Mind the Semantic Gap – Ausnutzung von Proxy, Cache und WAF für Angriffe auf Webanwendungen und Webservices

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31.05.2023, German OWASP Day 2023, Frankfurt

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Cybersicherheit DevSecOps Compliance

Technology
Arts Sciences
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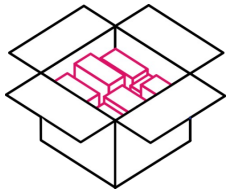

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Stille Post

Hoai Viet Nguyen und Niklas Henrichs

Mind the Semantic Gap – Nutzung von Proxy, Cache und WAF für Angriffe auf Webanwendungen und Webservices

Selektive Wahrnehmung

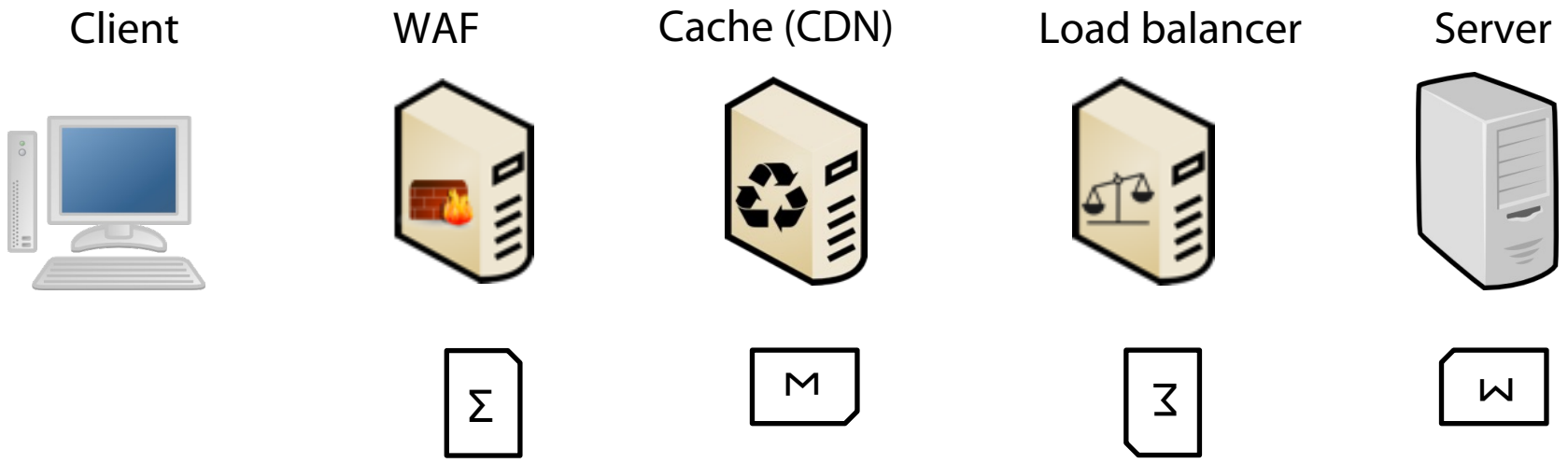
- Jeder Mensch hat unterschiedliche Wahrnehmungen
- Kulturbedingt
- Erfahrungsbedingt
- Sympathiebedingt – Halo-Effekt

Unterschiedliche Interpretation von HTTP Nachrichten [BNGL21]

- Implementierung der HTTP Engines
  - Implementierungsumgebung (Programmiersprachen, OS, Entwickler:innen)
  - Fehler in der Implementierung
  - Verantwortlichkeiten
- HTTP Versionen
  - HTTP/1.0, HTTP/1.1
  - HTTP/2
  - HTTP/3
- Interpretationsspielraum der RFCs

[BNGL21] A. Büttner, H. V. Nguyen, N. Gruschka, and L. Lo Iacono. Less is Often More: Header Whitelisting as Semantic Gap Mitigation in HTTP-Based Software Systems, IFIP SEC, 2021

Intermediäre Systeme (Middleboxes) [RFC3234]



Semantic gap: Difference in interpreting an object by two or more entities [Jana2012]

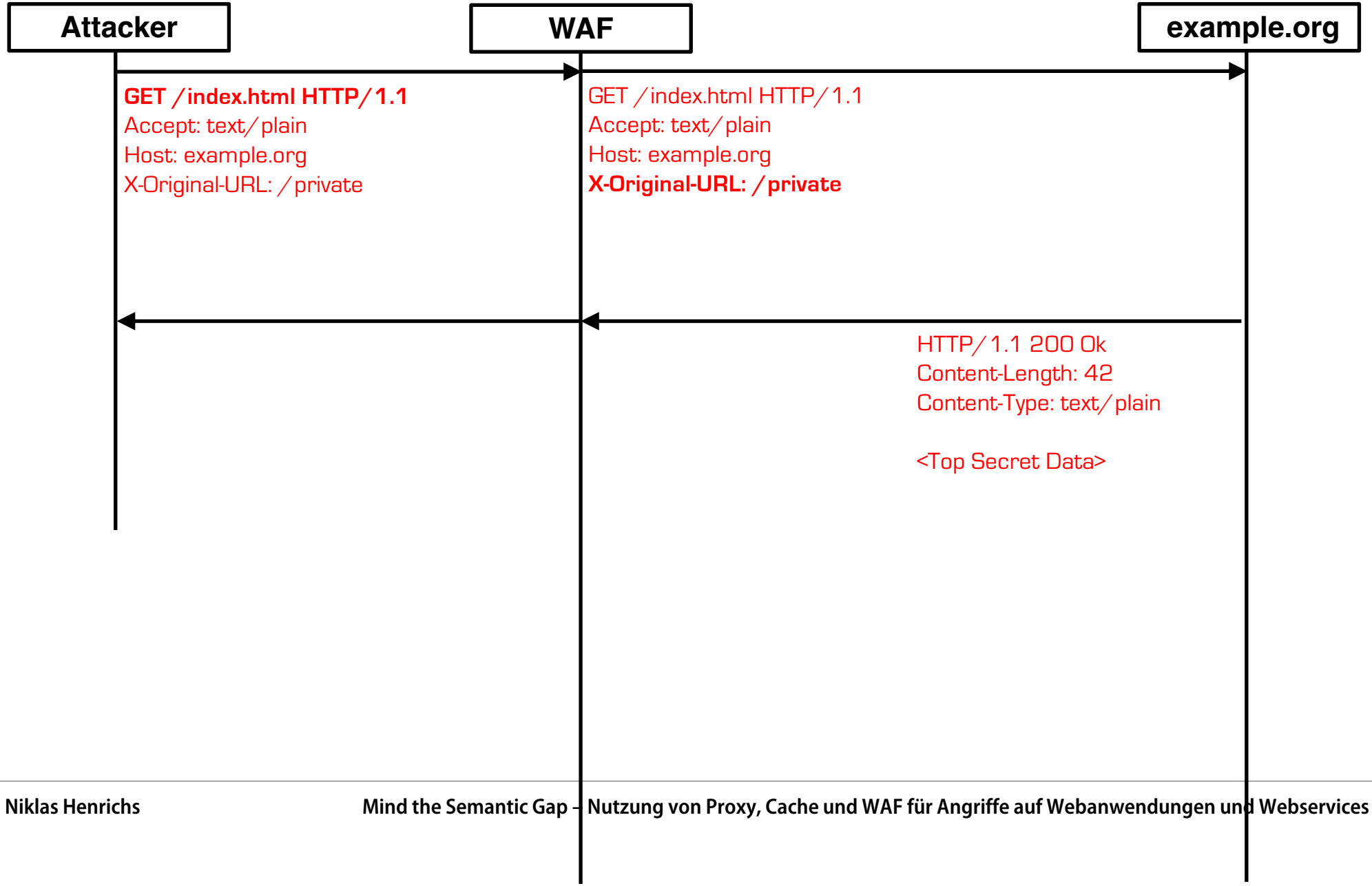
[RFC3234] B. Carpenter and S. Brim. Middleboxes: Taxomony and Issues, RFC 3234, URL: https://tools.ietf.org/html/rfc3234

[Jana2012] S. Jana and V. Shmatikov: „Abusing file processing in malware detectors for fun and profit“, 33rd IEEE Symposium on Security and Privacy, 2012

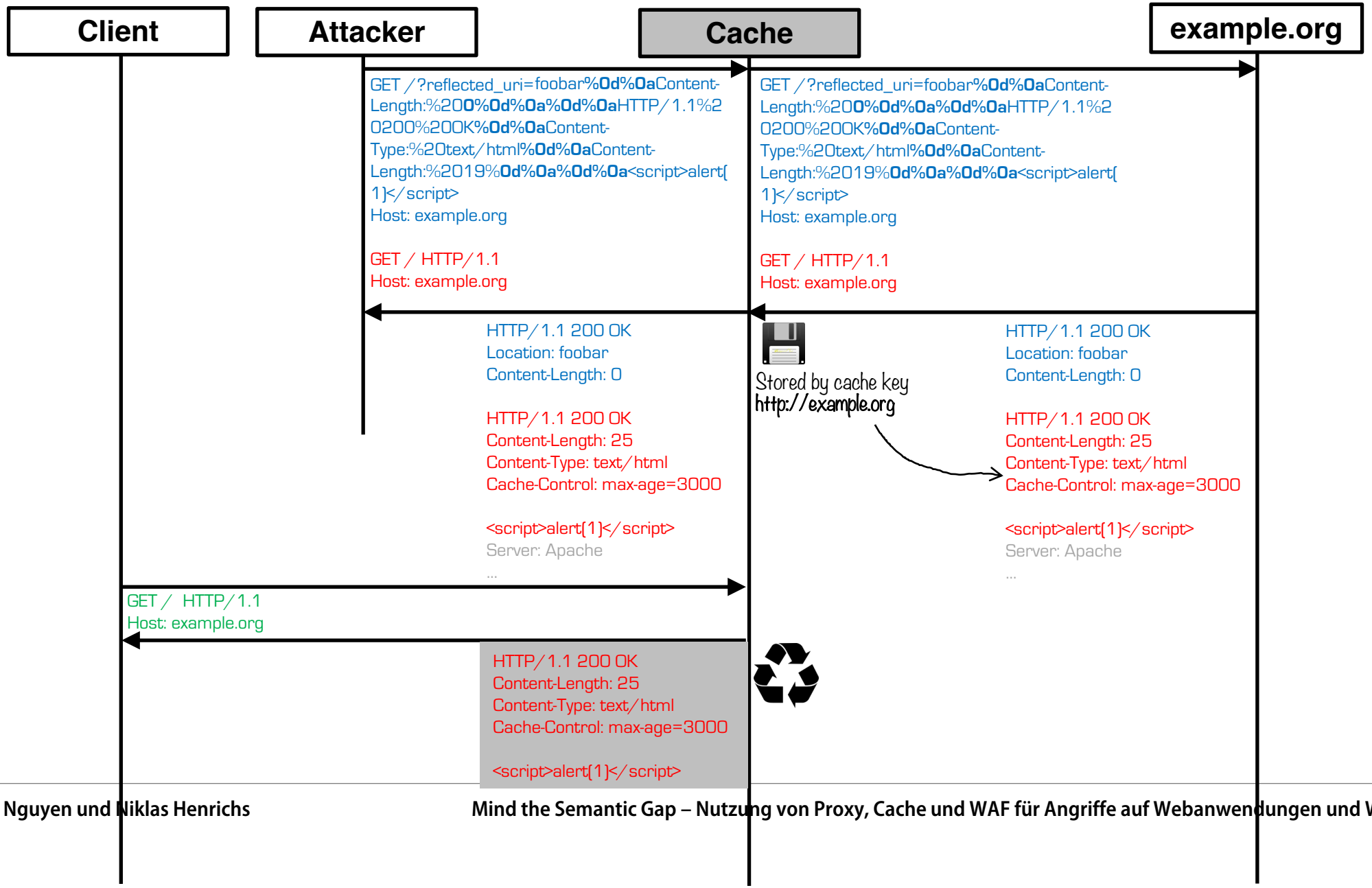
Bekannte Semantic Gap Risiken

- Cache poisoning
- Security control bypassing
- Request/Response desynchronisation
- Denial of Service (DoS)

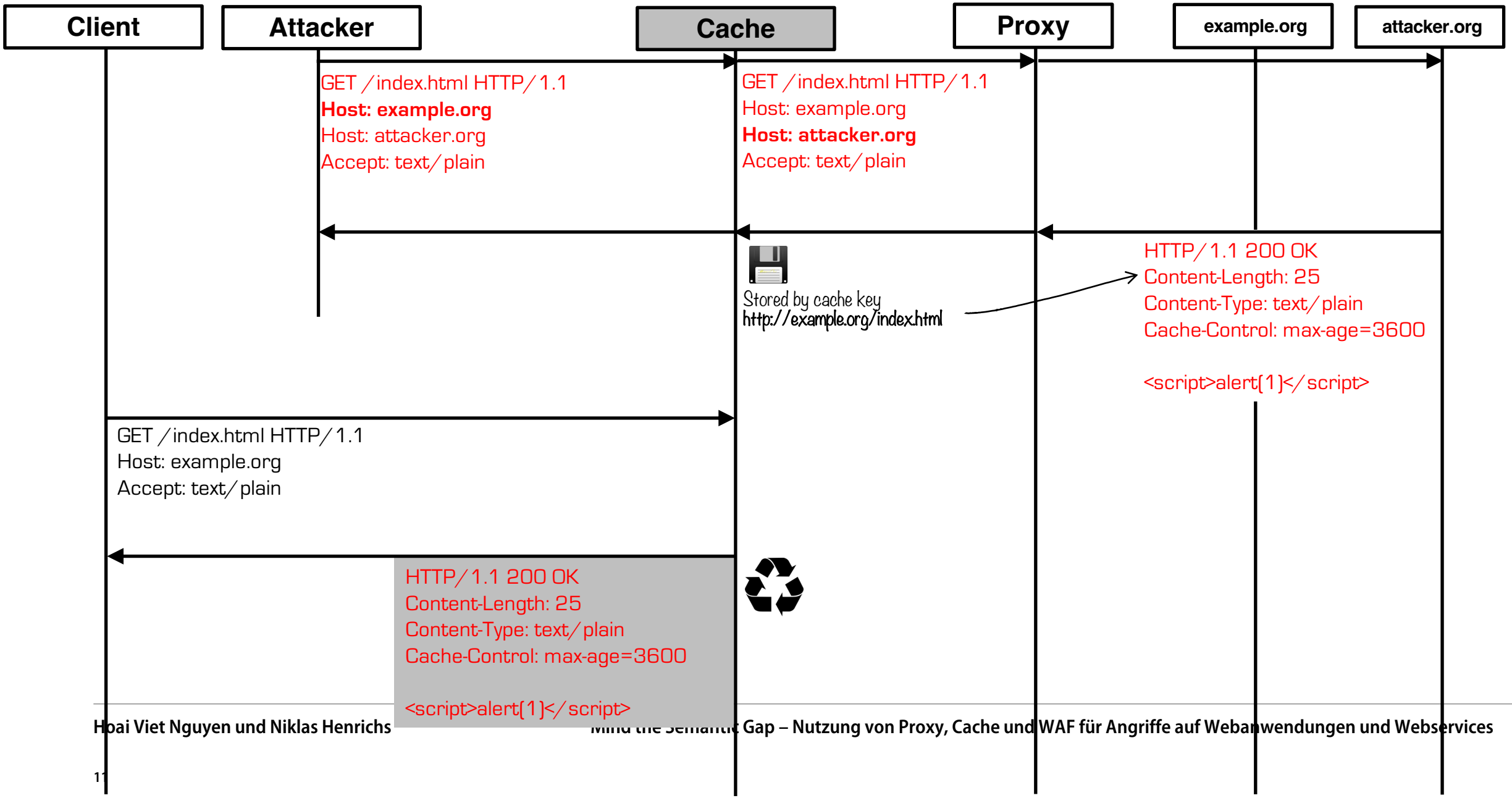
WAF bypassing mit X-Original-URL [Kettle2018]



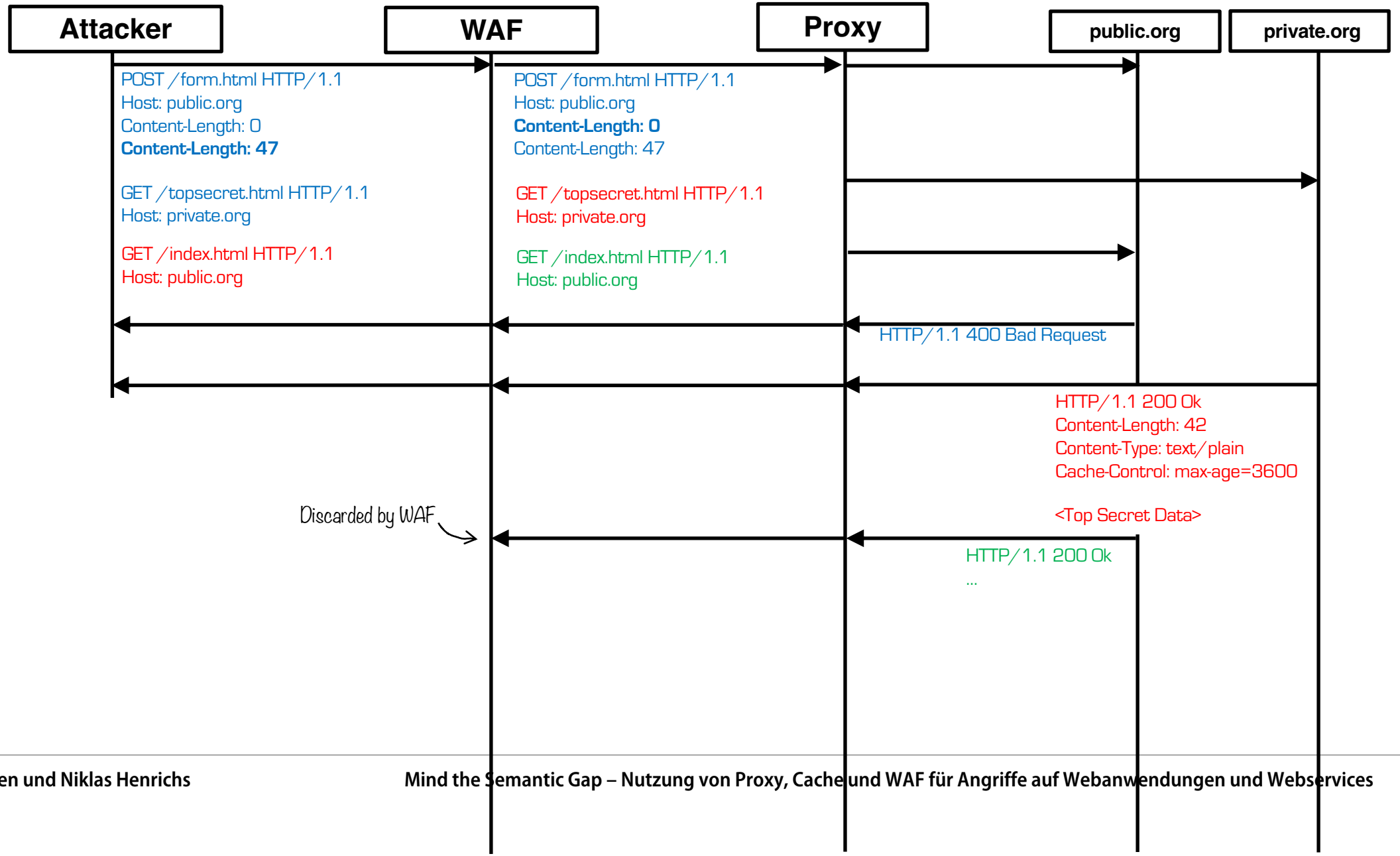
Response Splitting (Cache Poisoning) [Klein2004]



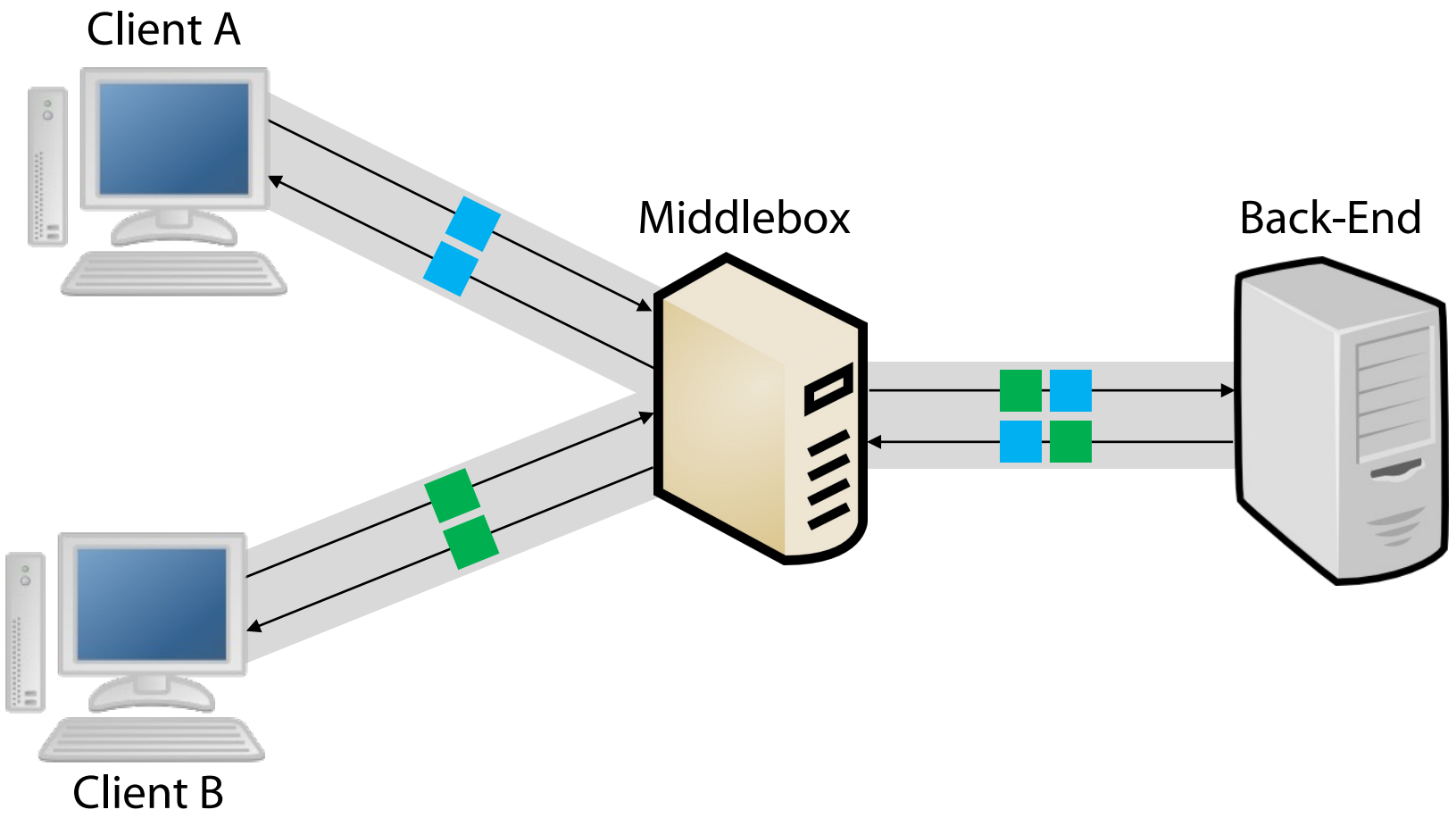
Host of Trouble (Cache Poisoning) [Chen2016]



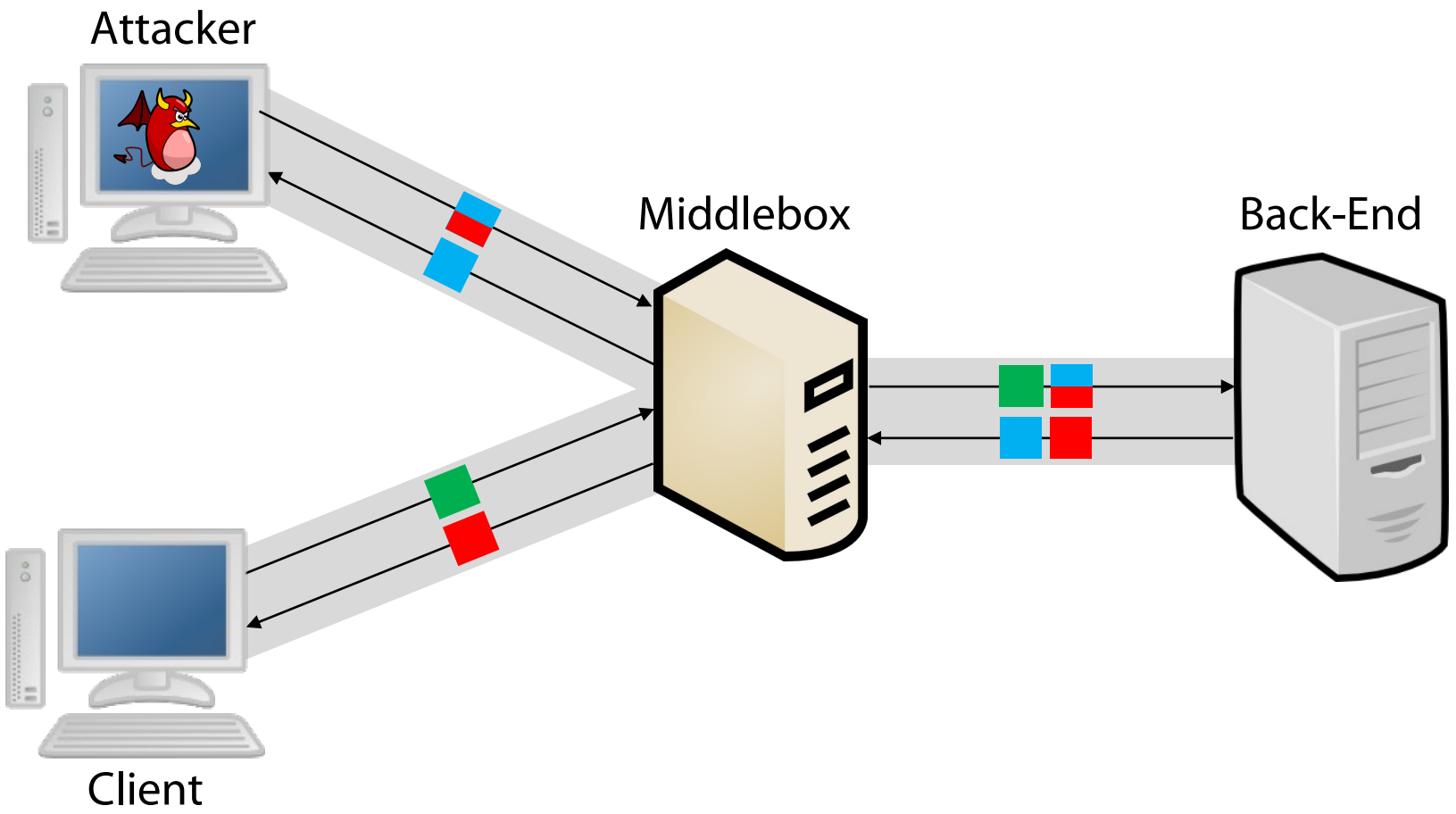
Request Smuggling (WAF Bypassing) [Linhart2005]



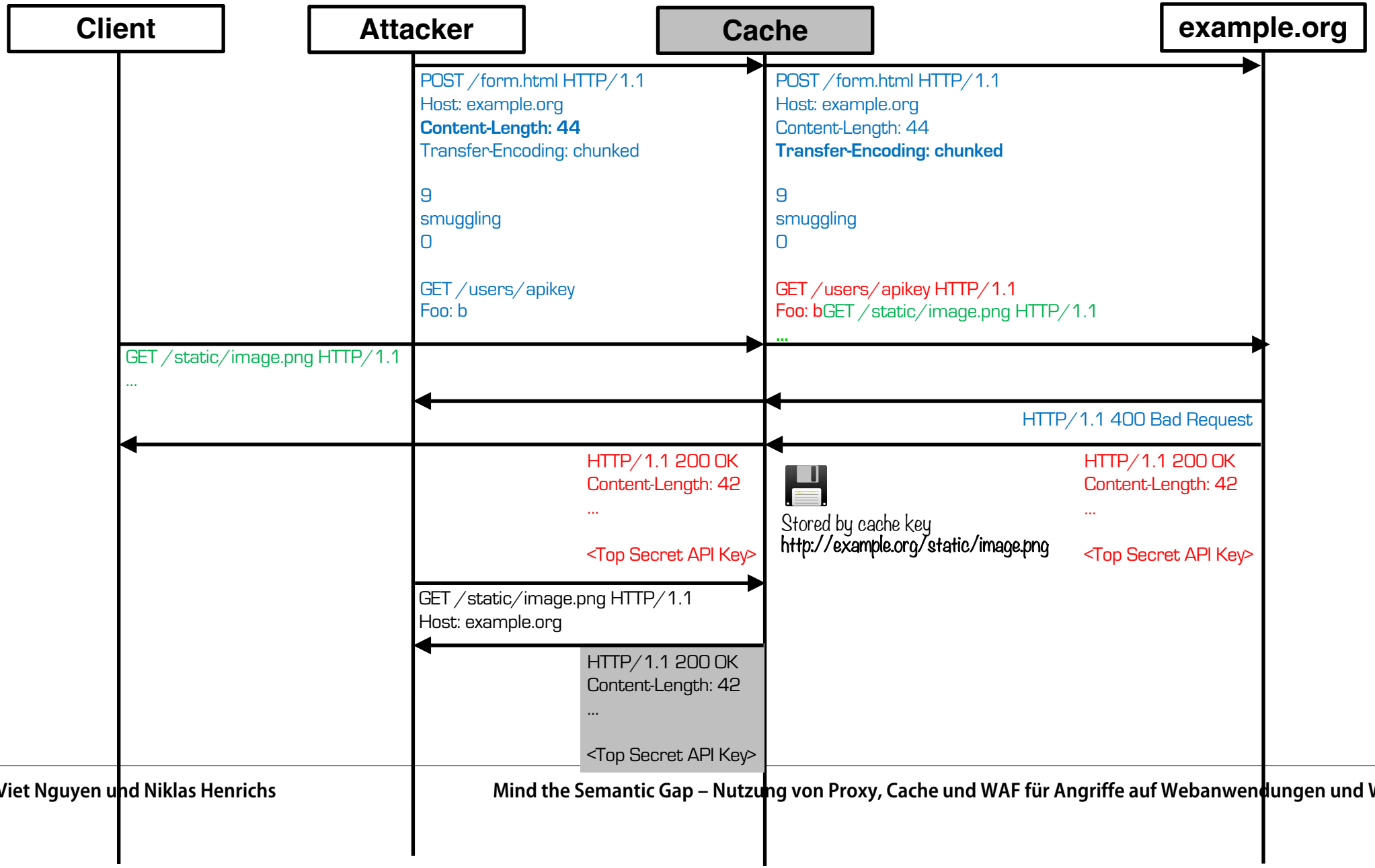
Mehrere Request über ein TCP Socket zum Back-End



HTTP Desynchronisation



Request Smuggling (Web Cache Deception) [Kettle2019]



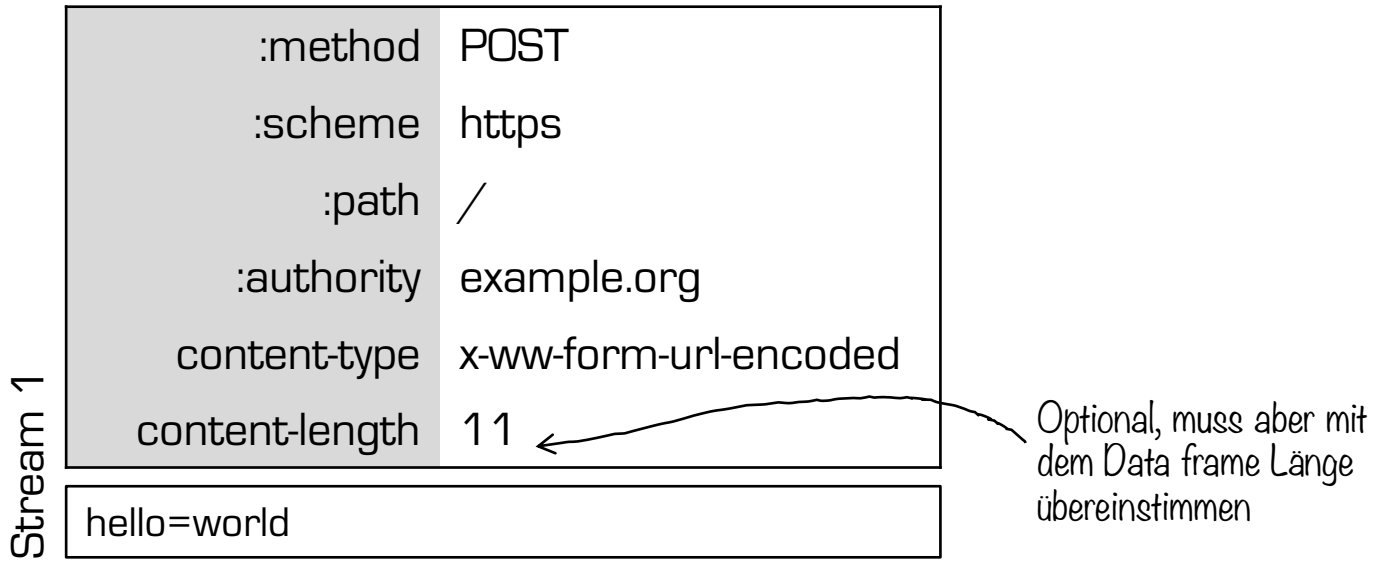
HTTP/2

- HTTP/2 ist ein binäres Protokoll
- HTTP Nachricht wird in Frames definiert
- Jeder Frame beinhaltet bestimmte Header
- Headerfelder u.a:
  - Length
  - Type
    - 0x01: HEADERS
    - 0x00: DATA
  - Stream
- HTTP/2 ändert nicht die Semantik von HTTP/1, sondern nur das Encoding

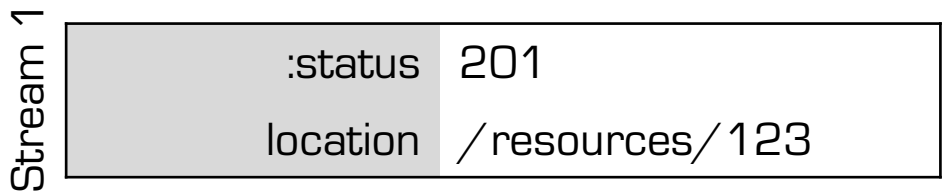
Nachrichtenlänge mit diesem Headerfeld definiert und nicht durch Content-Length oder Transfer-Enconding

HTTP/1.1 vs HTTP/2

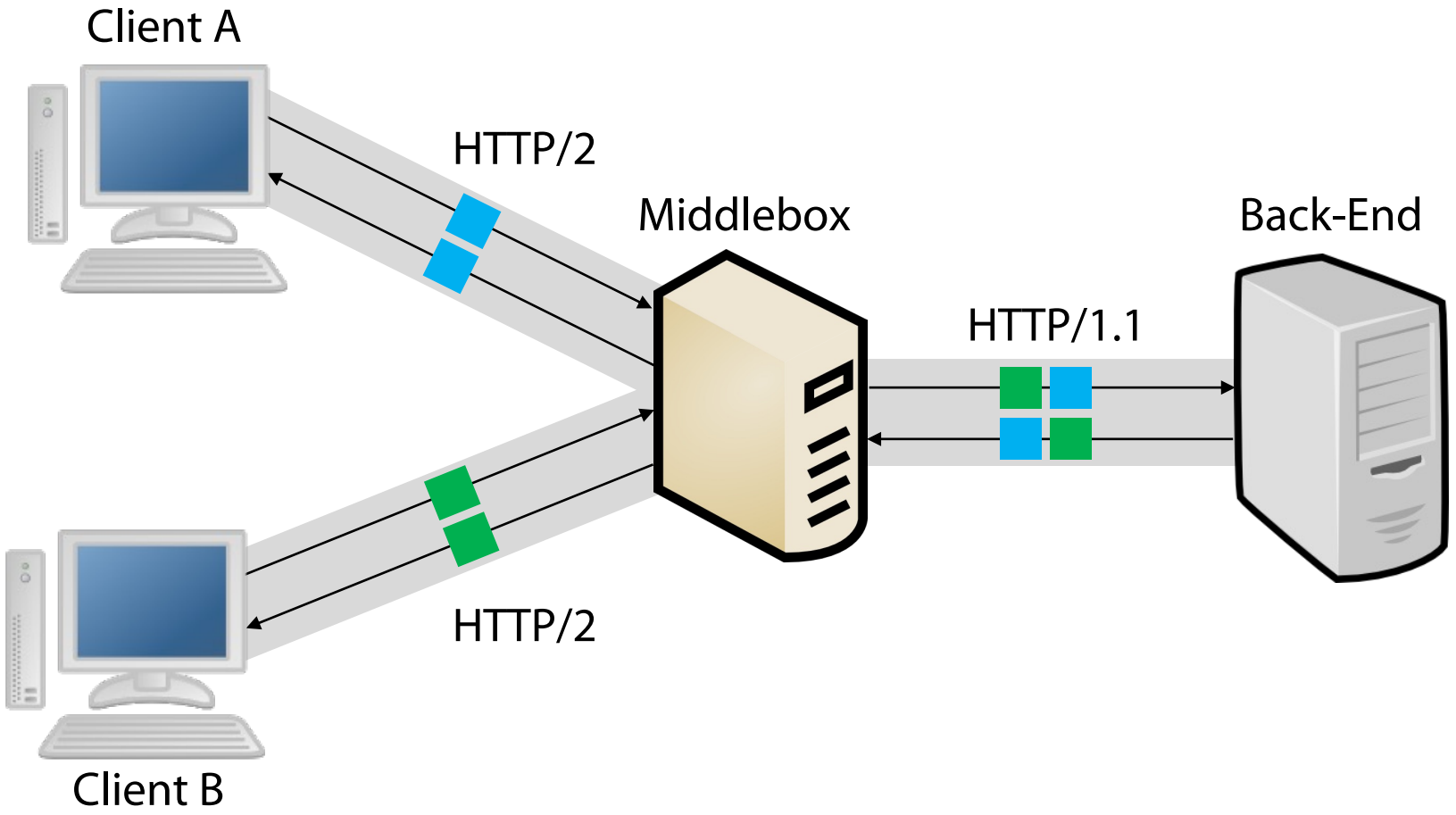
```
POST / HTTP/1.1
Host: example.org
Content-Type: x-www-form-urlencoded
Content-Length: 11

hello=world
```



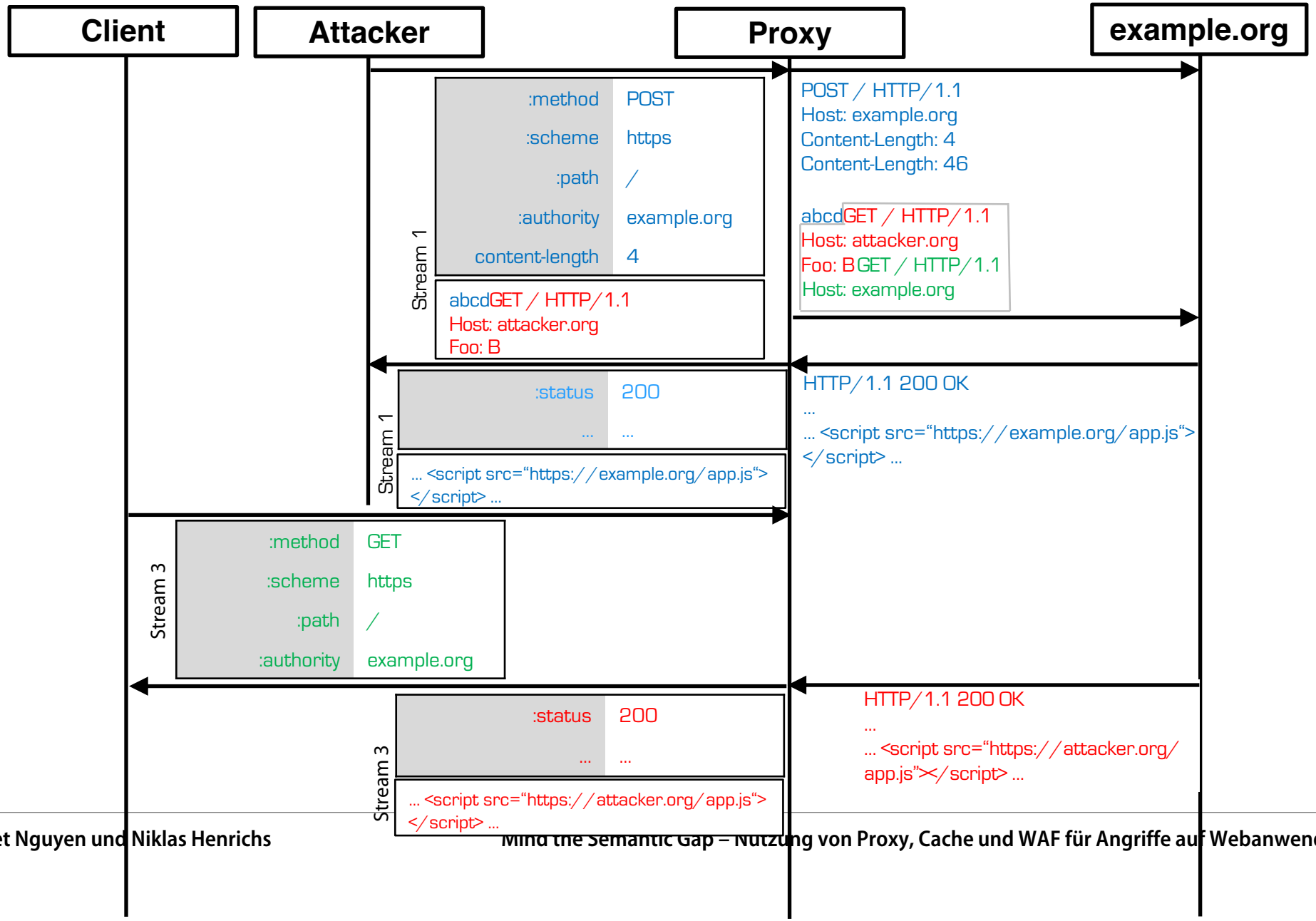

```
HTTP/1.1 201 Created
Location: /resources/123
```



HTTP/2 zu HTTP/1.1



Request Smuggling (Response Poisoning) [Kettle2022]



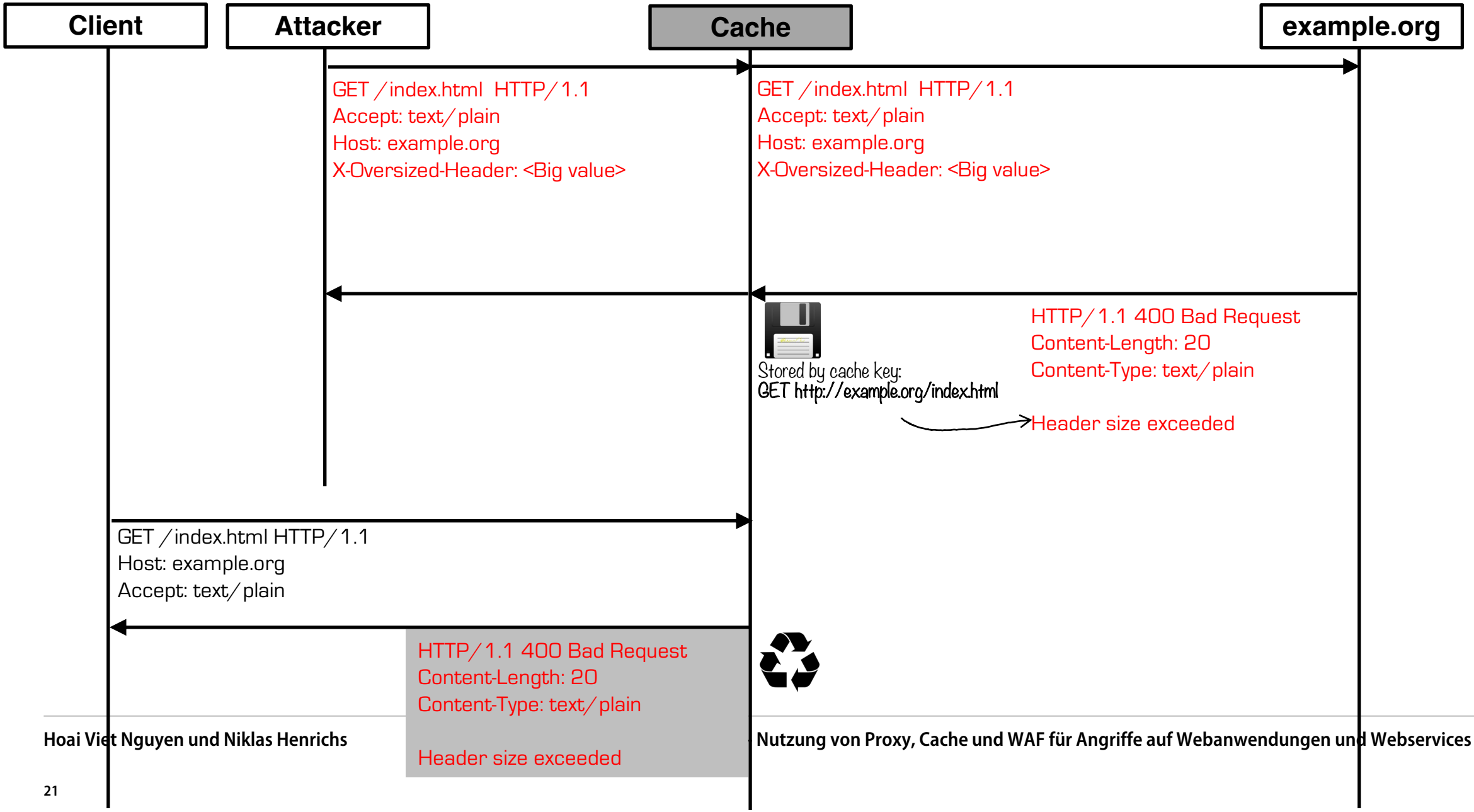
Empfehlung von RFCs und OWASP [RFC7230] [OWASPTOP10]

- Eingabevalidierung
- Blocken von doppelten Headern
- Blocken von Metacharactern
- Blocken von zu großen Header
- …

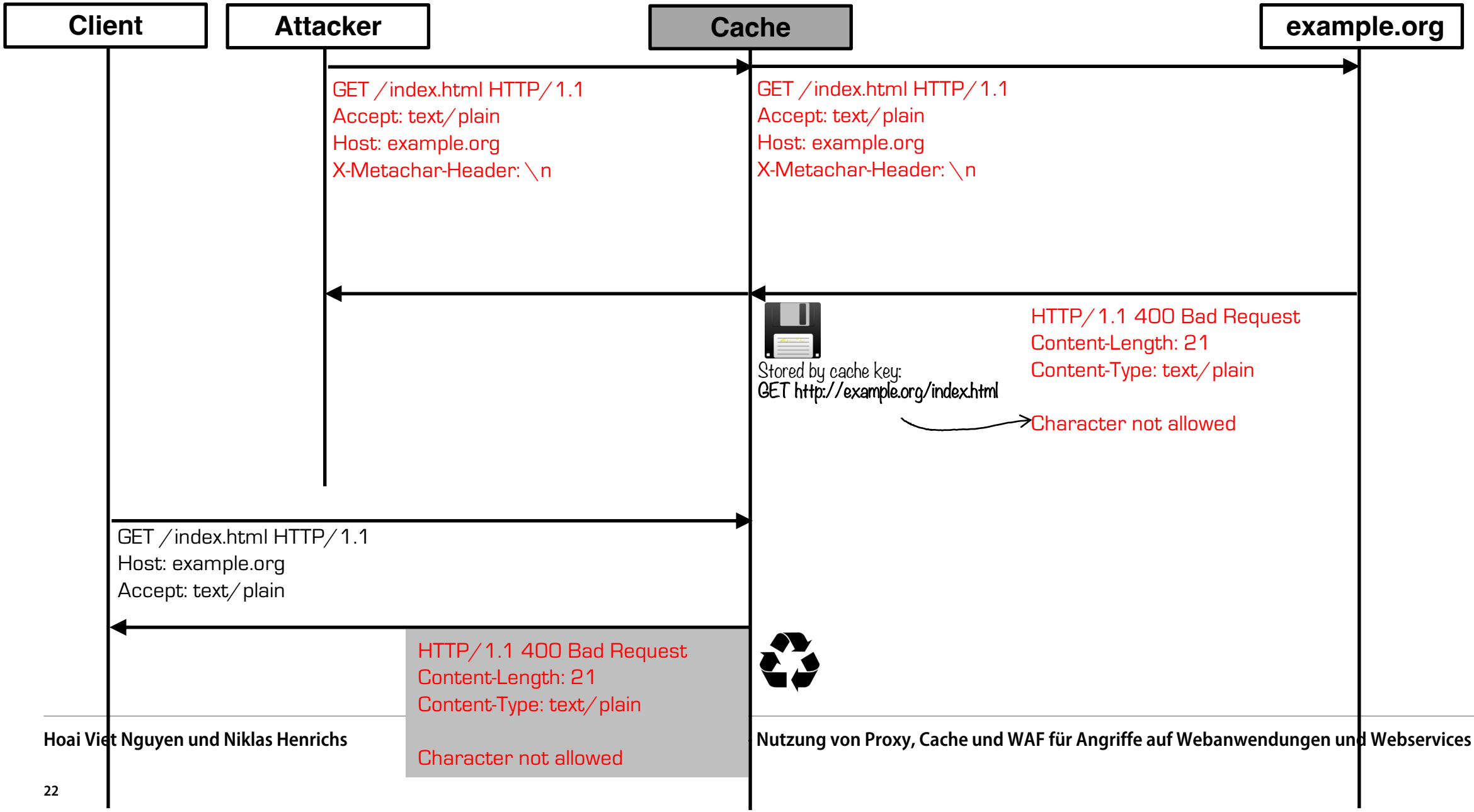
[RFC7230] R. Fielding and J. Reschke: "Hypertext Transfer Protocol (HTTP/1.1): Message Syntax and Routing", RFC 7230, IETF, 2014. https://tools.ietf.org/ html/rfc7230.

[OWASPTOP10] OWASP: "OWASP TOP 10", 2021. https://owasp.org/Top10/

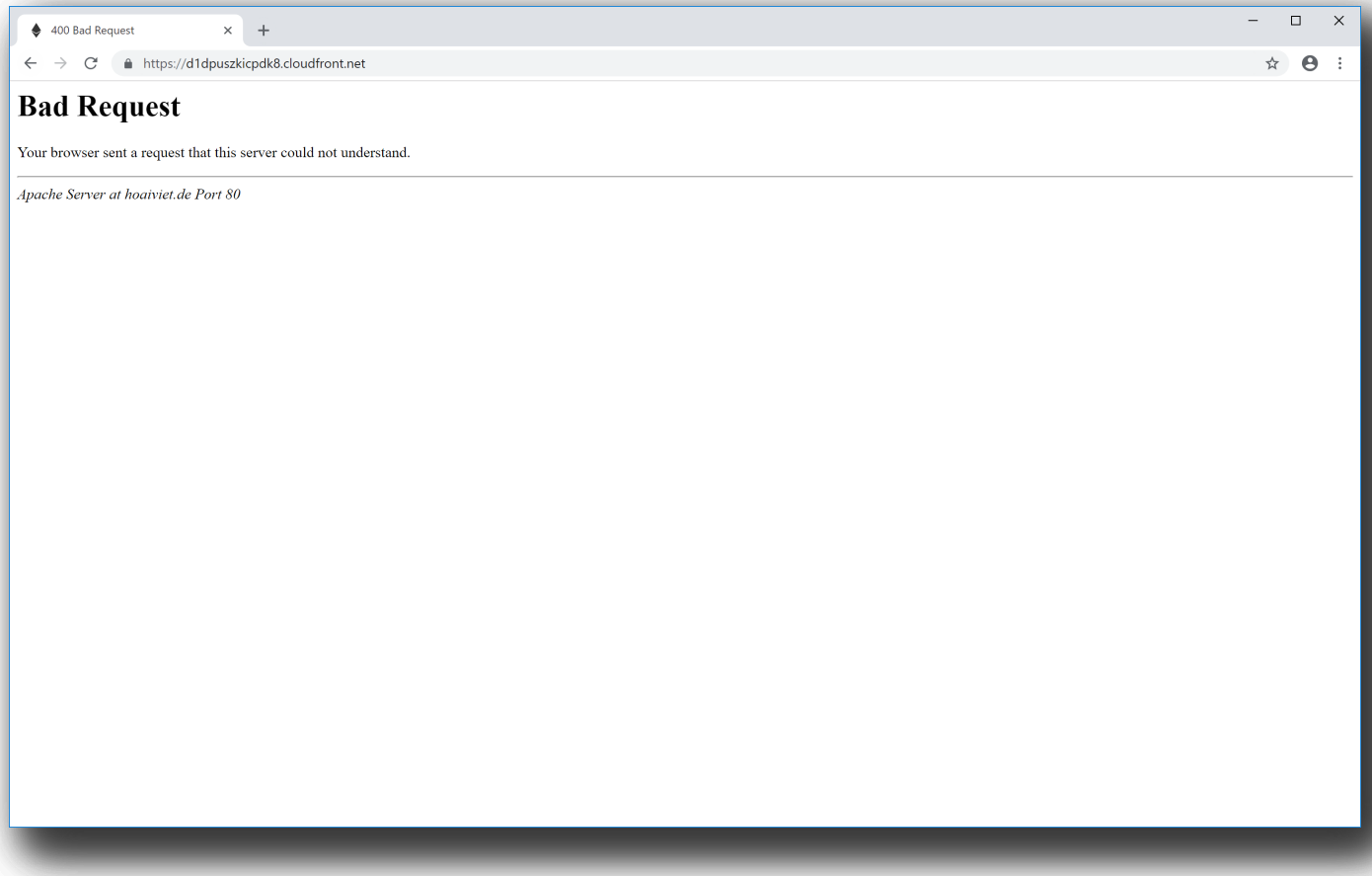
CPDoS HTTP Header-Oversize Attack (HHO) [Nguyen2019]



CPDoS HTTP Meta Character Attack (HMC) [Nguyen2019]



HHO CPDoS-Angriff on ethereum.org



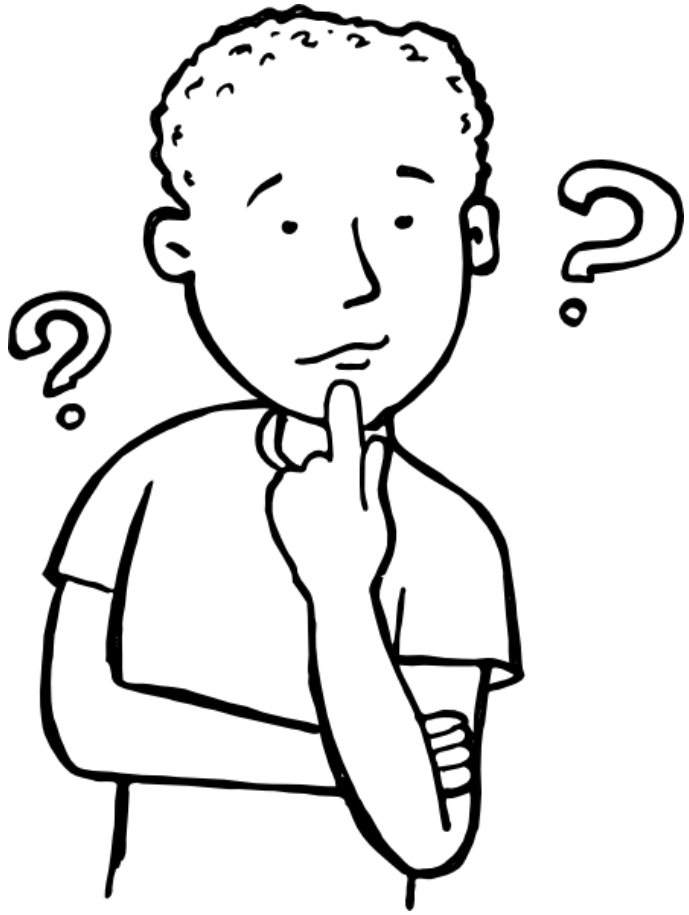
Weitere Arbeiten im Bereich Semantic Gap (Ausschnitt)

- Practical Web Cache Poisoning Attacks, Blackhat, https://portswigger.net/blog/practical-web-cache-poisoning
- HTTP Desync Attacks: Request Smuggling Reborn, https://portswigger.net/research/http-desync-attacks-request-smuggling-reborn
- HTTP/2: The Sequel is Always Worse, https://portswigger.net/research/http2
- Browser-Powered Desync Attacks: A New Frontier in HTTP Request Smuggling, https://portswigger.net/research/browser-powered-desync-attacks
- How an Akamai misconfiguration earned us USD 46.000, https://blog.hacktivesecurity.com/index.php/2022/09/17/http/
- FRAMESHIFTER: Security Implications of HTTP/2-to-HTTP/1 Conversion Anomalies, https://www.usenix.org/system/files/sec22-jabiyev.pdf
- HDiff: A Semi-automatic Framework for Discovering Semantic Gap Attack in HTTP Implementations, https://www.jianjunchen.com/p/hdiff.dsn22.pdf

Andere CPDoS-Varianten (Ausschnitt)

- Responsible denial of service with web cache poisoning, https://portswigger.net/research/responsible-denial-of-service-with-web-cache-poisoning
- Bypassing Web Cache Poisoning Countermeasures, https://portswigger.net/research/bypassing-web-cache-poisoning-countermeasures
- Practical Web Cache Poisoning Attacks, Blackhat, https://portswigger.net/blog/practical-web-cache-poisoning
- CORS'ing a Denial of Service via cache poisoning, https://nathandavison.com/blog/corsing-a-denial-of-service-via-cache-poisoning
- Abusing HTTP hop-by-hop request headers, https://nathandavison.com/blog/abusing-http-hop-by-hop-request-headers
- Cache-Key Normalization - What could go wrong?, https://iustin24.github.io/Cache-Key-Normalization-Denial-of-Service/

Was kann ich gegen Semantic Gap Angriffe tuen?



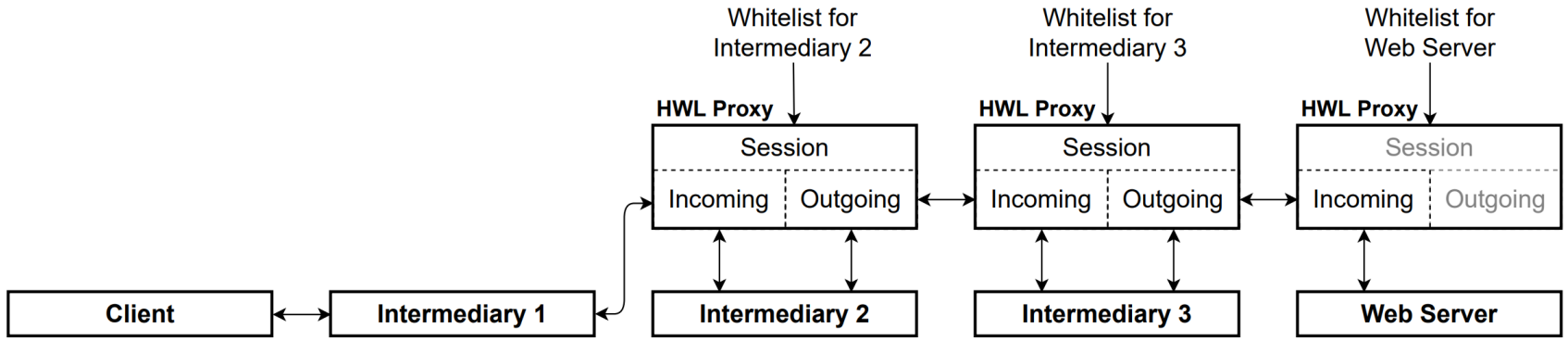
Compliance mit Standards

- Semantic Gap Schwachstellen resultieren durch Missachtung der RFCs
  - Doppelte Header
  - Caching von unerlaubten Status Codes
  - Fehlende Prüfung von Längen Header
- Prüfung auf Einhaltung der Standards
- Tools
  - Cache Testing Tool [NLF19]
  - Cache Tests von Mark Nottingham, https://cache-tests.fyi/

Whitelisting [BNGL21]

- Nur erlaubte Header werden akzeptiert
- Alle anderen Header werden gefiltert

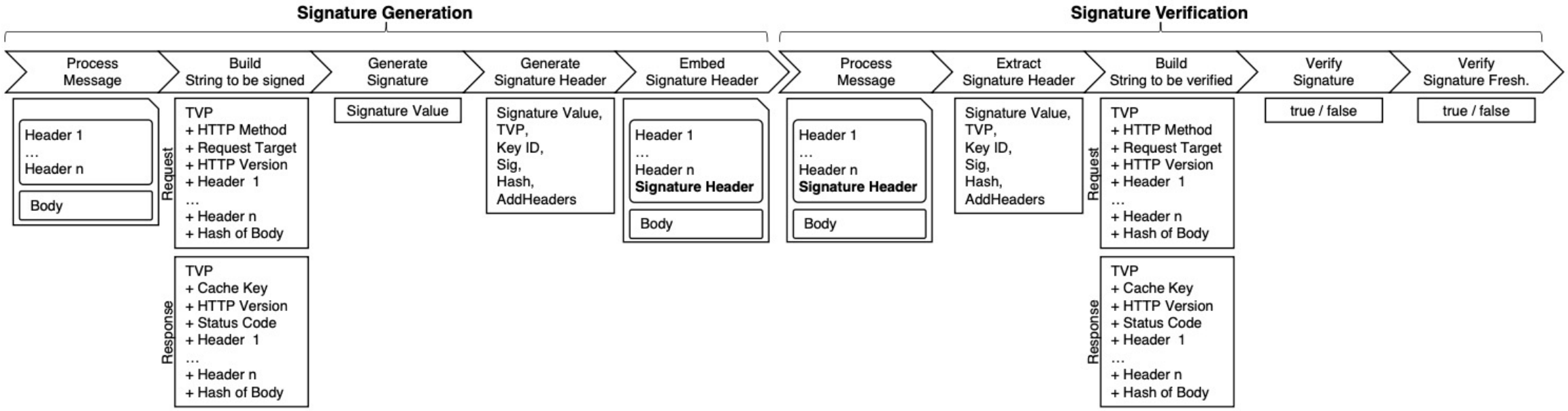
```
[
    {"key": "host"},
    {"key": "connection", "val": "(close|keep-alive)"},
    {"key": "content-length", "val": "\\d+"}
]
```



[BNGL21] A. Büttner, H. V. Nguyen, N. Gruschka, and L. Lo Iacono. Less is Often More: Header Whitelisting as Semantic Gap Mitigation in HTTP-Based Software Systems, IFIP SEC, 2021

HTTP Signaturen [Nguyen2020]

- Signatur der HTTP Nachrichten
- Prüfung der Response Signatur erkennt Cache Poisoning und Desyncronisation



[Nguyen2020] H. V. Nguyen and L. Lo Iacono. CREHMA: Cache-ware REST-ful Authentication Scheme, CODASPY, 2020

Weitere Gegenmaßnahmen

- DevSecOps
- Security Assessments in gleicher Umgebung wie Produktion
- Konsistente Verwendung von HTTP Versionen

Takeaways

- **Semantic Gap in verteilten Systemen wohl nicht vermeidbar**
- **Prognose: Mehr Semantic Gap Schwachstellen werden auftauchen**
- **Weitere Forschungsarbeiten sind notwendig**
  - Schwachstellen in HTTP Implementierungen
  - Parsing von Nachrichten
  - Gegenmaßnahmen

Referenzen

[BNGL21] A. Büttner, H. V. Nguyen, N. Gruschka, and L. Lo Iacono. Less is Often More: Header Whitelisting as Semantic Gap Mitigation in HTTP-Based Software Systems, IFIP SEC, 2021

[Chen2016] J. Chen, J. Jiang, H. Duan, N. Weaver, T. Wan, and V. Paxson, Host of Troubles: Multiple Host Ambiguities in HTTP Implementations, 23th ACM SIGSAC Conference on Computer and Communications Security (CCS), 2016

[Jana2012] S. Jana and V. Shmatikov, Abusing file processing in malware detectors for fun and profit, 33rd IEEE Symposium on Security and Privacy, 2012

[Kettle2018] J. Kettle, Practical Web Cache Poisoning Attacks, Blackhat, 2018. https://portswigger.net/blog/practical-web-cache-poisoning

[Kettle2019] J. Kettle, HTTP Desync Attacks: Request Smuggling Reborn, DEF CON 27, 2019, https://portswigger.net/research/http-desync-attacks-request-smuggling-reborn

[Kettle2021] J. Kettle, HTTP/2: The Sqeuel is Always Worse, Blackhat USA, 2021, https://portswigger.net/research/http2

[Klein2004] A. Klein, Divide and Conquer – HTTP Response Splitting Whitepaper, 2004

[Linhart2005] C. Linhart, A. Klein, R. Heled, and S. ORRIN, Http Request Smuggling, 2005, http://www.cgisecurity.com/lib/ HTTP-Request-Smuggling.pdf

[Nguyen2019] H. V. Nguyen, L. Lo Iacono, and H. Federrath, Your Cache has Fallen: Cache-Poisoned Denial-of-Service Attacks, 26th ACM SIGSAC Conference on Computer and Communications Security (CCS), 2019

[Nguyen2020] H. V. Nguyen and L. Lo Iacono. CREHMA: Cache-ware REST-ful Authentication Scheme, CODASPY, 2020

[NLF19] H. V. Nguyen, L. Lo Iacono, and H. Federrath. Mind the Cache: Large-Scale Analysis of Web Caching. In: 34rd ACM/SIGAPP Symposium on Applied Computing (SAC), 2019.

Danke für Aufmerksamkeit

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