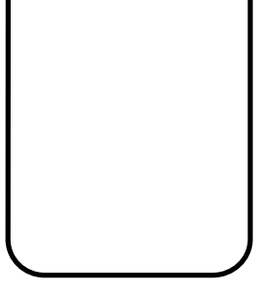
TLS

A Channel ID identifies the same “TLS channel” across different TLS connections





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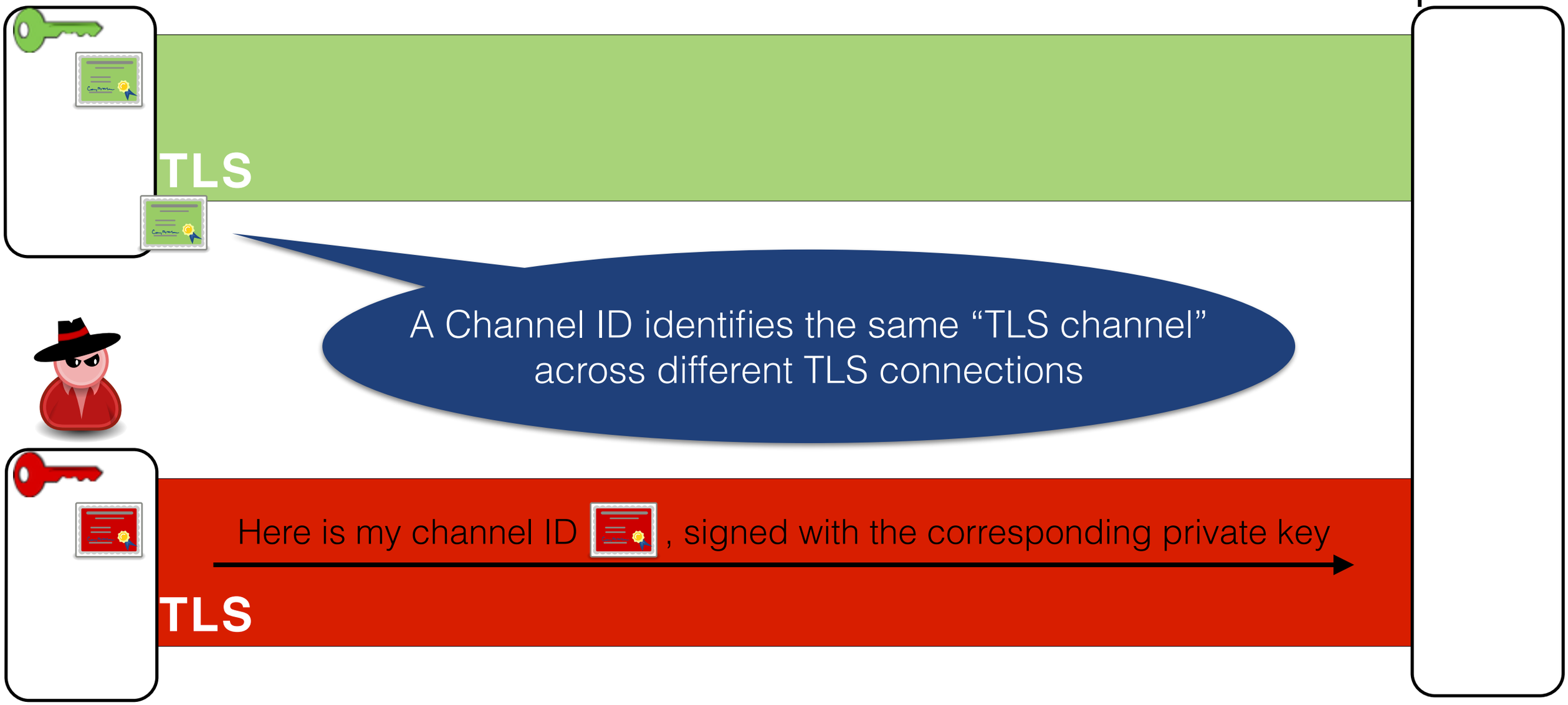

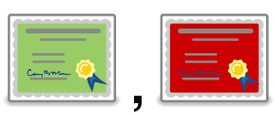

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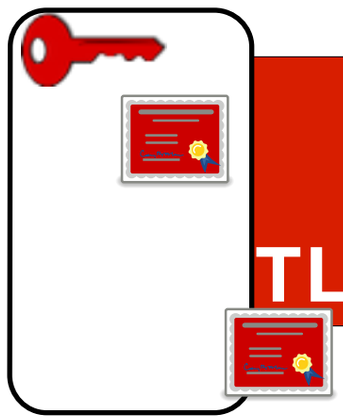

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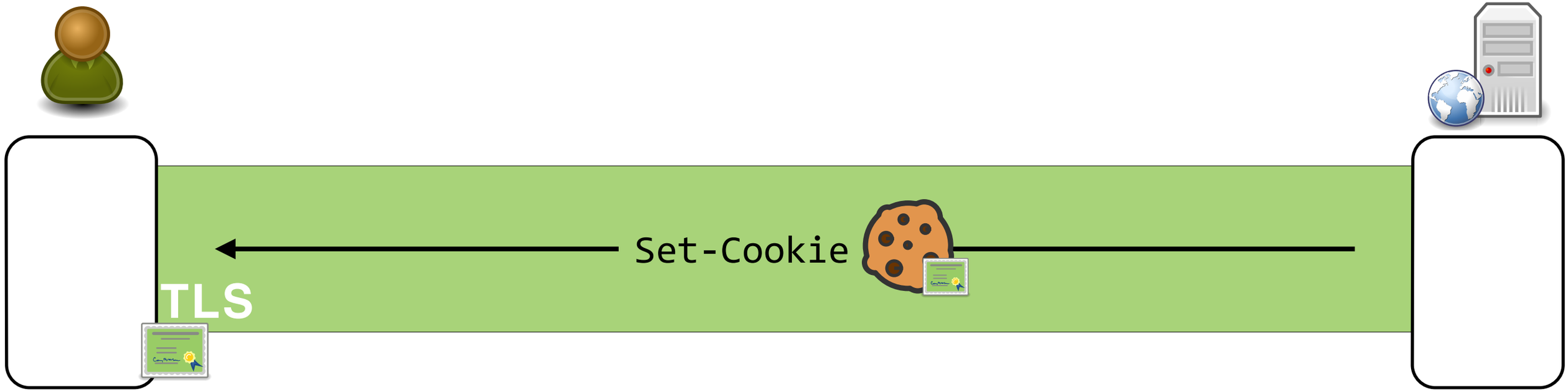
After initial login



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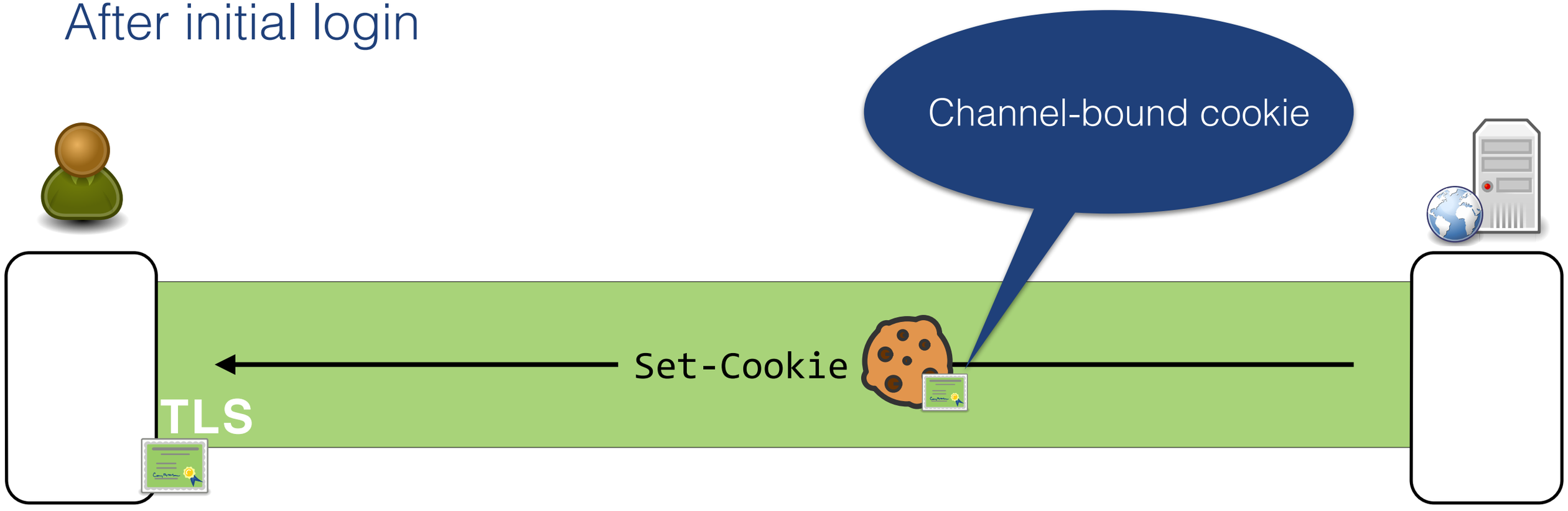

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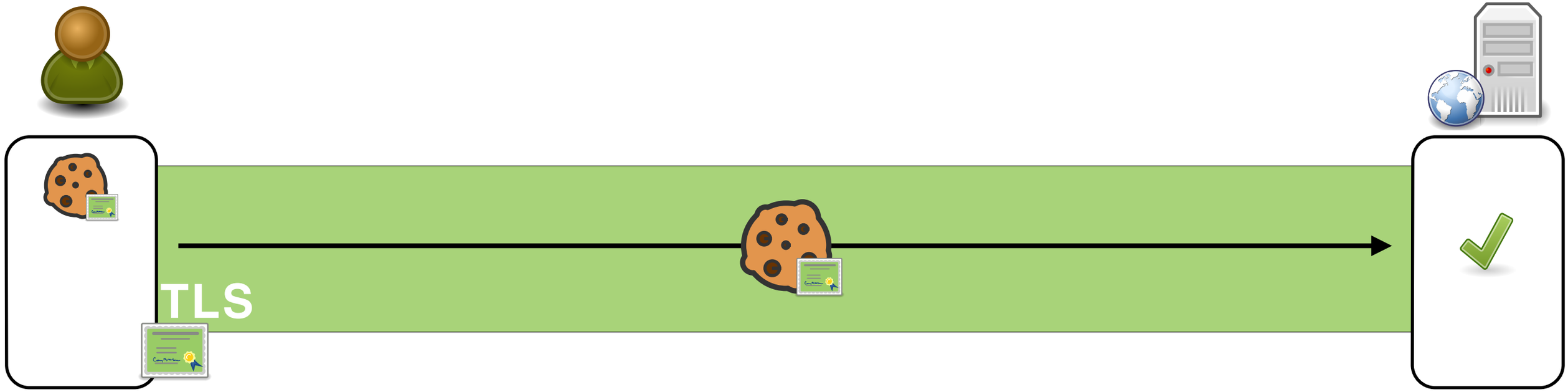

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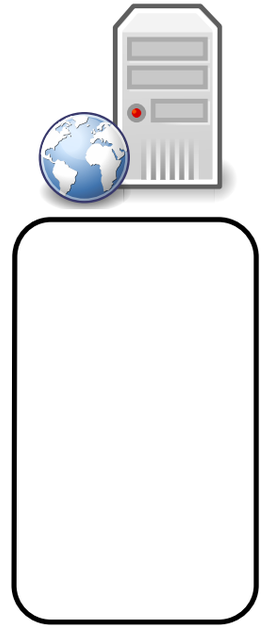

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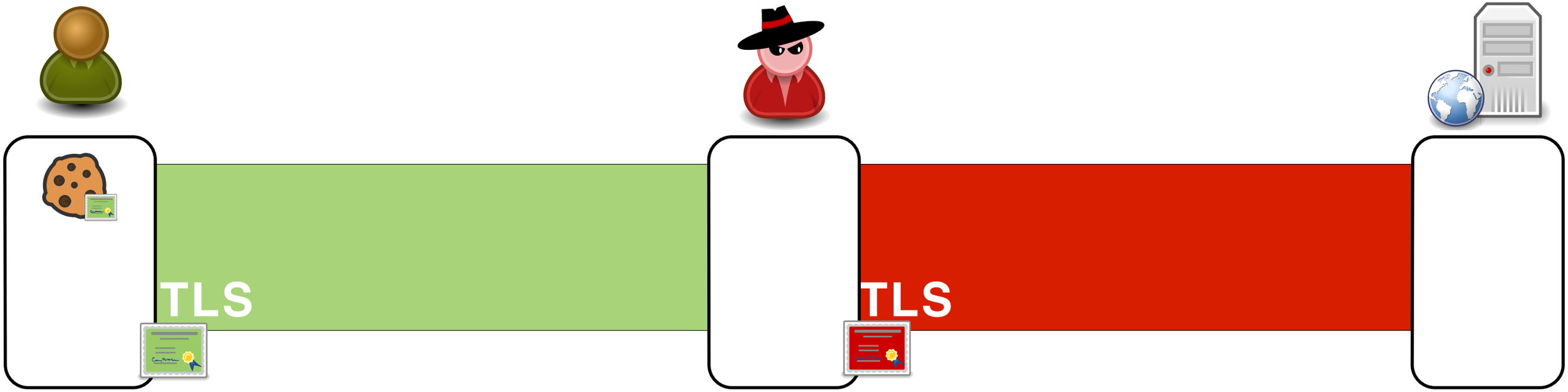

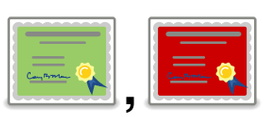 : TLS Channel IDs

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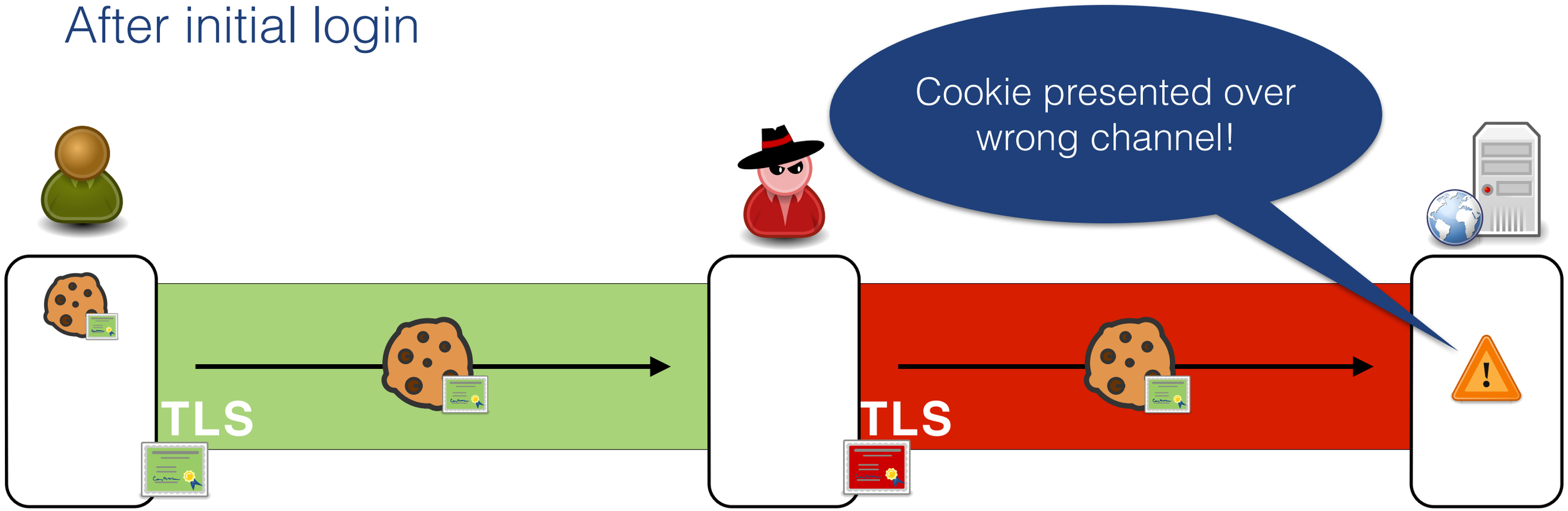

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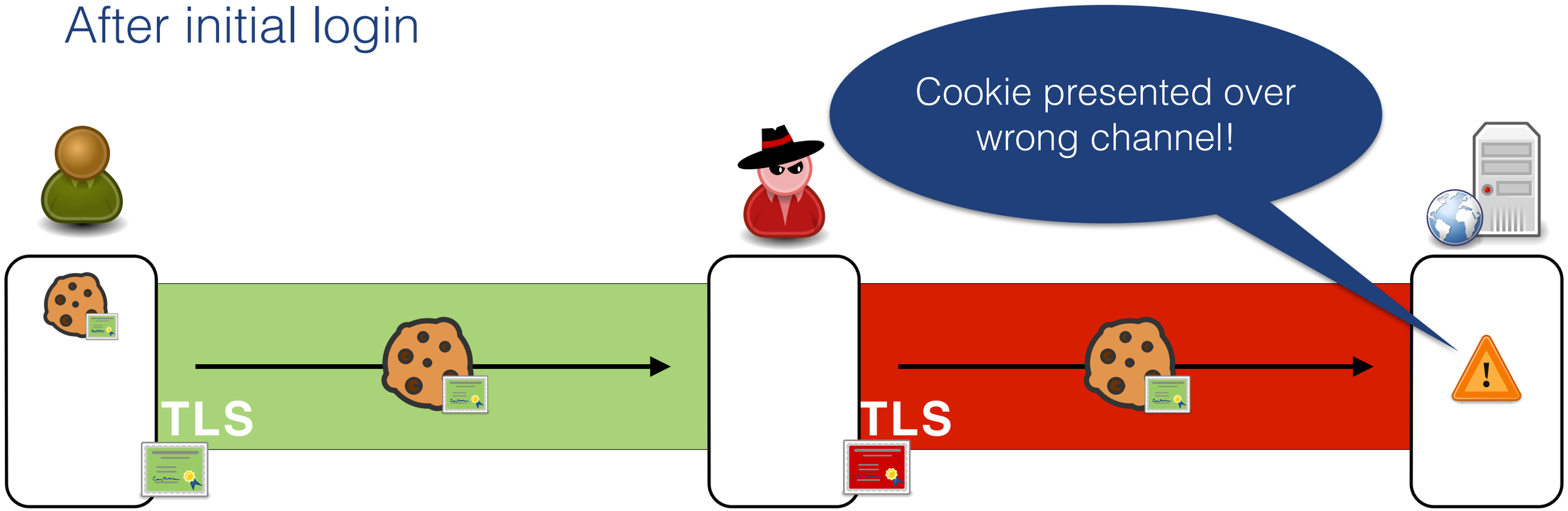

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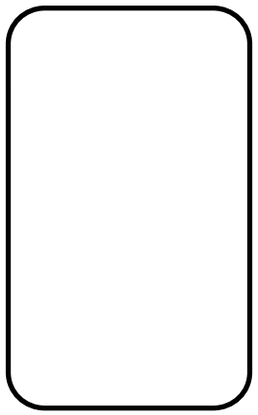
MITM-Script-In-The-Browser (MITM-SITB)

www.example.com



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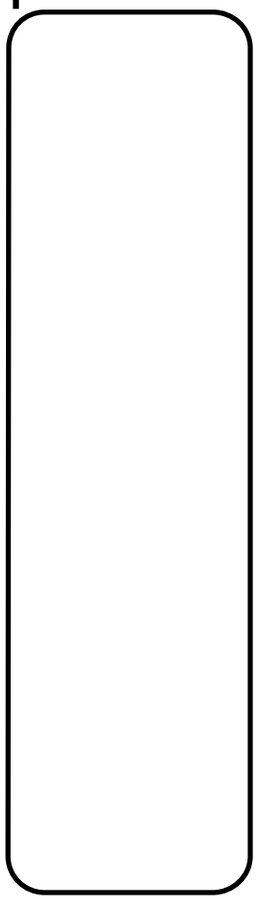

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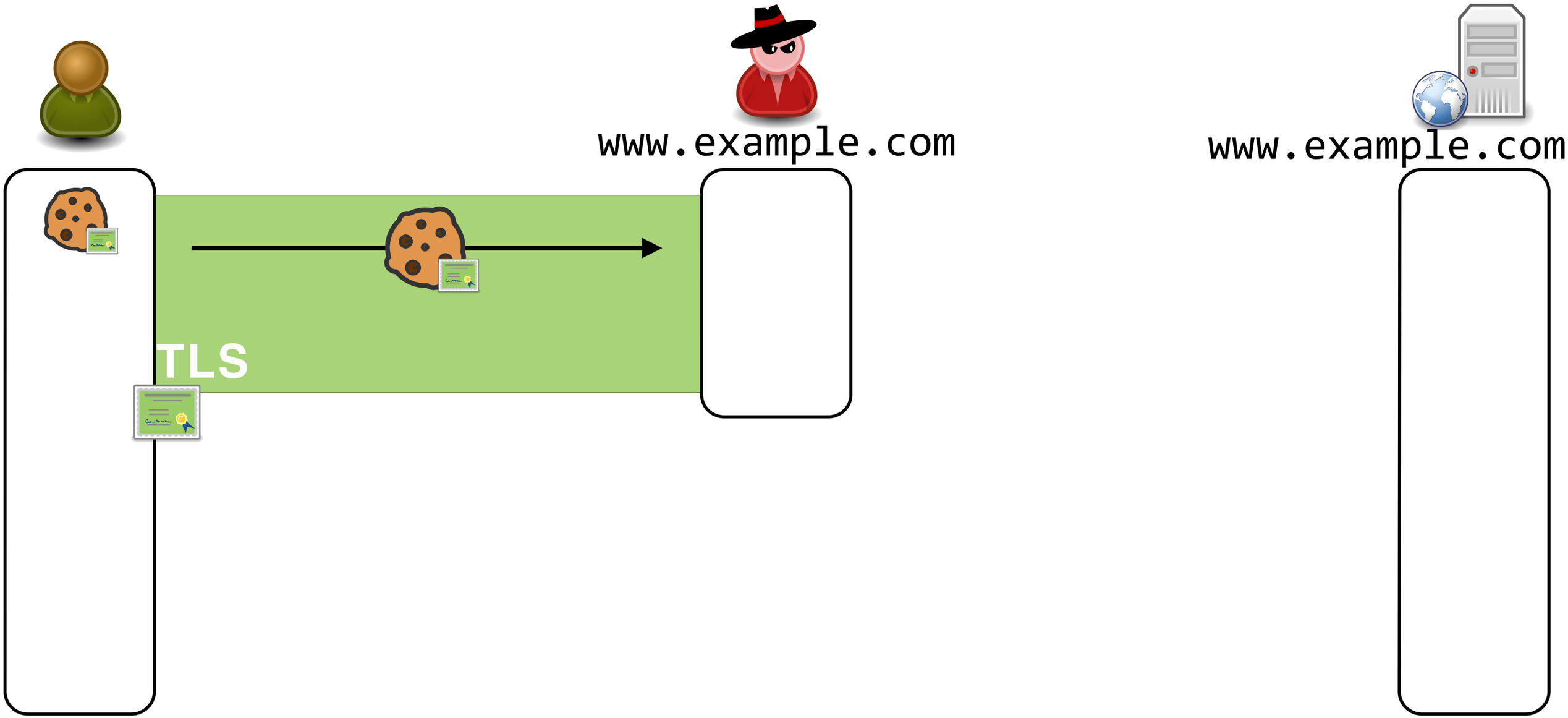

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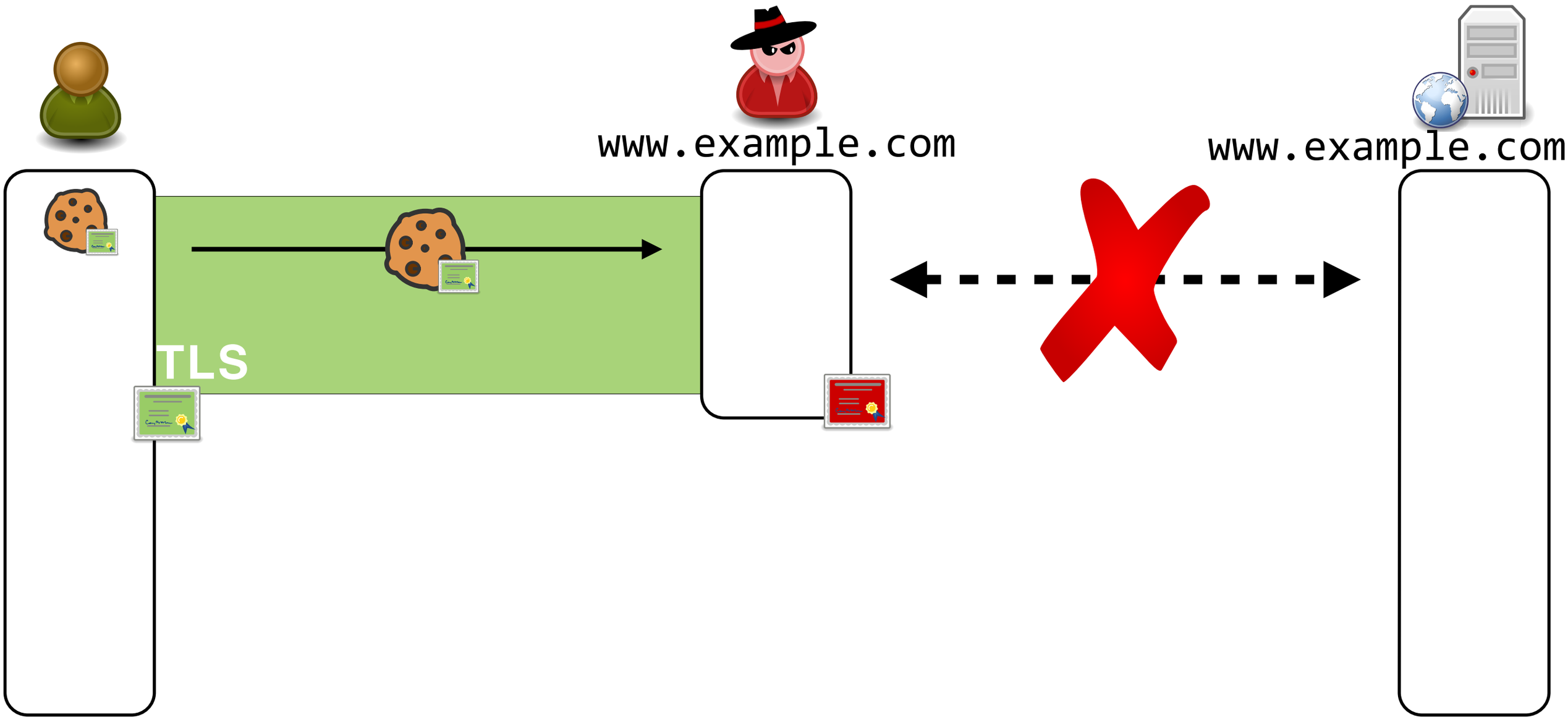

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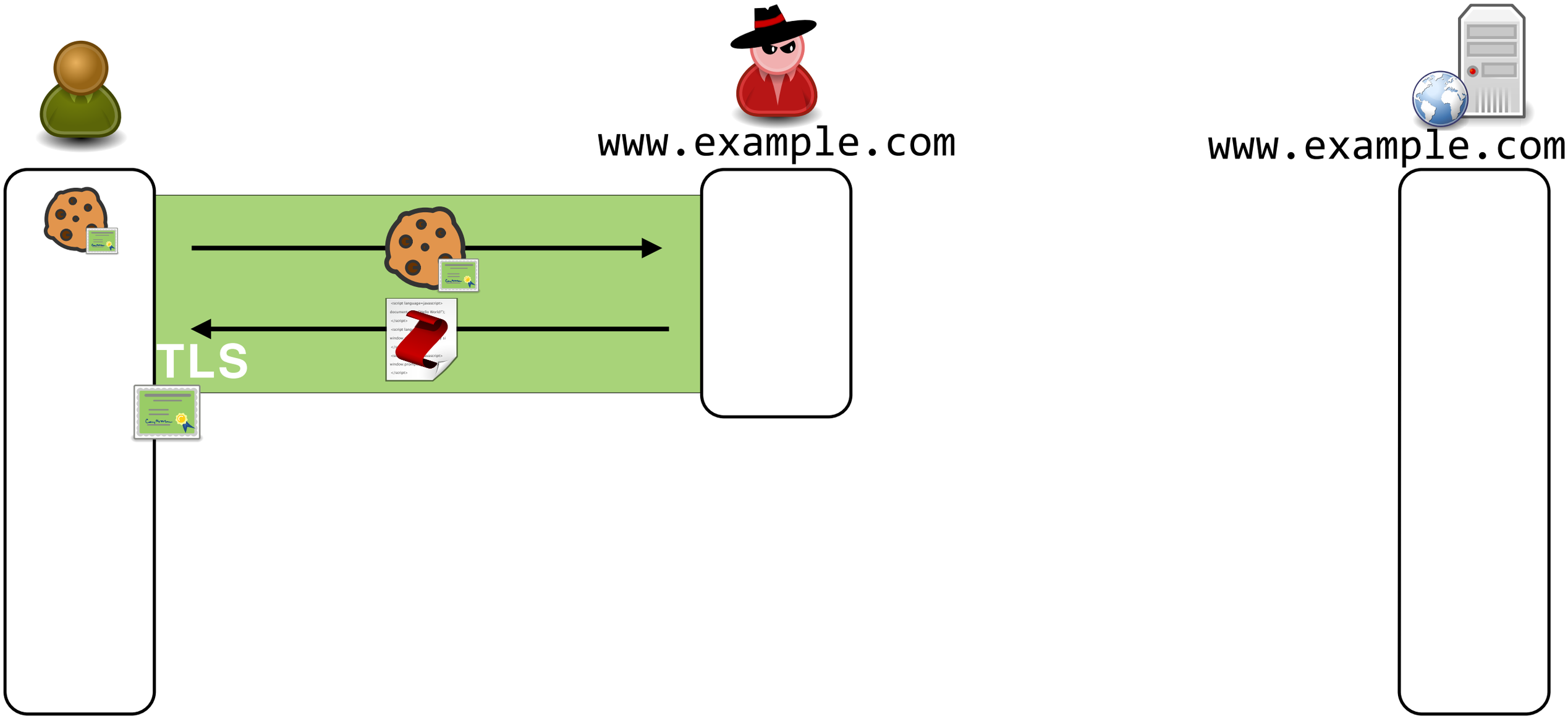

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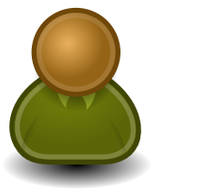

www.example.com

www.example.com

Executed within the target server's web origin

MITM-Script-In-The-Browser (MITM-SITB)

www.example.com

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TLS

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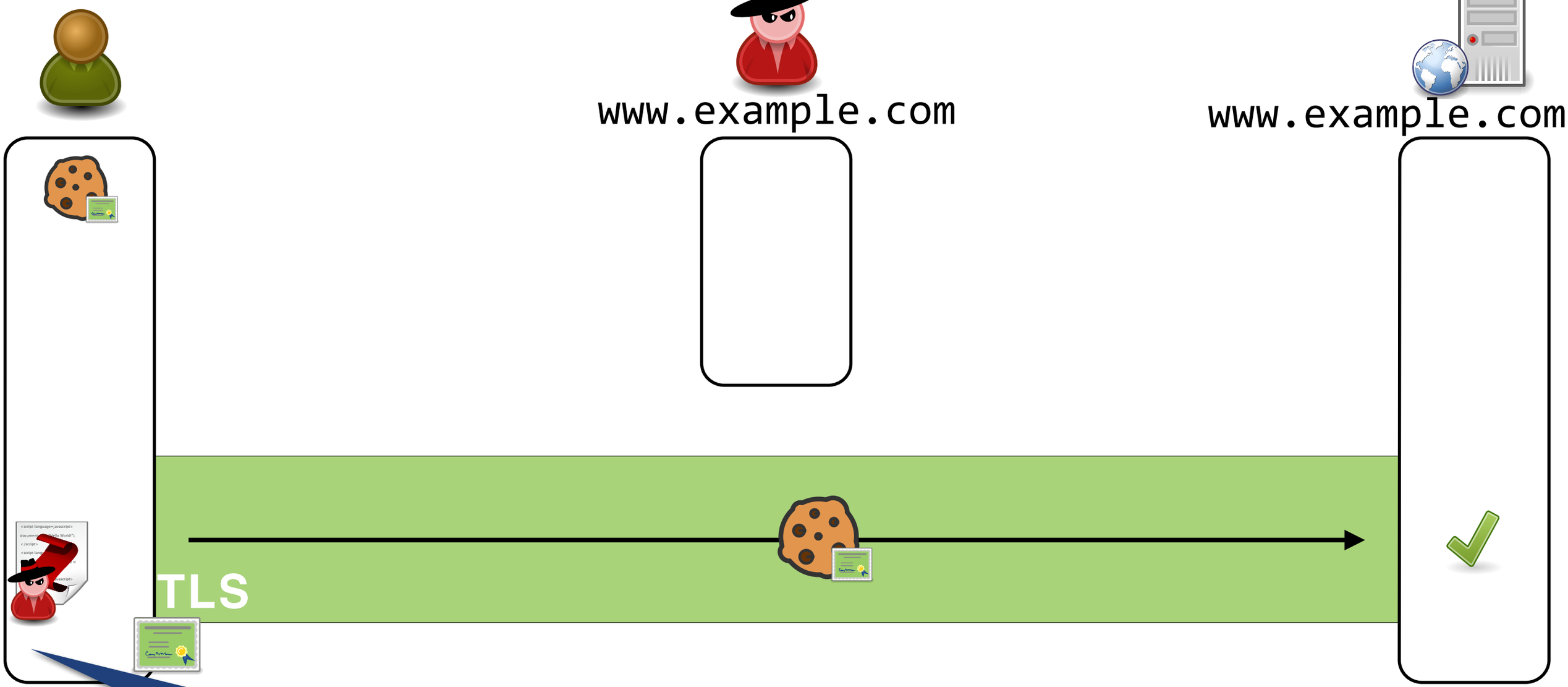

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▸ *Attacker impersonates the server and injects malicious but "trusted" client-side code*

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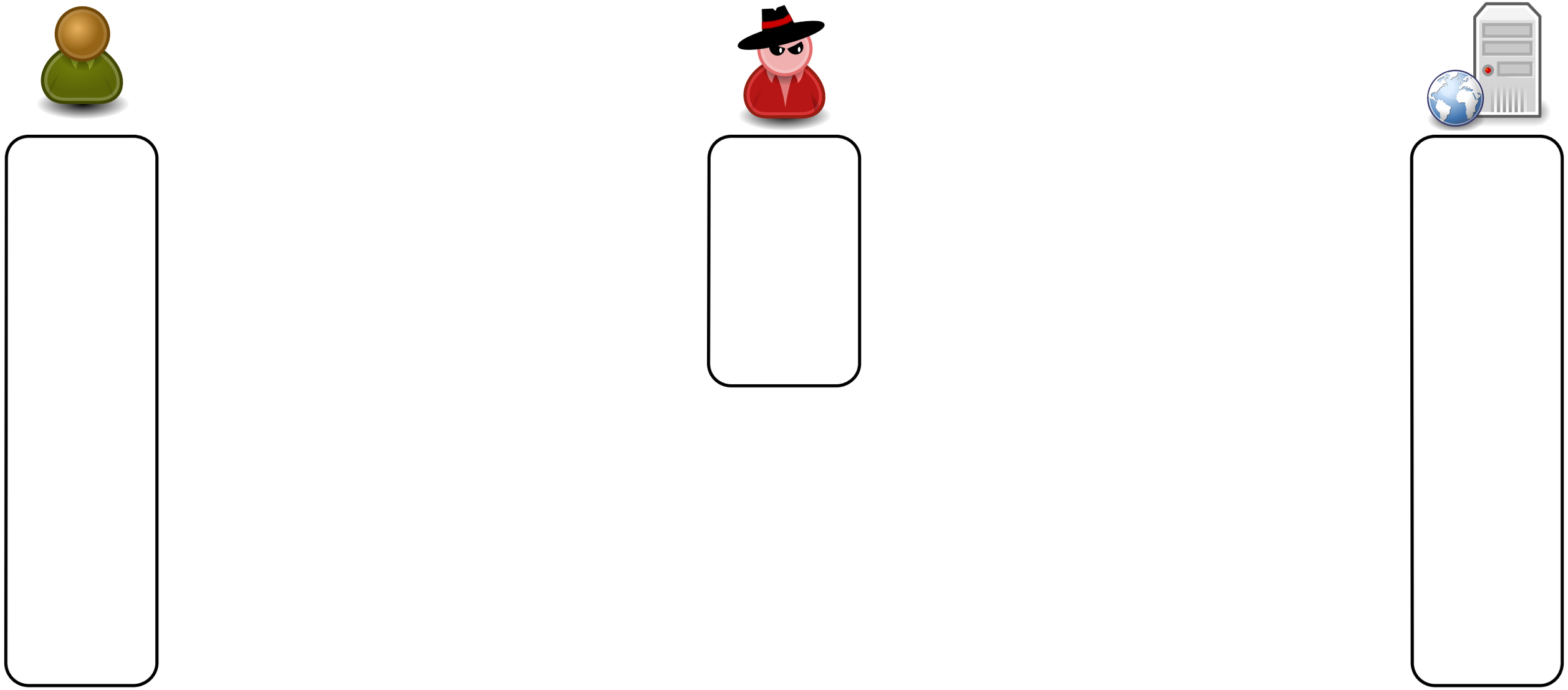
- *Attacker impersonates the server and injects malicious but "trusted" client-side code*

=> we cannot ignore **server authentication**
But…

Insight



Do we really need server authentication?

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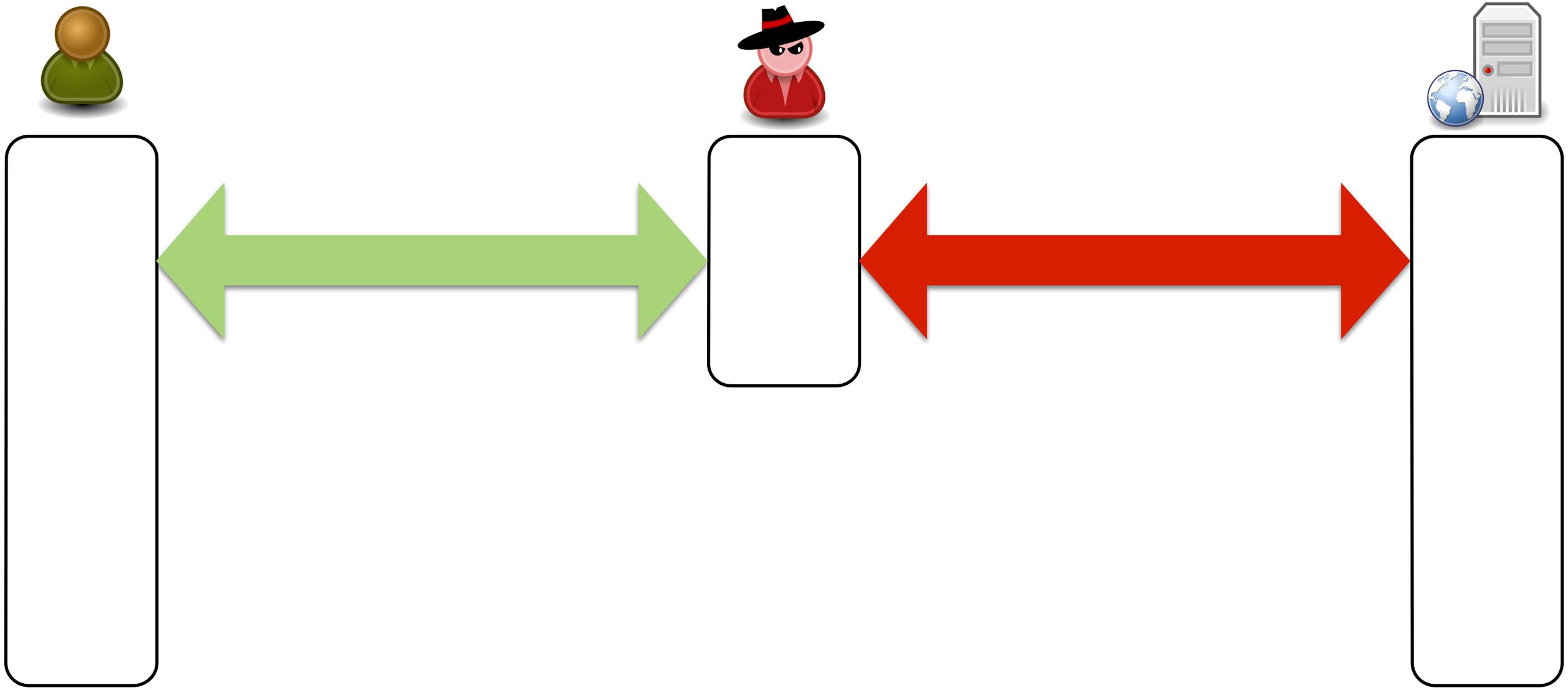
Insight



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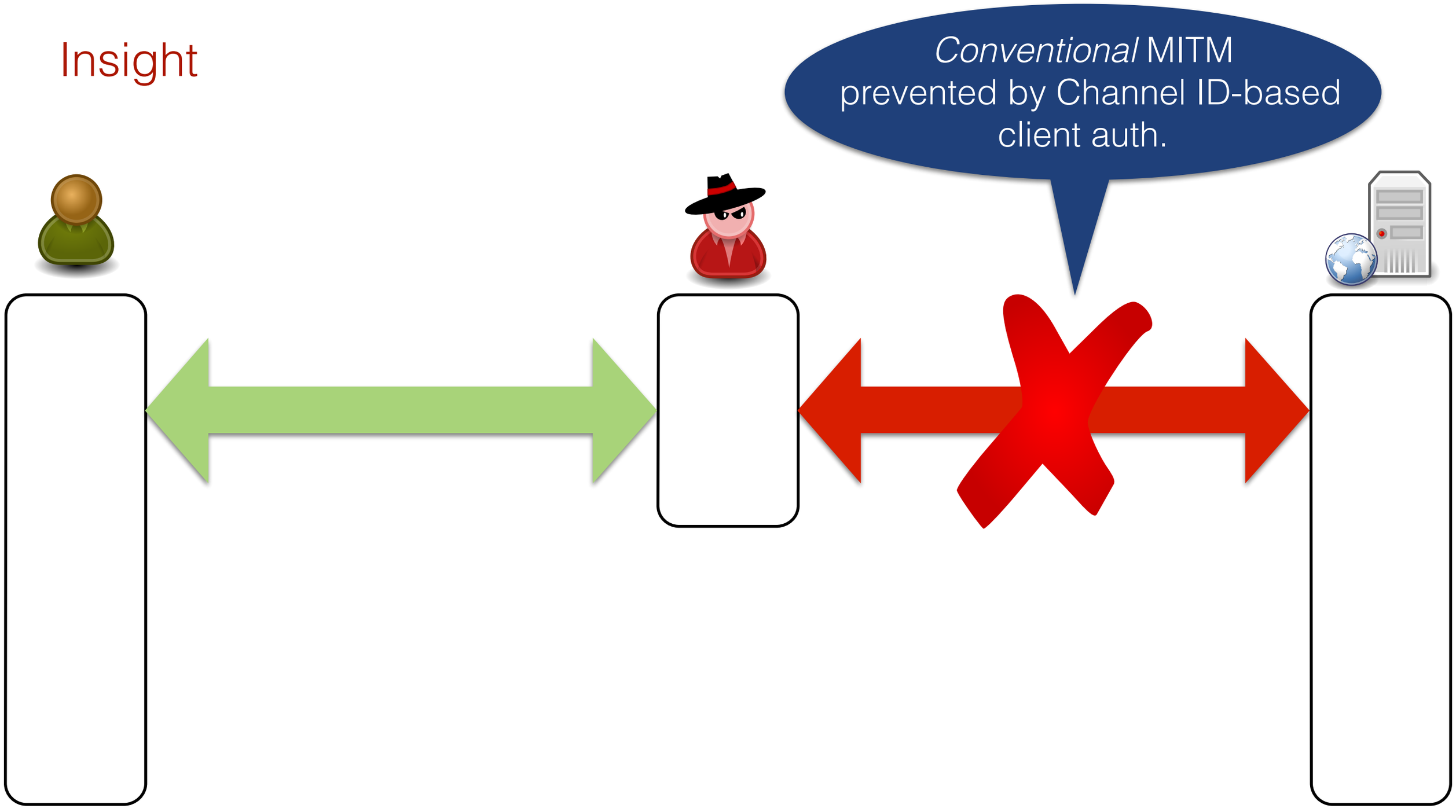

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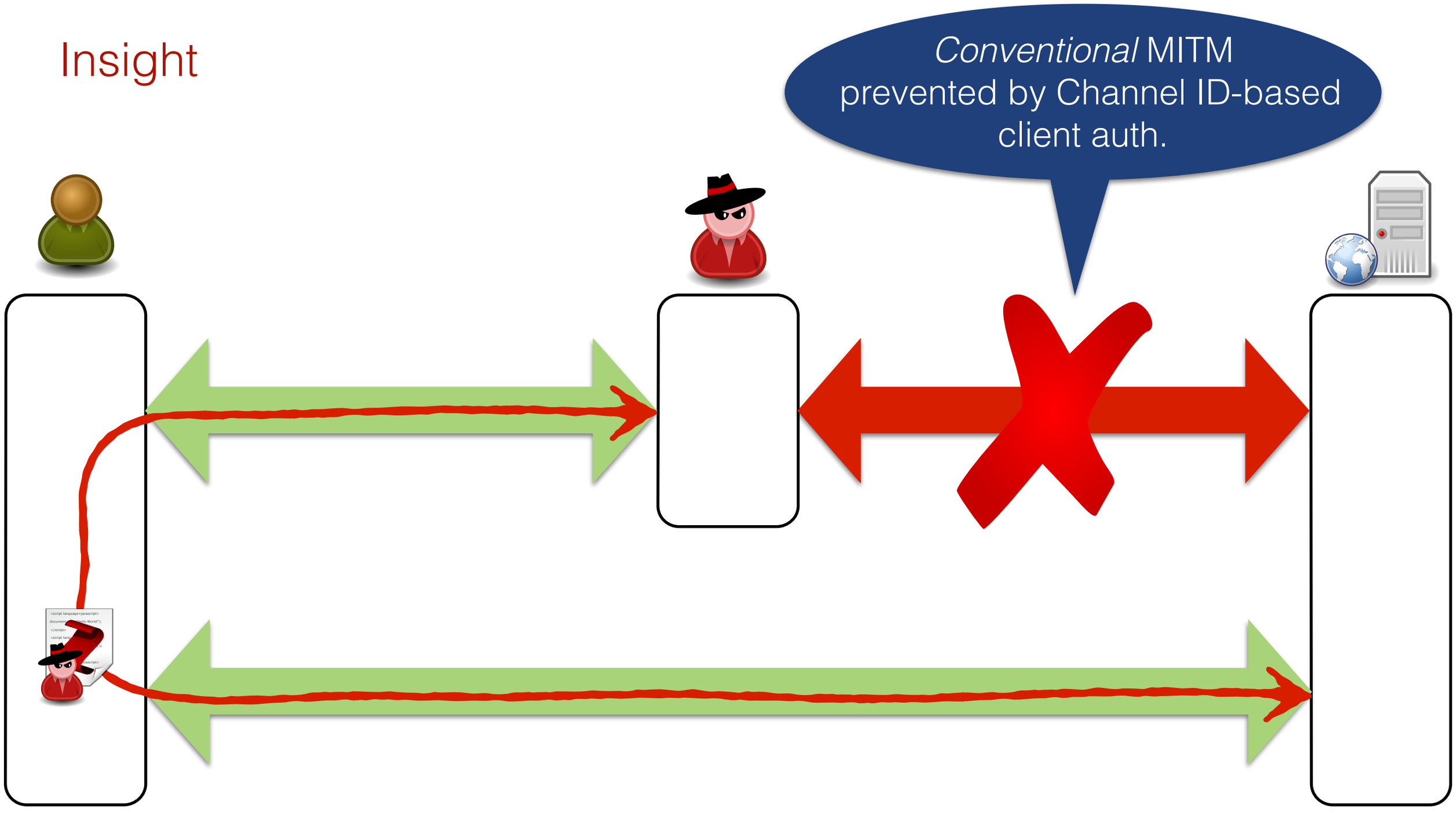

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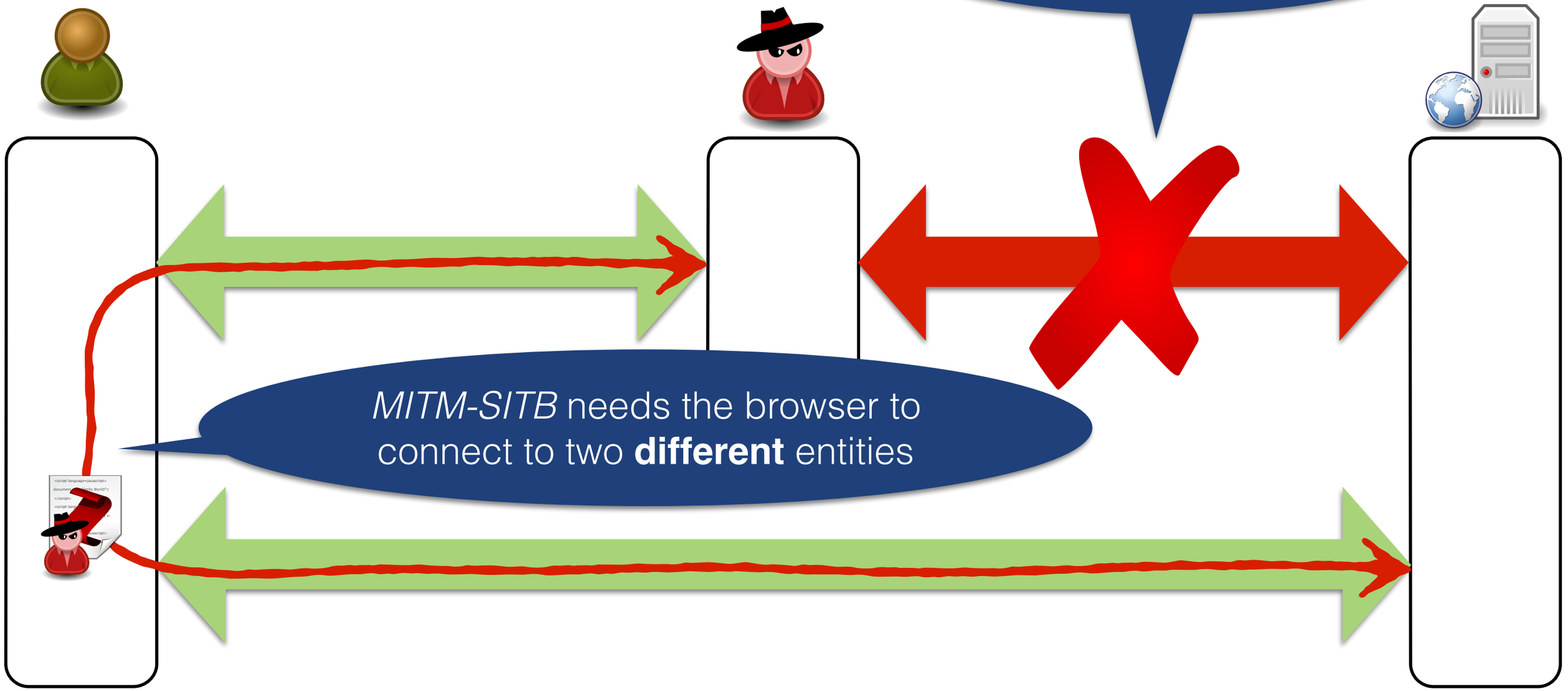

MITM-SITB needs the browser to connect to two **different** entities

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Insight

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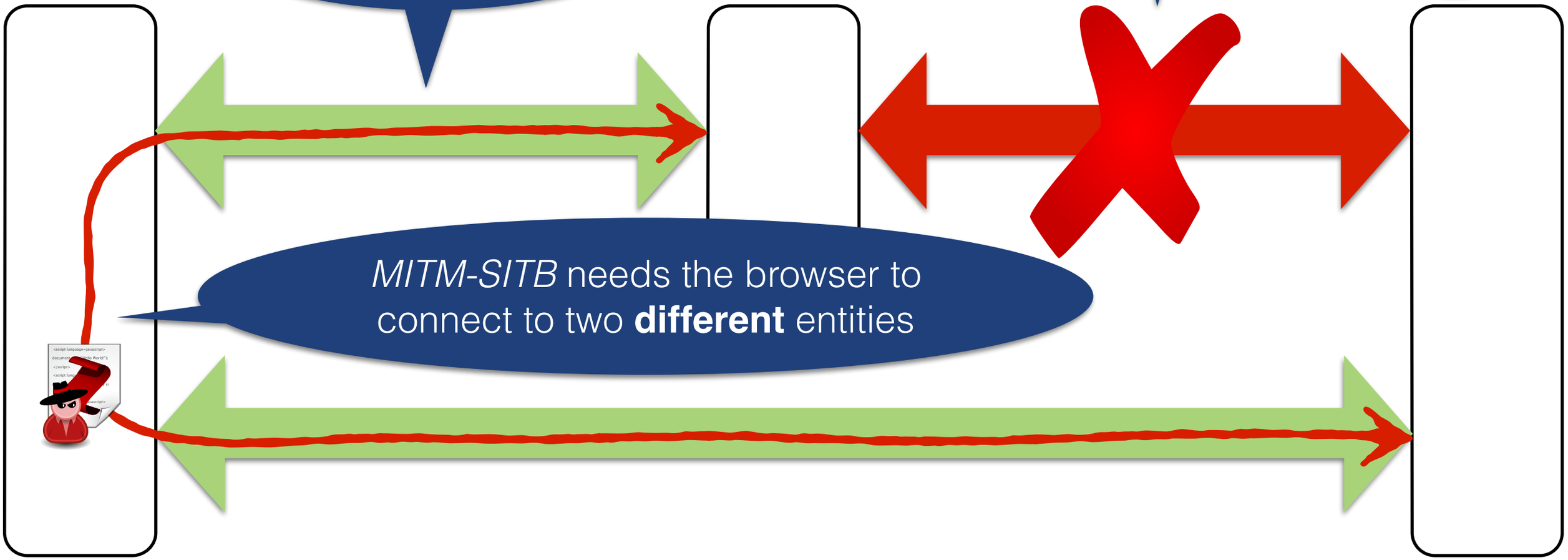
1. Attacker server (inject code)



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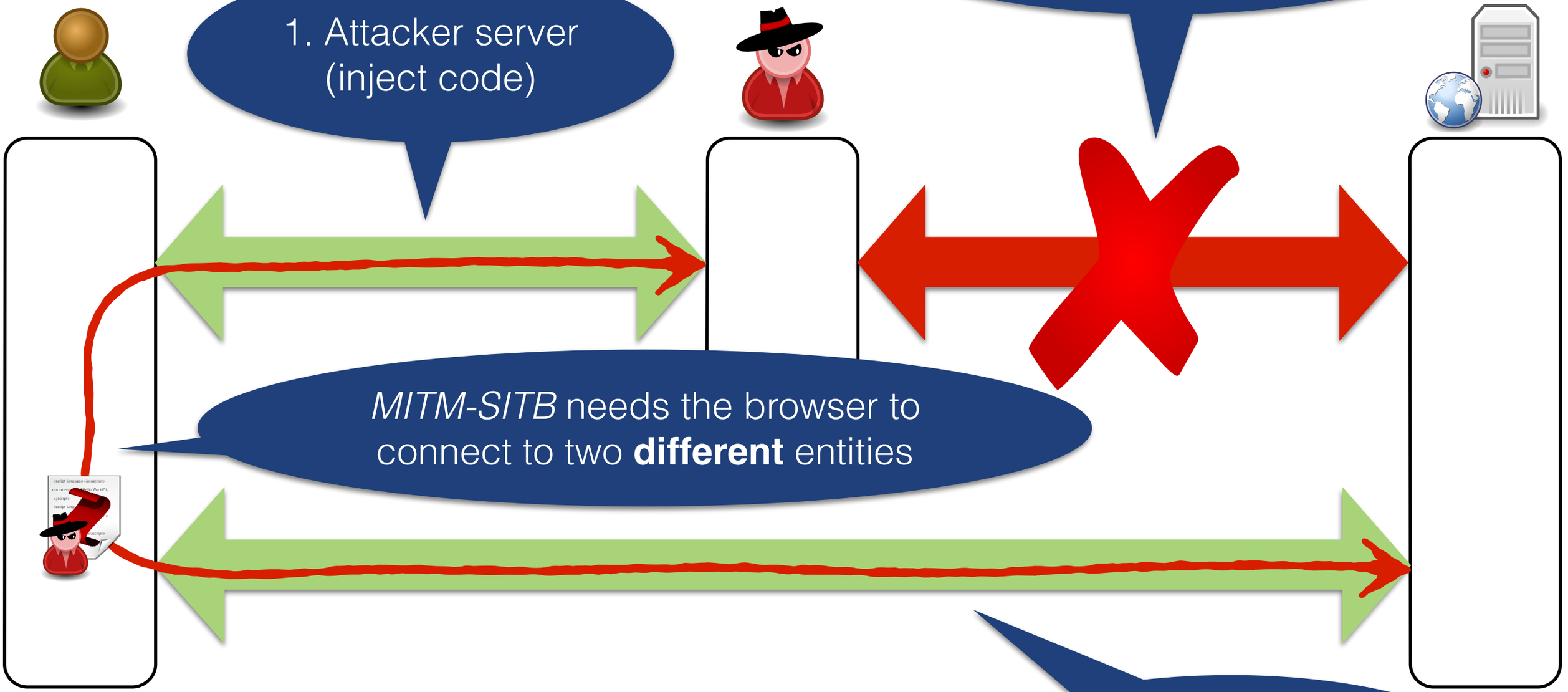
ETH zürich

Insight

Conventional MITM prevented by Channel ID-based client auth.

1. Attacker server (inject code)



MITM-SITB needs the browser to connect to two **different** entities

2. Legitimate server (access user account)

Do we really need server authentication?

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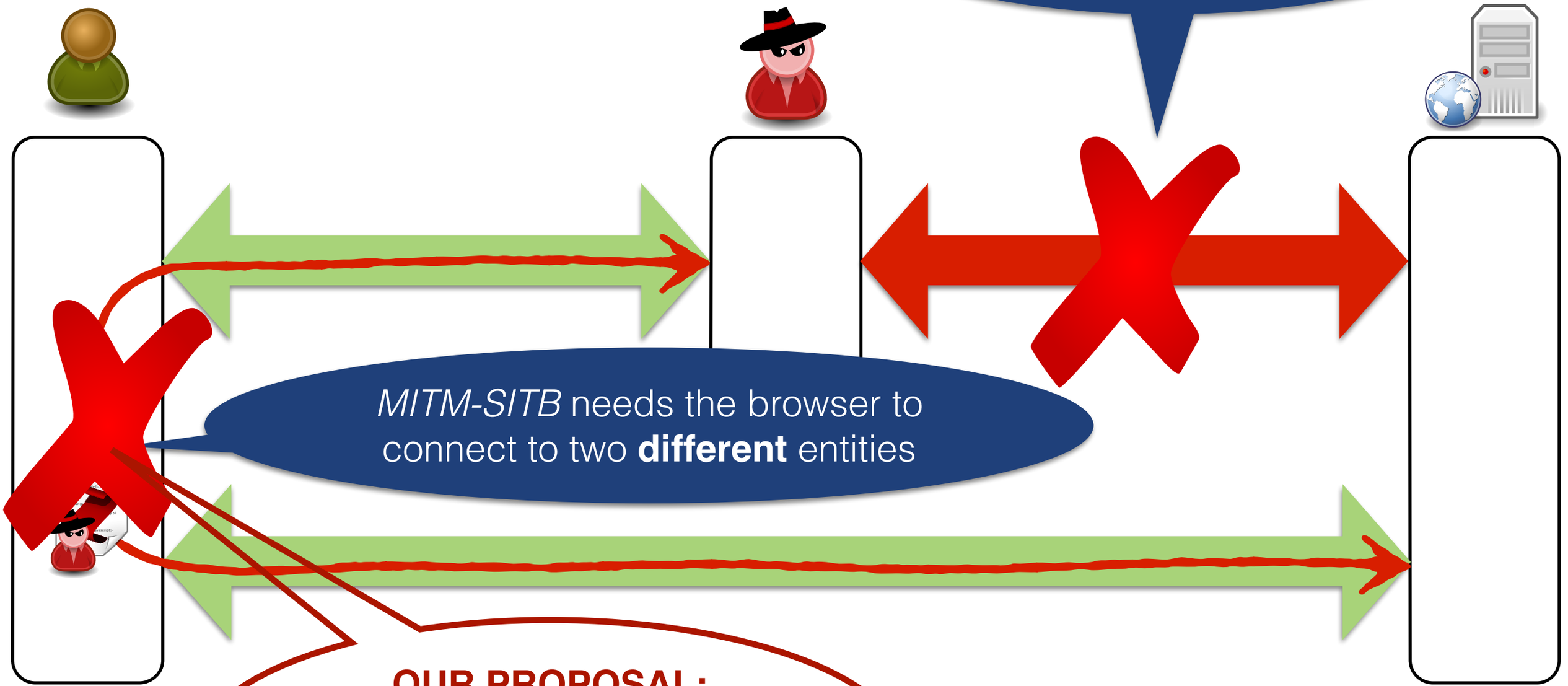
Insight

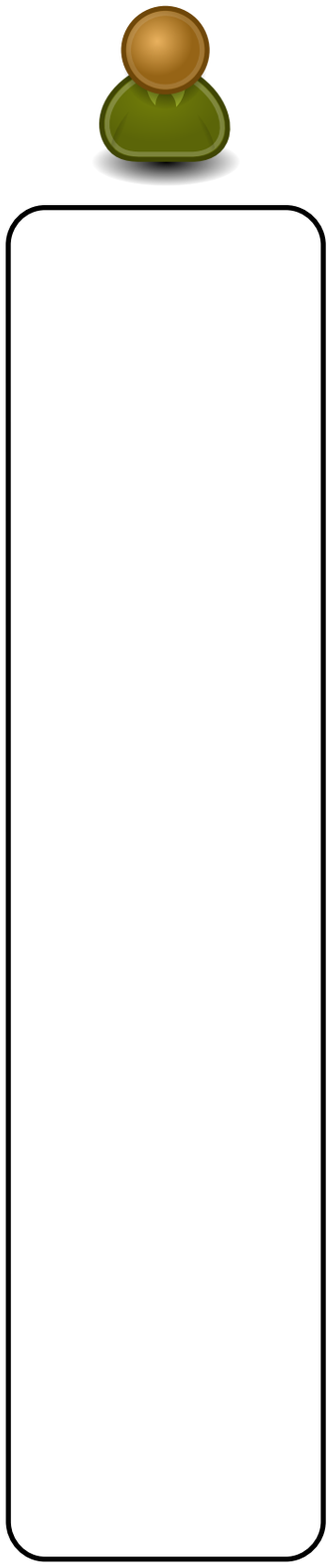
Conventional MITM prevented by Channel ID-based client auth.

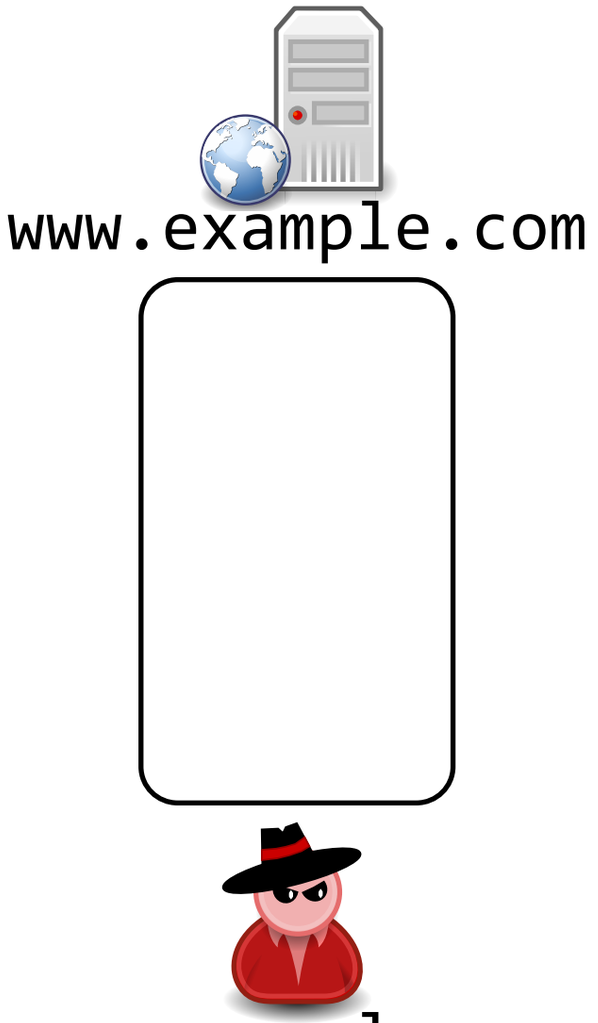


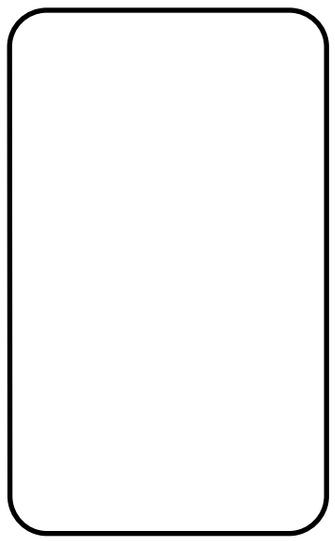
MITM-SITB needs the browser to connect to two **different** entities

OUR PROPOSAL:
ensure that the browser does not connect to different entities!

This Invariance is Enforced by the Browser







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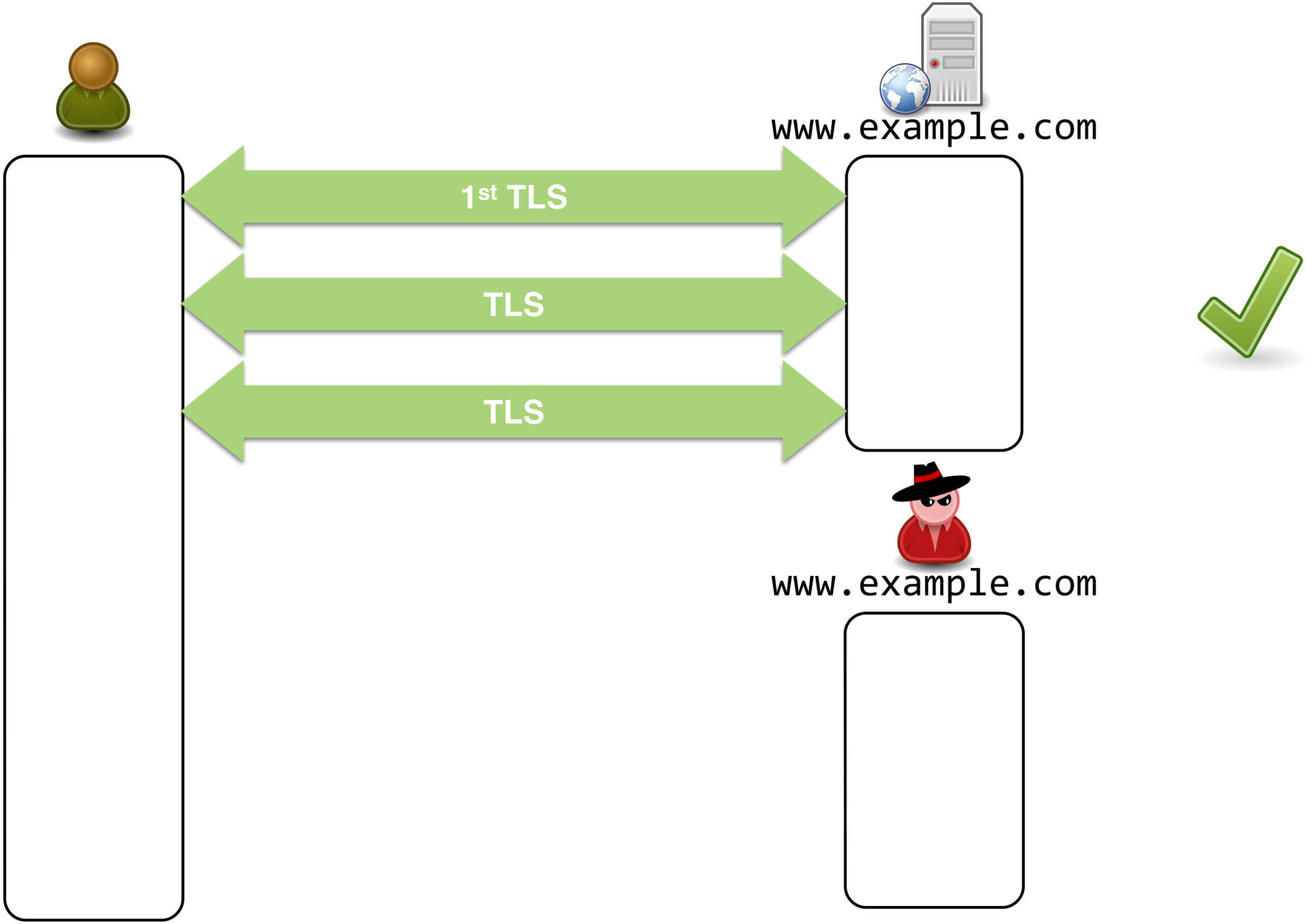

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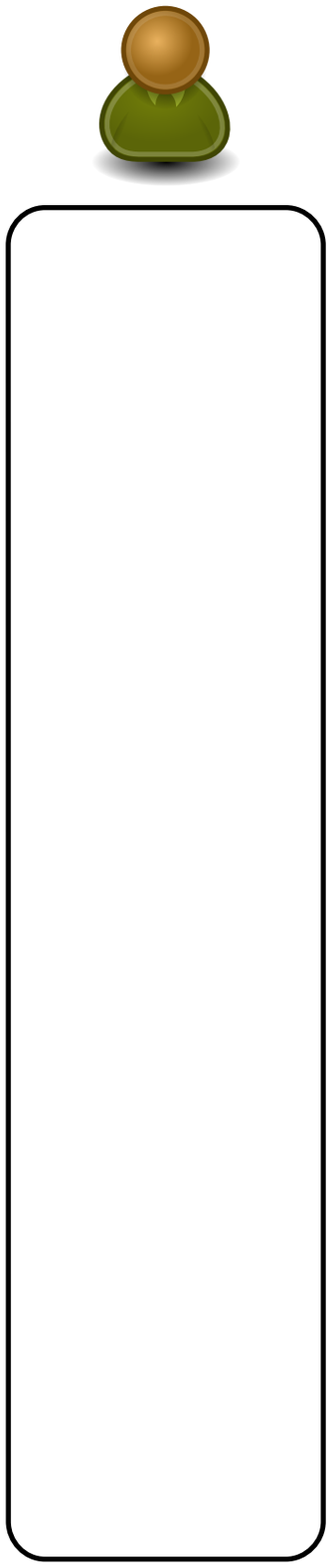

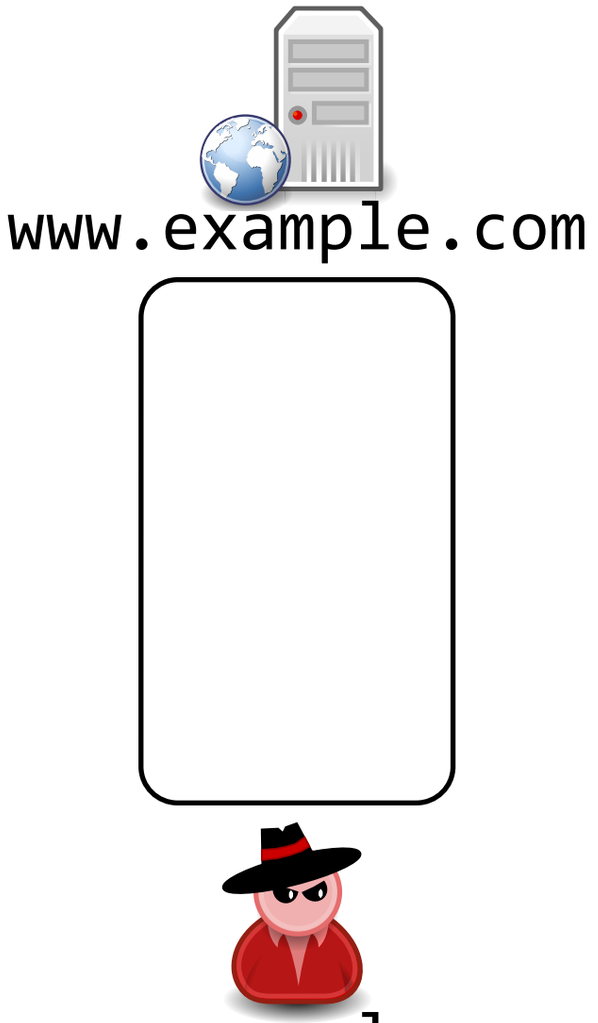

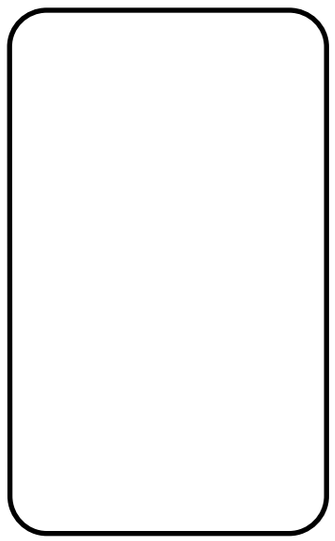

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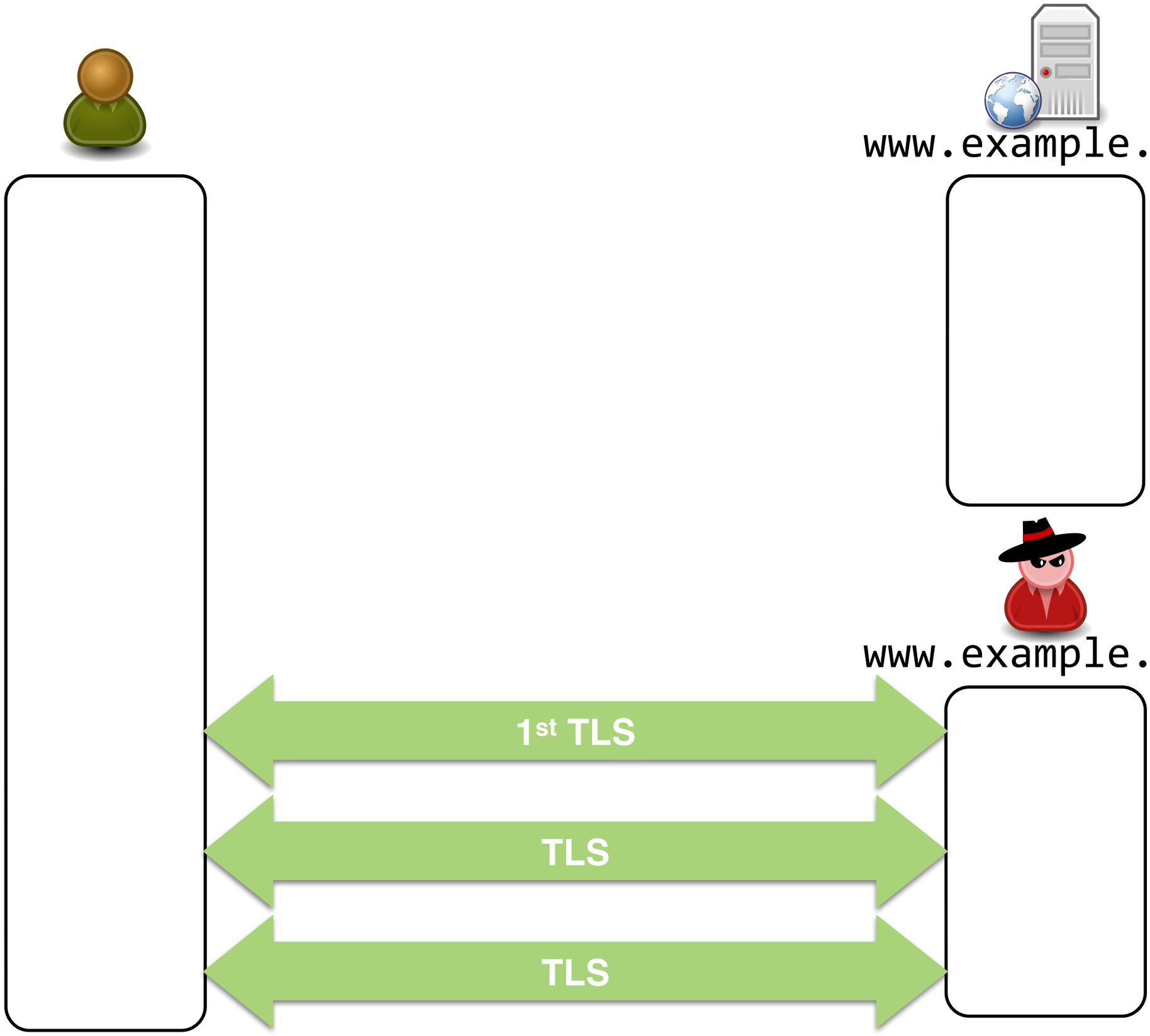

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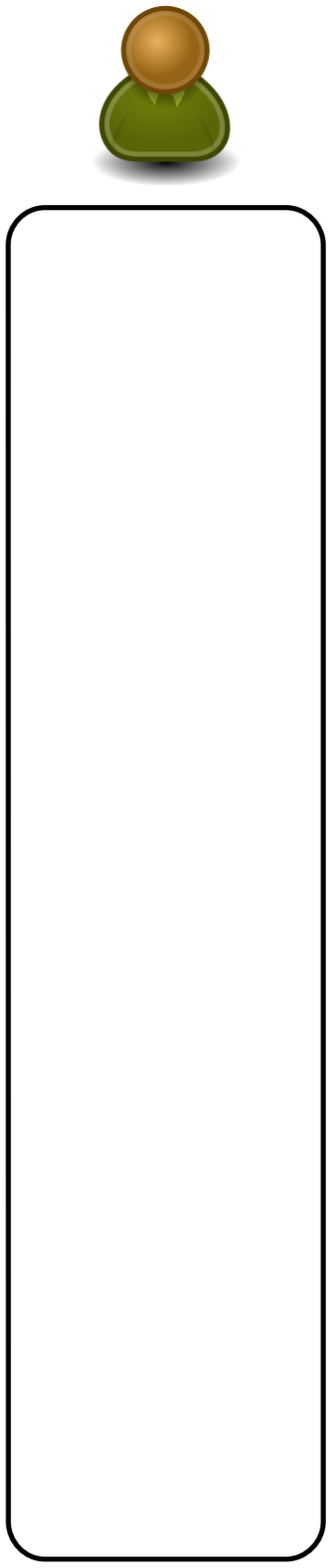
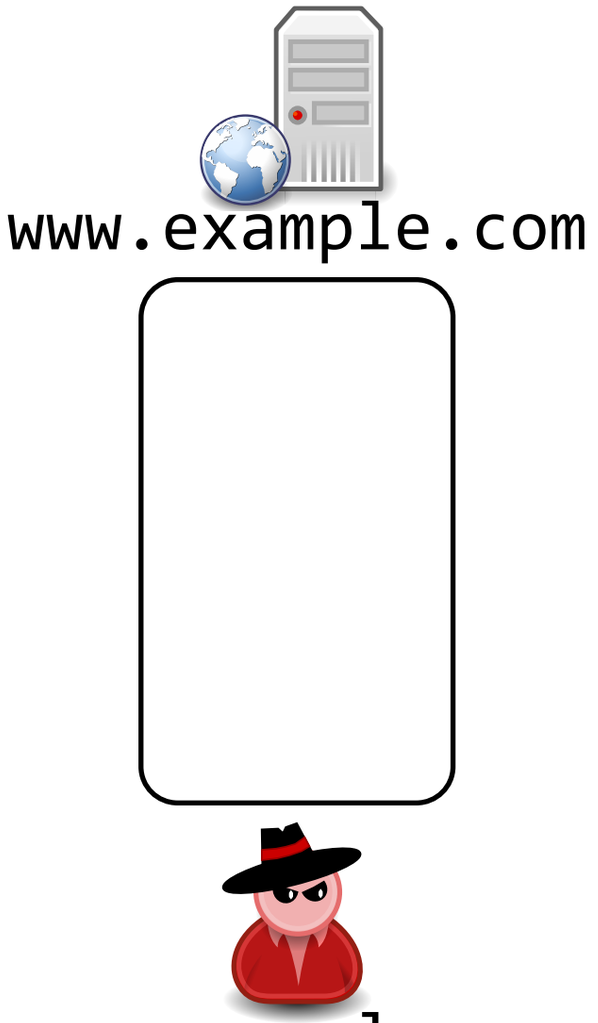
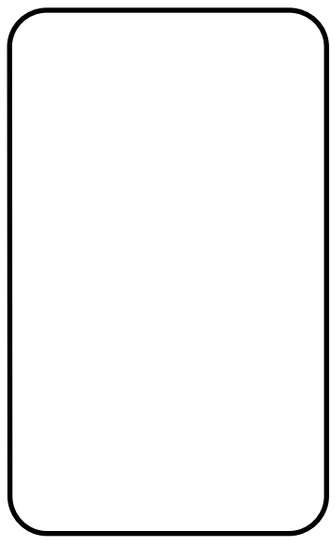






This Invariance is Enforced by the Browser

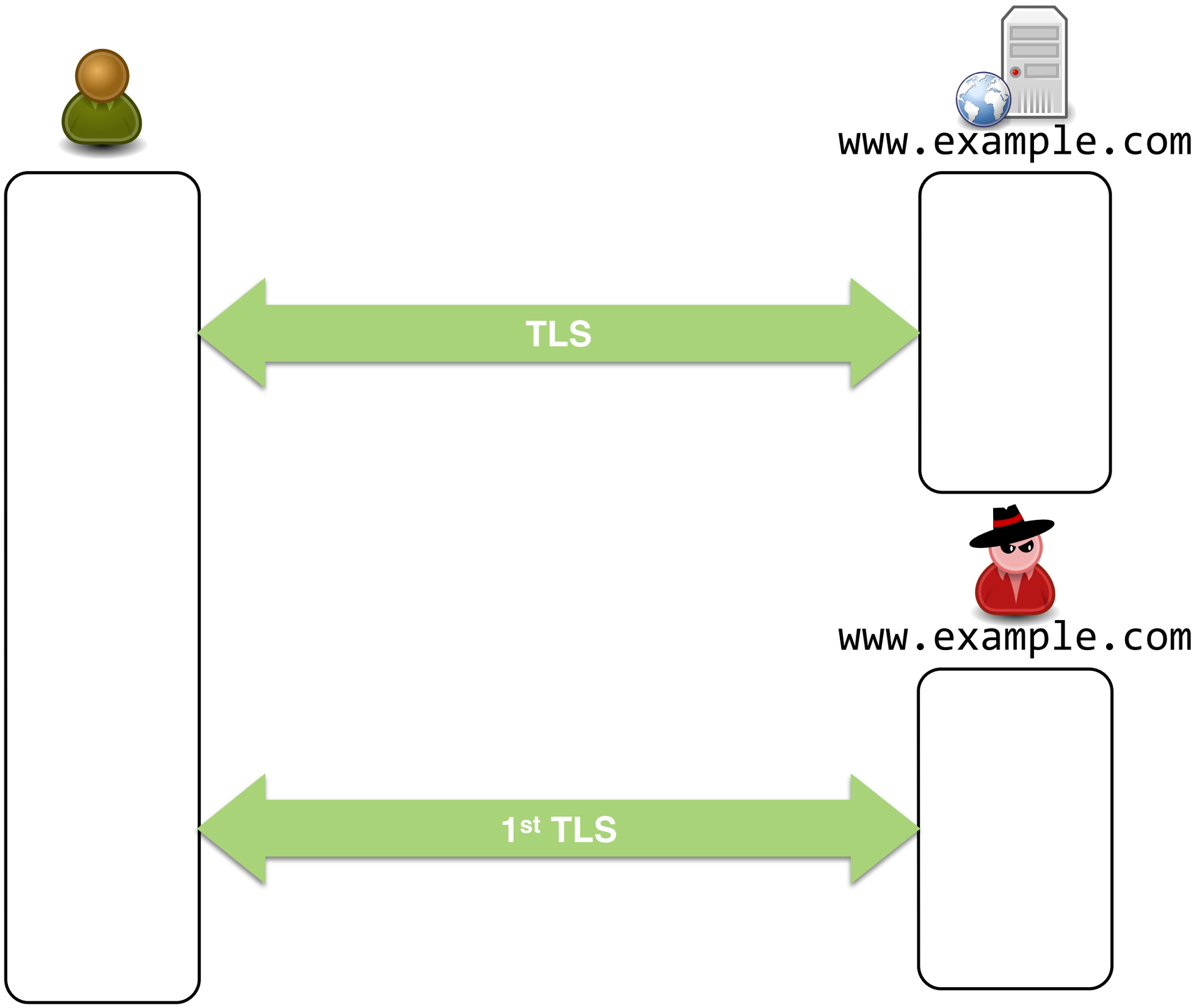
www.example.com

1st TLS

www.example.com

TLS

This Invariance is Enforced by the Browser



Example of Realizing Server Invariance

1. **Initialization (first connection)**
2. **Invariance verification**

www.example.com

Example of Realizing Server Invariance

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1. Initialization (first connection)
2. Invariance verification

www.example.com

1

r_b

store: $[r_b, r_s]$

TLS

‘Init’, r_b →

← r_s

r_s

store: [ , r_b, r_s]

Example of Realizing Server Invariance

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1. Initialization (first connection)
2. Invariance verification

www.example.com

r_b

store: $[r_b, r_s]$

1

r_s

store: [ , r_b, r_s]

‘Init’, r_b →

← r_s

TLS

2

‘Verify’, r_b →

$r_s \stackrel{?}{=} r'_s$

← r'_s

TLS

lookup: r'_s *from* [ , r_b]

TLS MITM prevention

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Weak client authentication + Server authentication

passwords, conventional HTTP cookies, OTP, …

certificate pinning, certificate transparency, …

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Strong client authentication + *Server invariance*

Channel ID-based (FIDO U2F, channel-bound cookies),…

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SISCA

Summary

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- In web, servers can ask clients to execute arbitrary code
  - needs to be taken into account in protocol and system analysis

- TLS Channel IDs vulnerable to MITM-SITB attacks

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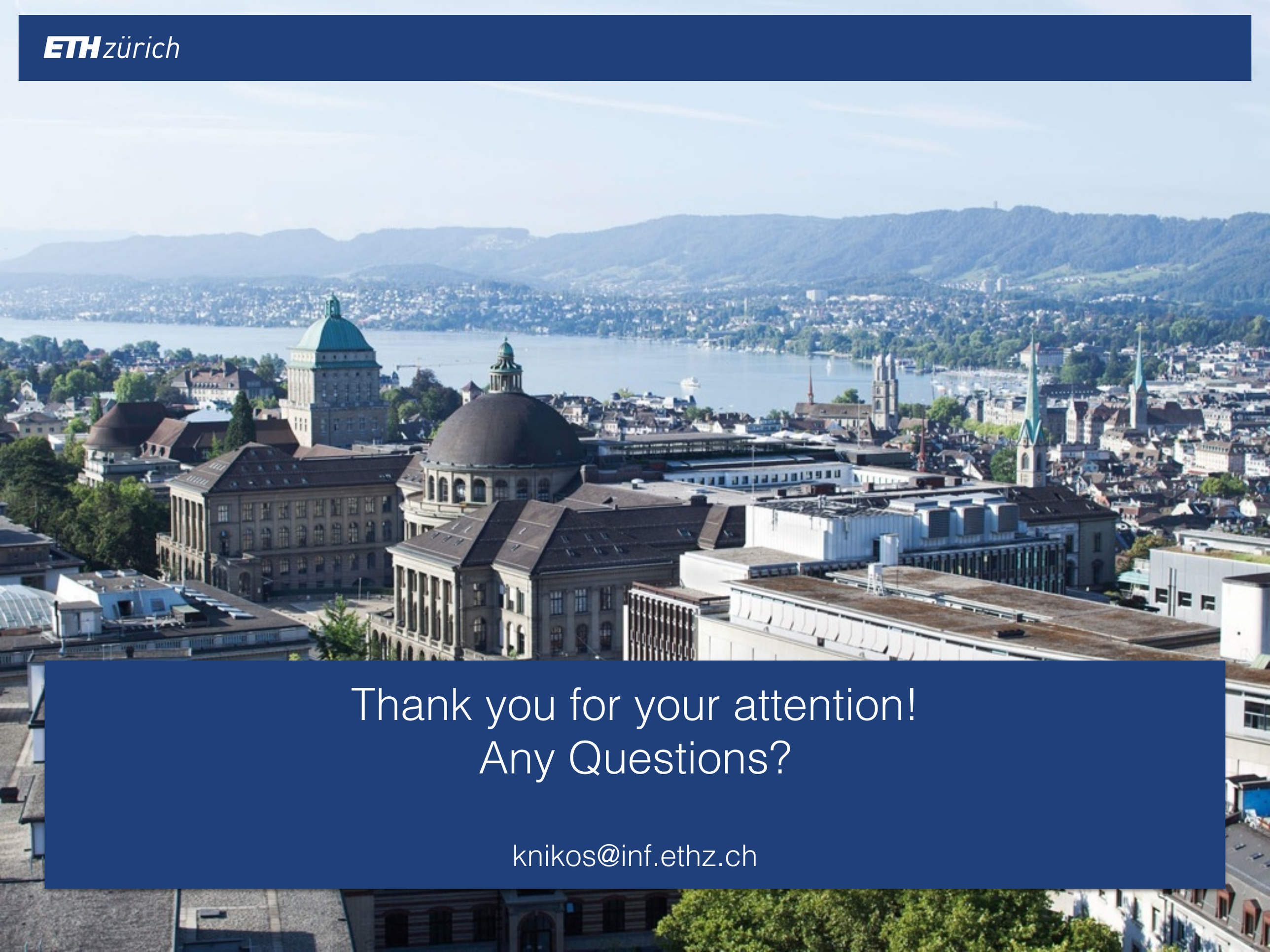
- In web, servers can ask clients to execute arbitrary code
  - needs to be taken into account in protocol and system analysis

- TLS Channel IDs vulnerable to MITM-SITB attacks

- To prevent MITM attacks we need either:
  - server authentication *or…*
  - **server invariance with Channel ID-based client authentication**

- Server invariance is easier to achieve than server authentication
  => we propose SISCA: Server Invariance with Strong Client Authentication



Thank you for your attention!
Any Questions?

knikos@inf.ethz.ch