Compression Bombs Strike Back

Giancarlo Pellegrino
gpellegrino@mmci.uni-saarland.de

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OWASP
The Open Web Application Security Project

About Me

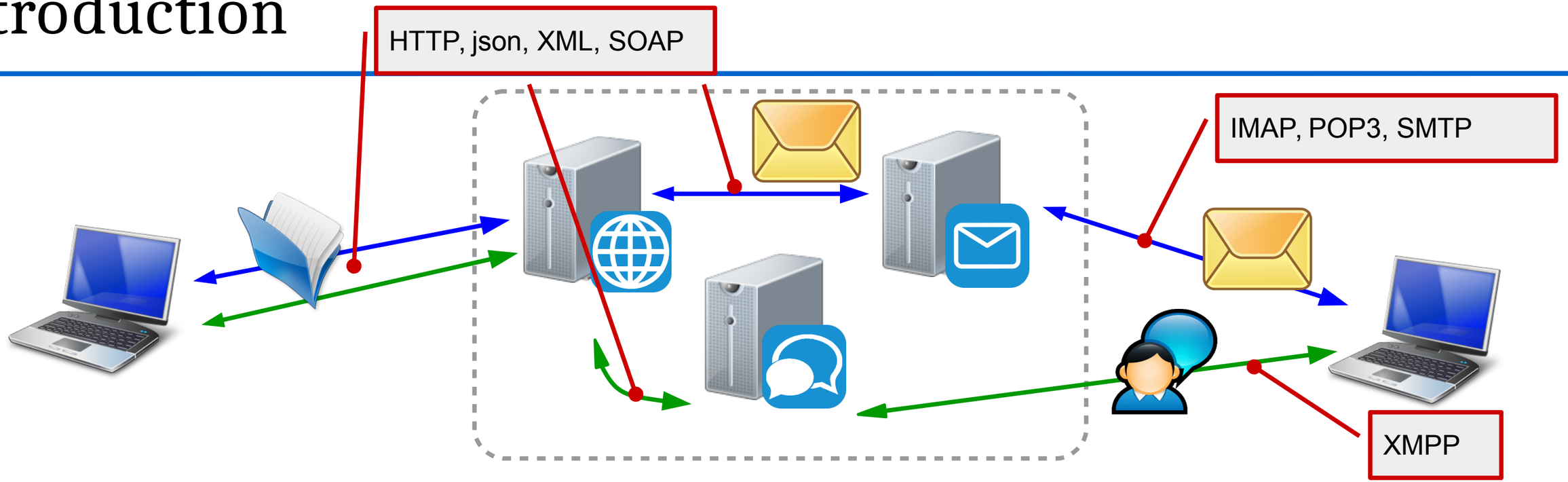
- Post doctoral researcher of the System Security group at CISPA, Saarland University, Germany
- Research focus:
  - Web application security / security protocols
  - Vulnerability detection (logic vulns, Server-Side Requests Abuses, CSRF)

CISPA
Center for IT-Security, Privacy and Accountability

UNIVERSITÄT DES SAARLANDES

- Former member of S3 group at EURECOM, Sophia-Antipolis, France
- Former research associate in the Security & Trust research group at SAP SE

Introduction



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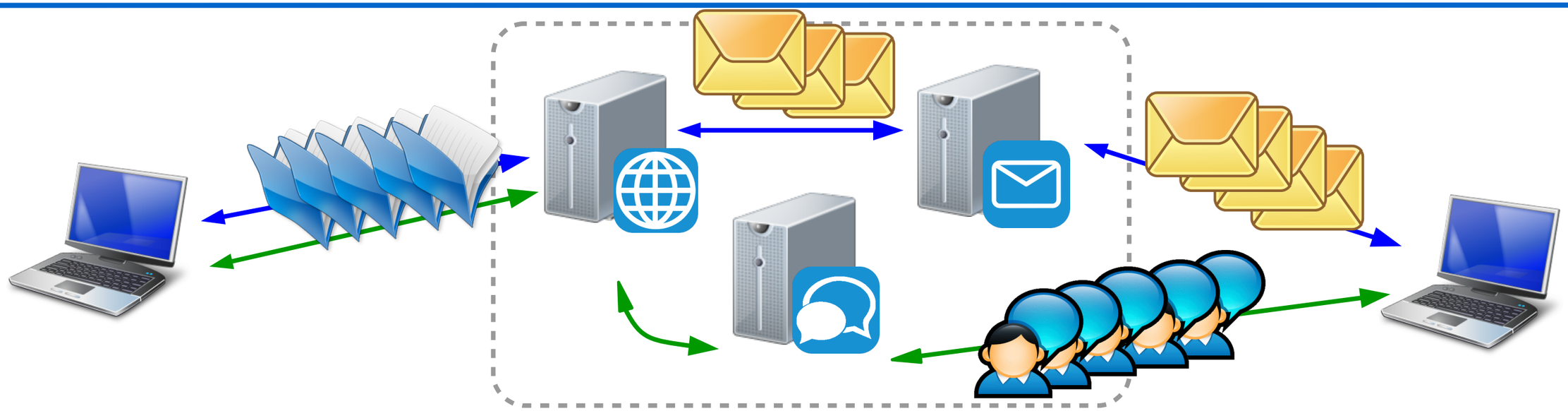

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  - More data → more transfer time → unresponsiveness → user unhappiness

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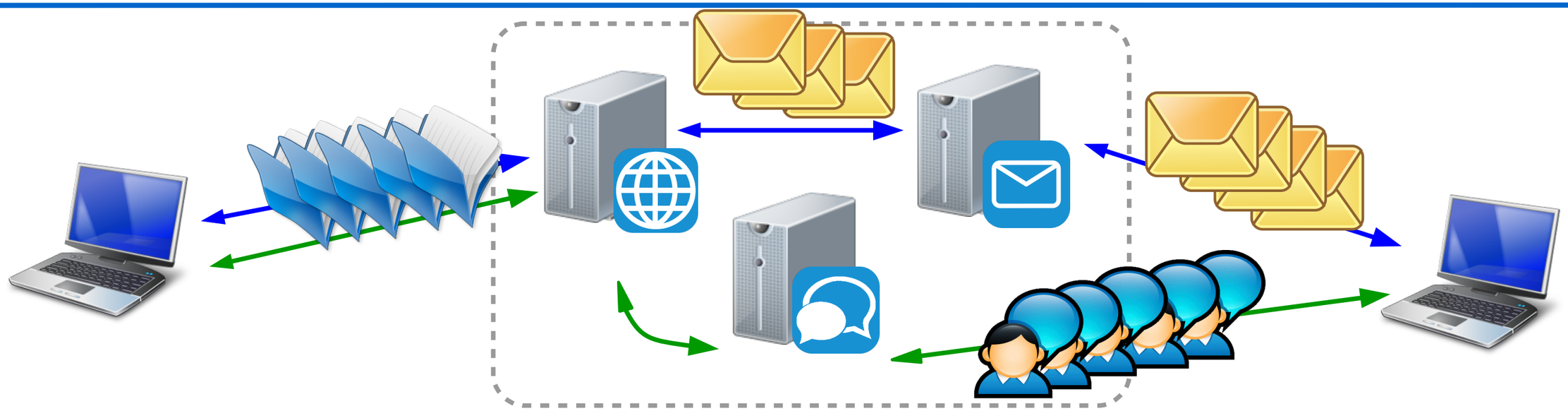

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- Amount of exchanged data continues to increase steadily
  - More data → more transfer time → unresponsiveness → user unhappiness
  - Avg web page size as Doom ~2.3MB [1]

[1] HTTP Archive: http://www.httparchive.org/interesting.php?a=All&l=Apr%201%202016

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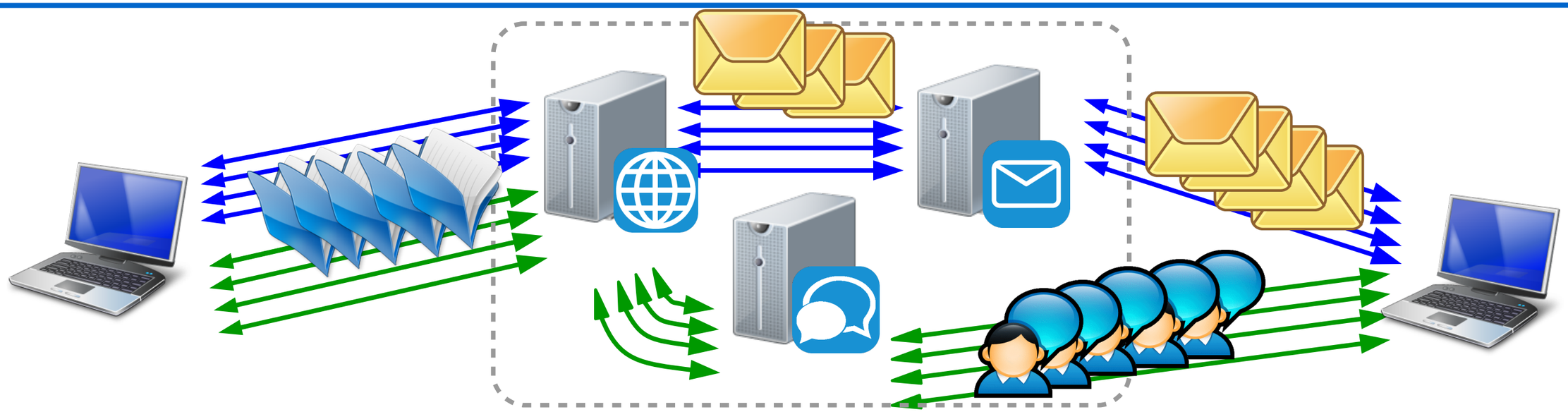

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- Solution 1: buy more bandwidth!

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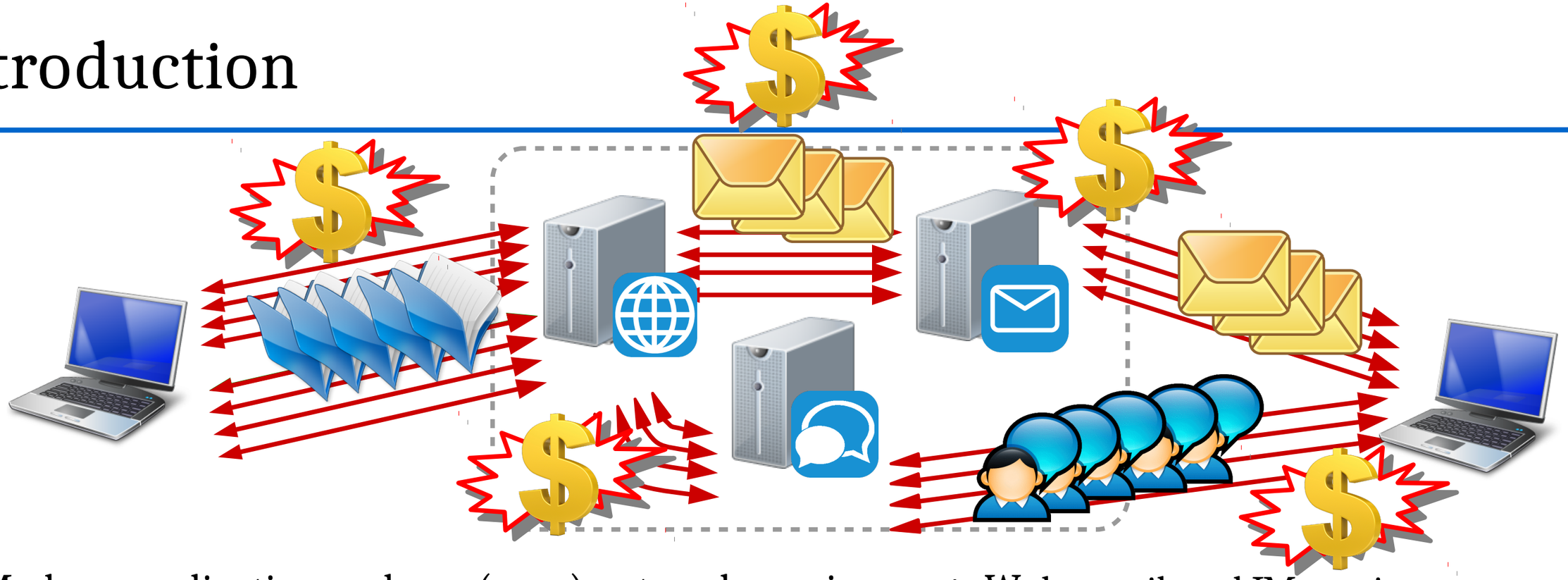

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  ➔ Bandwidth costs

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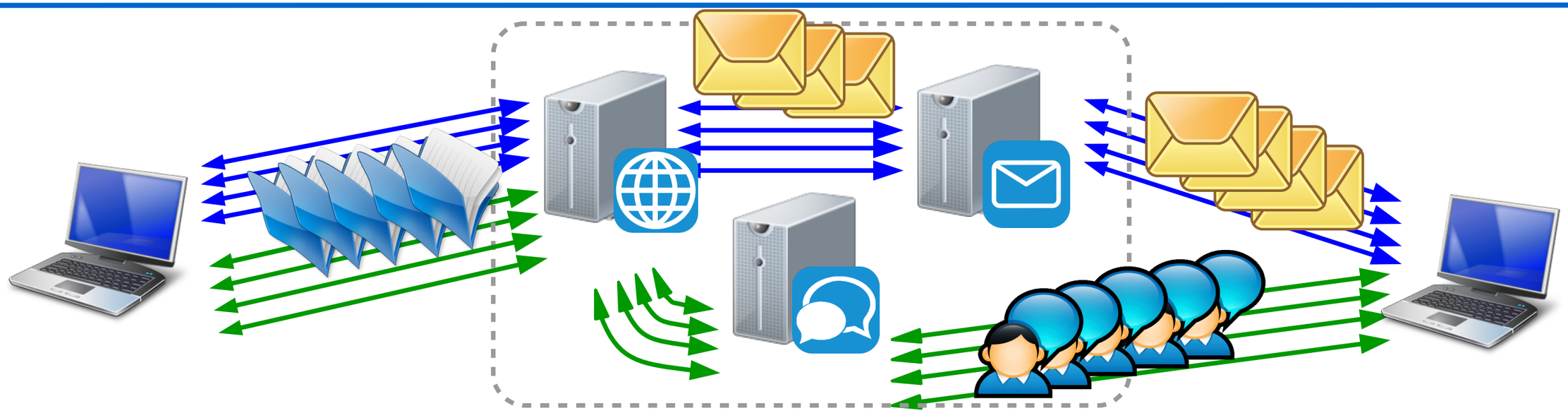

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- Another solution is …

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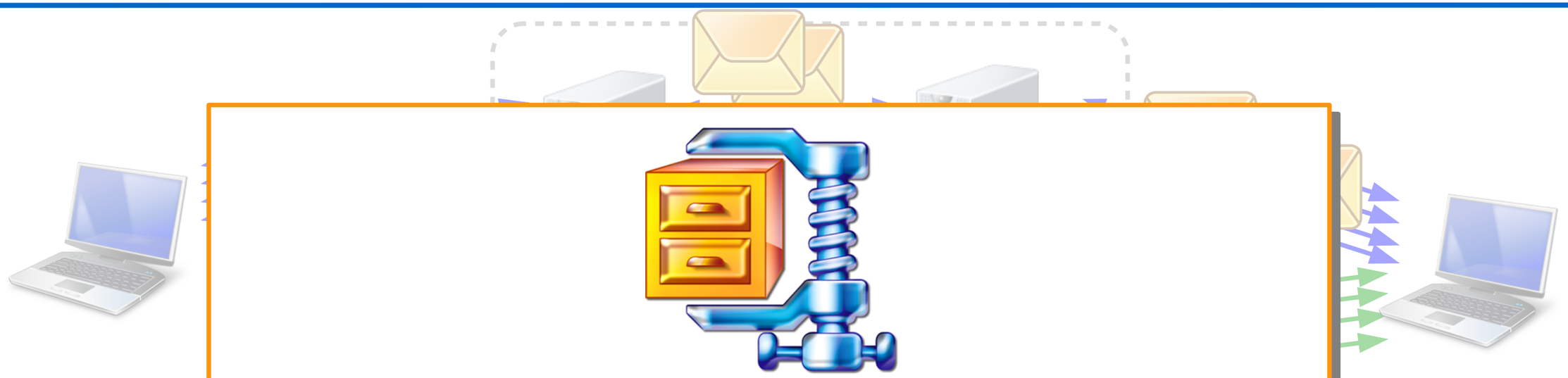
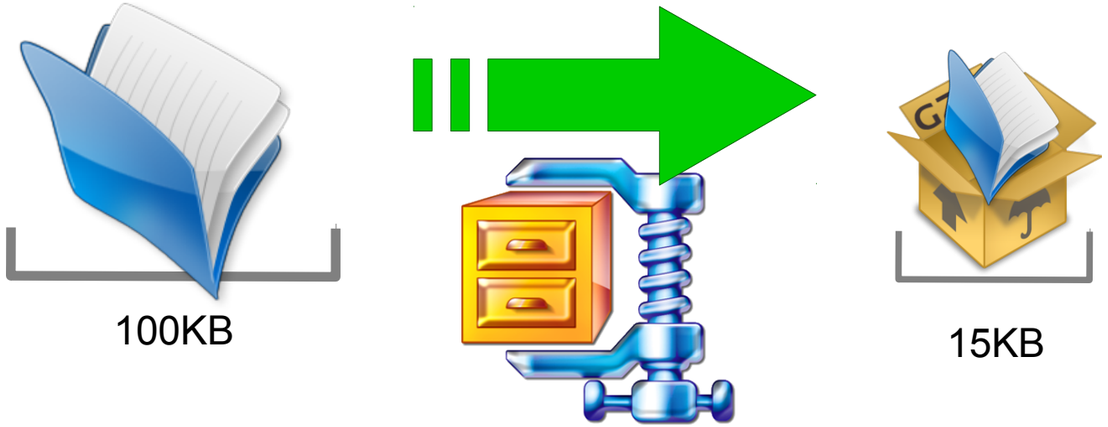


Data compression!

- Modern appli … rvices
- Amount of ex …
  - More data → more transfer time → unresponsiveness → user unhappiness
- Solution 1: buy more bandwidth!
  - ➔ Bandwidth costs
- Another solution is …

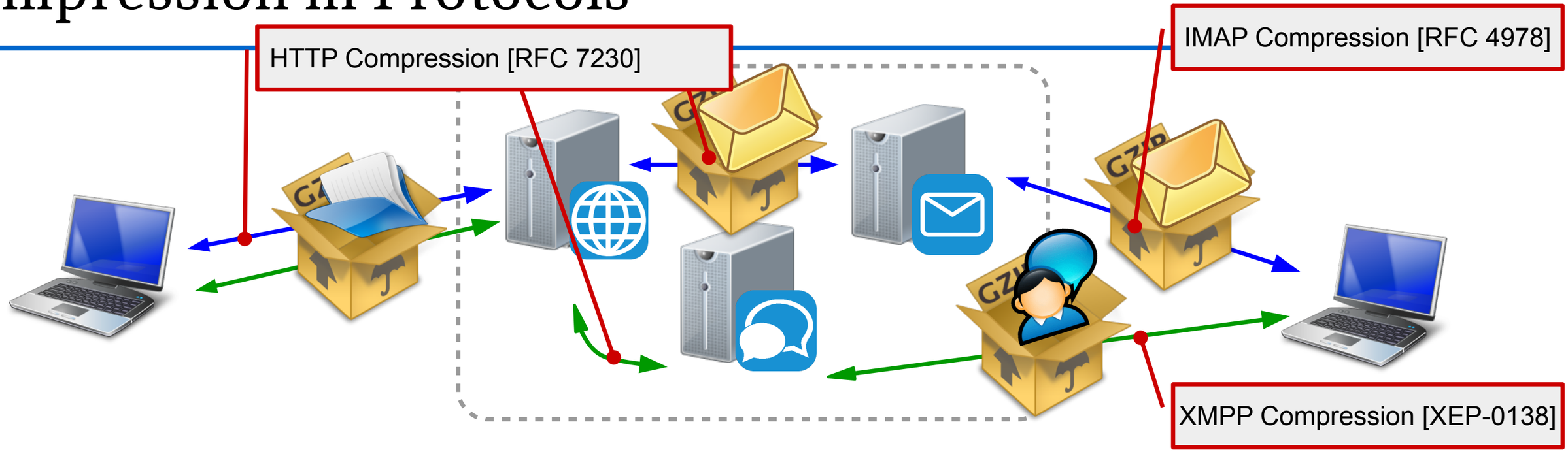
Data Compression



- Reduces # of bits of a string by removing redundancy
  - *lossless* if `decompr(compr(`d`))` = d or *lossy* if `decompr(compr(`d`))` ~= d
- Lots of algorithms (See [1])
- Among the most popular: Deflate [RFC 1951]
  - Implemented in libraries, e.g., zlib, or as a tool, e.g., gzip, and zip archive tool
  - Available in most of the programming languages

[1] SALOMON, D. Data Compression: The Complete Reference. Springer-Verlang, 2007.

Compression in Protocols



- Compression used by network protocols to reduce message size
- Mandated by protocol specifications
  - e.g., HTTP (response!) compression, IMAP, XMPP, SSH, PPP, and others
- Or implemented as custom feature
  - e.g., HTTP request compression

Compression in HTTP (RFC 7230)

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HTTP Request

```
GET / HTTP/1.1
Host: wikipedia.org
[...]
```

Retrieve default HTML page

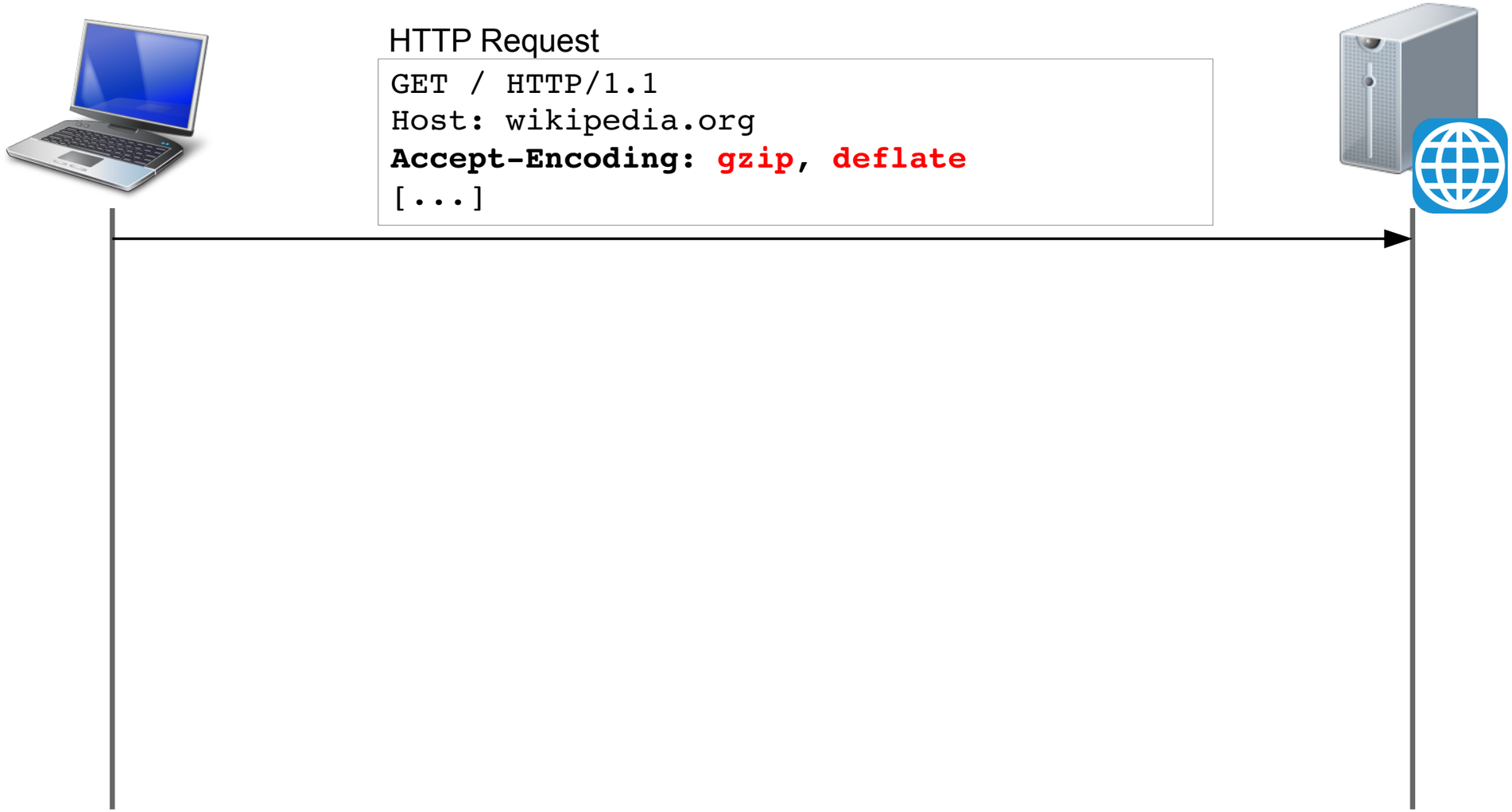
HTTP Response

```
HTTP/1.1 200 OK
[...]
Content-Length: 82170
Content-Type: text/html; charset=UTF-8

<!DOCTYPE html><html
[...]
```

~80Kb of page

Compression in HTTP (RFC 7230)



Compression in HTTP (RFC 7230)

HTTP Request

```
GET / HTTP/1.1
Host: wikipedia.org
Accept-Encoding: gzip, deflate
[...]
```

Select algorithm

HTTP Response

```
HTTP/1.1 200 OK
[...]
Content-Length: 18879
Content-Type: text/html; charset=UTF-8
Content-Encoding: gzip

[...]
```

Response size -70%

Compressed response body

Decompress

The Problem of Data Compression

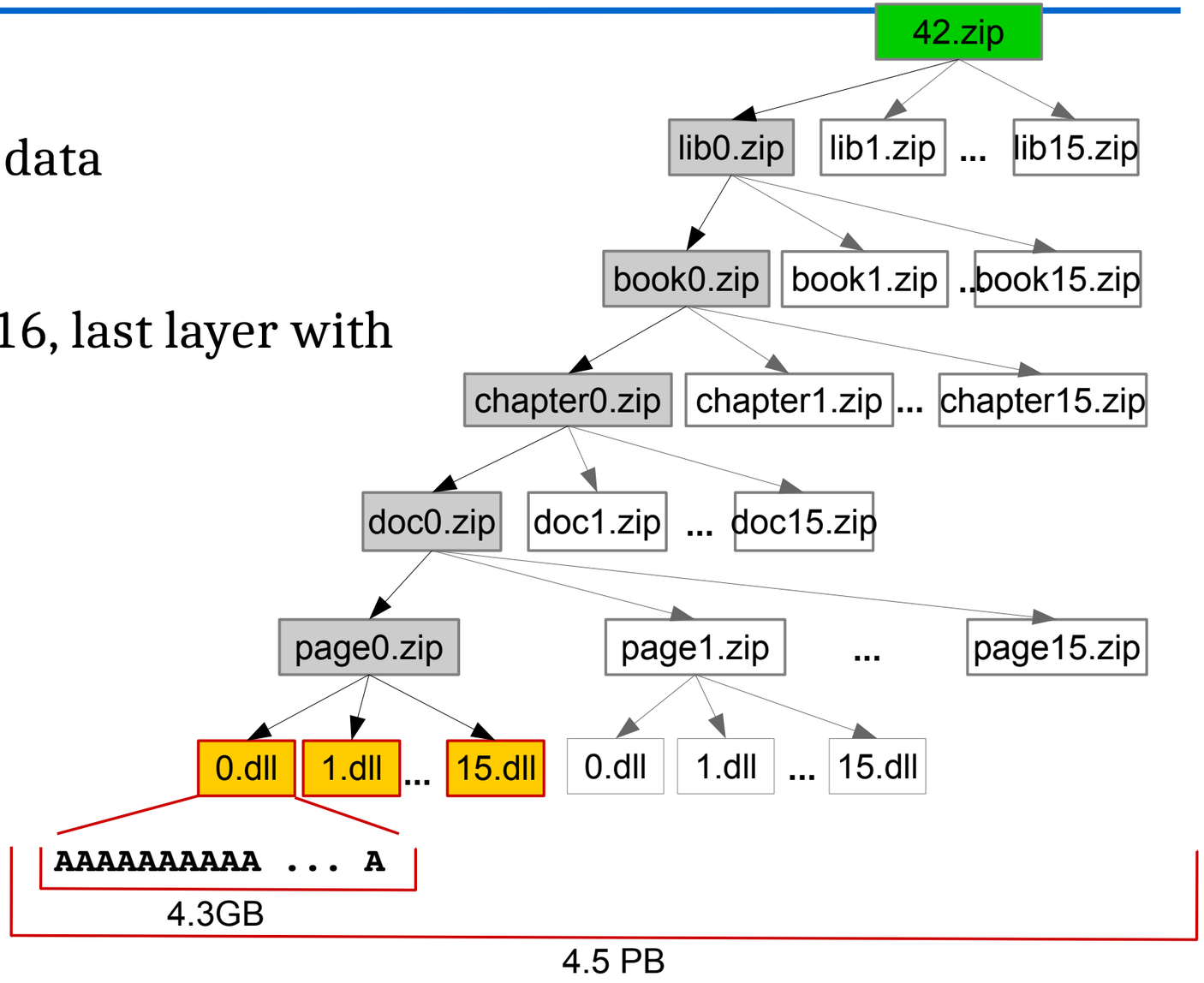
- If not properly implemented, it can make application vulnerable to DoS
- Risks:

1) **Intensive task**
   - Computationally intensive
   - If abused, it can stall an application
2) **Data Amplification**
   - Decompression increases the data to be processed (**compression rate of zlib ~1:1024**)
   - Internal components may not be designed to handle high volume of data
3) **Unbalanced Client-Server Scenario**
   - One party pre-compute compressed messages
   - The other one decompresses messages each time

- Popular examples from the past...

The Past: Zip Bombs (1996)

- 42 KB zip file → **4.5 PB** uncompressed data
- 5 layers of nested zip files in blocks of 16, last layer with text files of 4.3 GB each
- Cause Disk/Memory exhaustion
- Sent as attachment to crash anti-virus software



The Past: Billion Laughs (2003)

- Resource exhaustion in `libxml2` when processing nested XML entity definitions

```
<?xml version="1.0"?>
<!DOCTYPE lolz [
 <!ENTITY lol "lol">
 <!ELEMENT lolz (#PCDATA)>
 <!ENTITY lol1 "&lol;&lol;&lol;&lol;&lol;&lol;&lol;&lol;&lol;&lol;">
 <!ENTITY lol2 "&lol1;&lol1;&lol1;&lol1;&lol1;&lol1;&lol1;&lol1;&lol1;&lol1;">
 <!ENTITY lol3 "&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;&lol2;">
 <!ENTITY lol4 "&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;&lol3;">
 <!ENTITY lol5 "&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;&lol4;">
 <!ENTITY lol6 "&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;&lol5;">
 <!ENTITY lol7 "&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;&lol6;">
 <!ENTITY lol8 "&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;&lol7;">
 <!ENTITY lol9 "&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;&lol8;">
]>
<lolz>&lol9;</lolz>
```

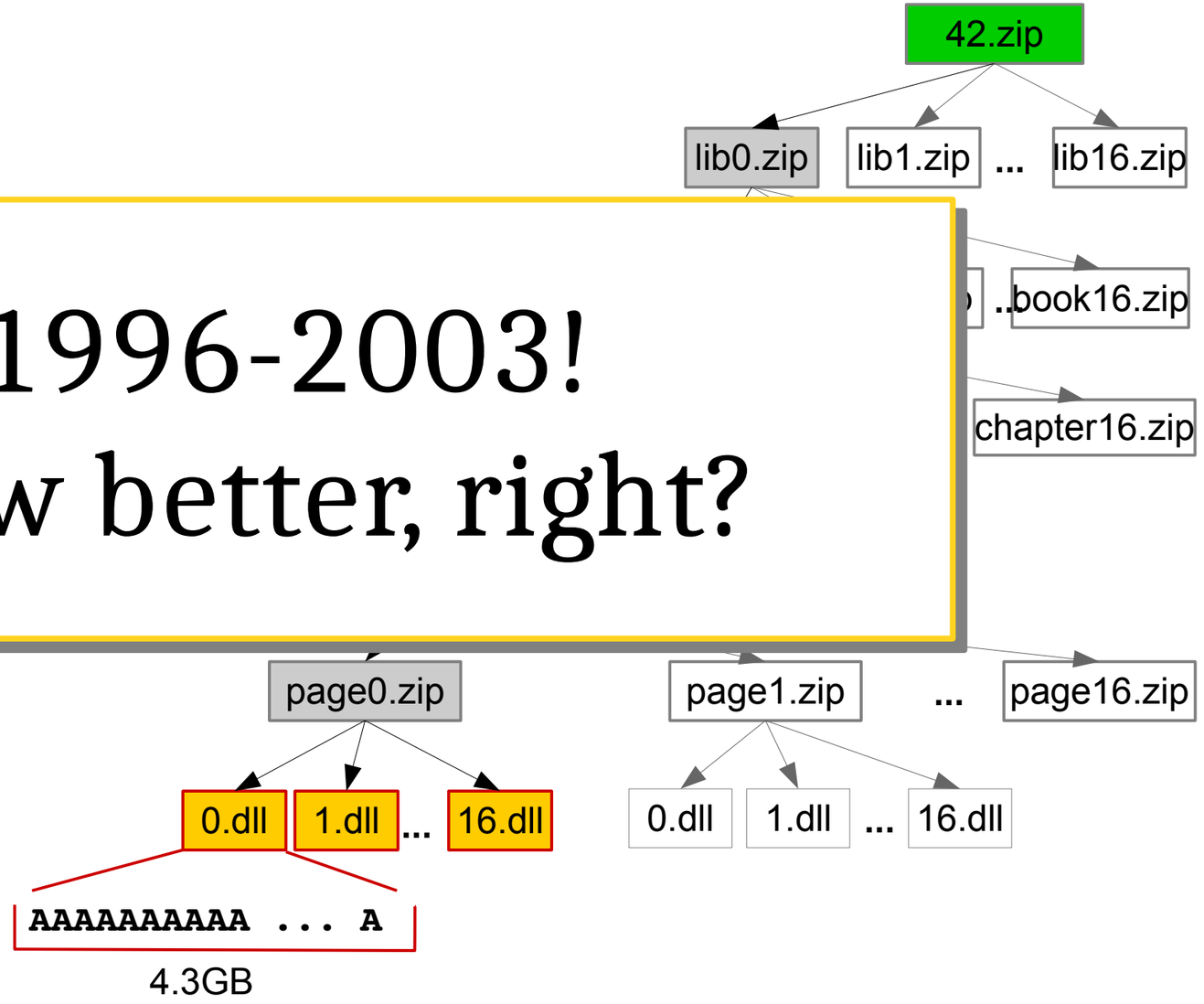
- 810 bytes of XML document expanded to **3GB**

The Past: Zip Bombs and Billion Laughs

```
<?xml version="1.0"?>
<!DOCTYPE lolz [
 <!ENTITY lo
 <!ELEMENT l
 <!ENTITY lo
 <!ENTITY lo
 <!ENTITY lo
 <!ENTITY lo
 <!ENTITY lo
 <!ENTITY lo
 <!ENTITY lo
 <!ENTITY lo
 <!ENTITY lo
]>
<lolz>&lol9;</lolz>
```

This was 1996-2003!

Now we know better, right?



The Present

- Reviewed protocol specs, design patterns, and coding rules

  Unawareness of the risks, **guidelines** on handling data compression are **missing** or **misleading**

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   - Patterns to solve vulns. during design phase : *DoS Safety*, *Compartmentalization*, and *Small Process*
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3. Secure Coding Rules
   - Only one, i.e., Anti-Zip Bomb coding rule
   - ➔ Sadly, incorrect

The Present

- Reviewed protocol specs, design patterns, and coding rules

Unawareness of the risks, **guidelines** on handling data compression are **missing** or **misleading**

1. Protoc
   - → No d… …s, but unex…
2. Secure…
   - Patte…
   - → How… …
3. Secure Coding Rules
   - Only one, i.e., Anti-Zip Bomb coding rule
   - → Sadly, incorrect

How does this lack of common knowledge and understanding affect implementations?

Impact on Implementations

HTTP (Response) Compression (RFC 7230)

HTTP Request

```
GET / HTTP/1.1
Host: wikipedia.org
Accept-Encoding: gzip, deflate
[...]
```

Select algoritm

HTTP Response

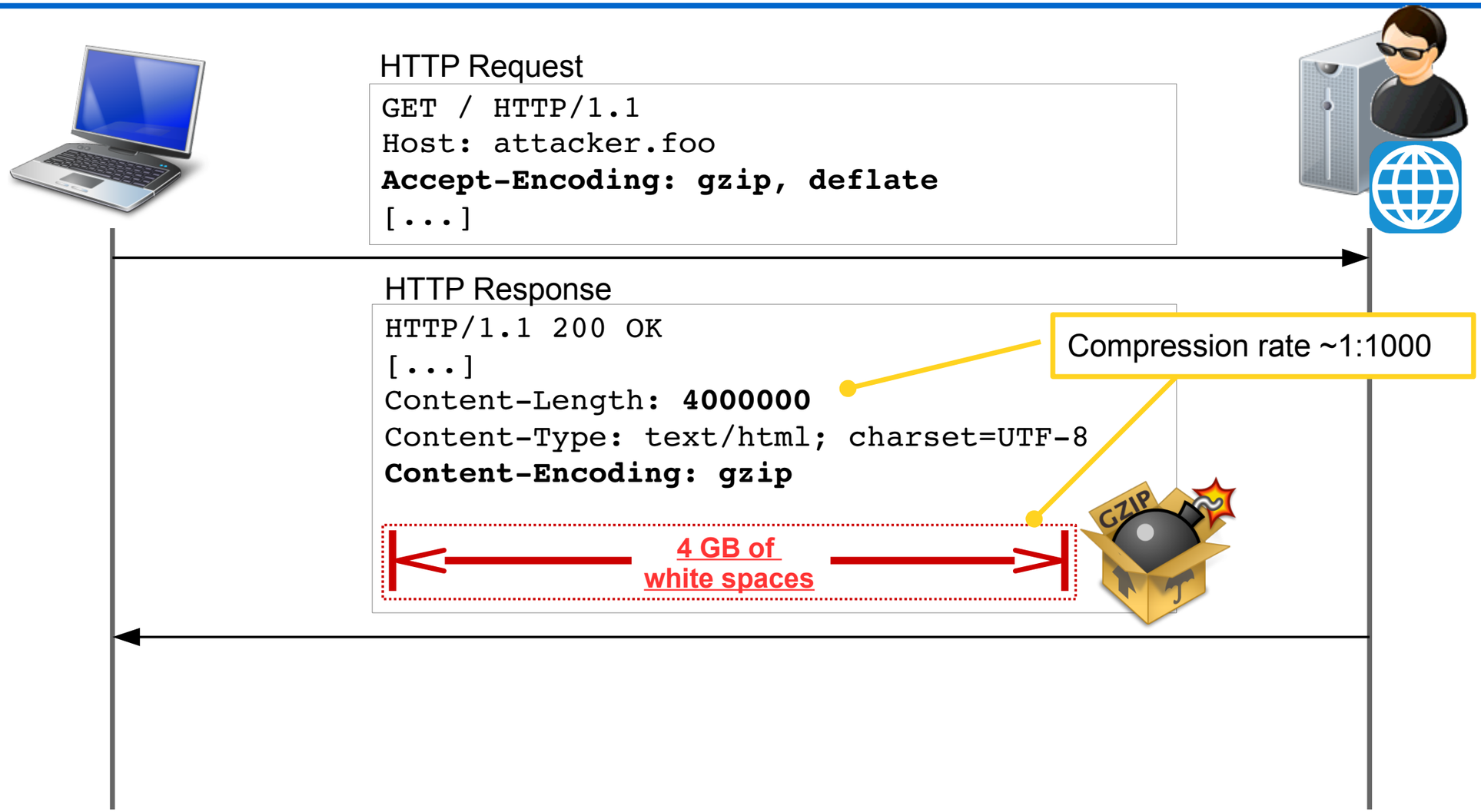
```
HTTP/1.1 200 OK
[...]
Content-Length: 18879
Content-Type: text/html; charset=UTF-8
Content-Encoding: gzip

[...]
```

Response size -70%

Compressed response body

Decompress

Compression Bombs against Web Browsers #1



See: Geoff Jones http://blog.cyberis.co.uk/2013/08/vulnerabilities-that-just-wont-die.html

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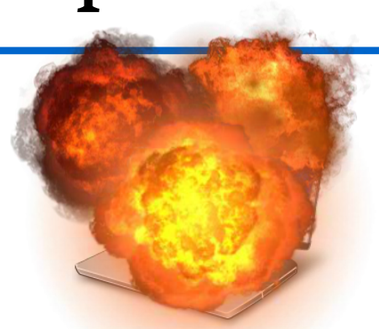


HTTP Request

```
GET / HTTP/1.1
Host: attacker.foo
Accept-Encoding: gzip, deflate
[...]
```

HTTP Response

```
HTTP/1.1 200 OK
[...]
Content-Length: 4000000
Content-Type: text/html; charset=UTF-8
Content-Encoding: gzip
```

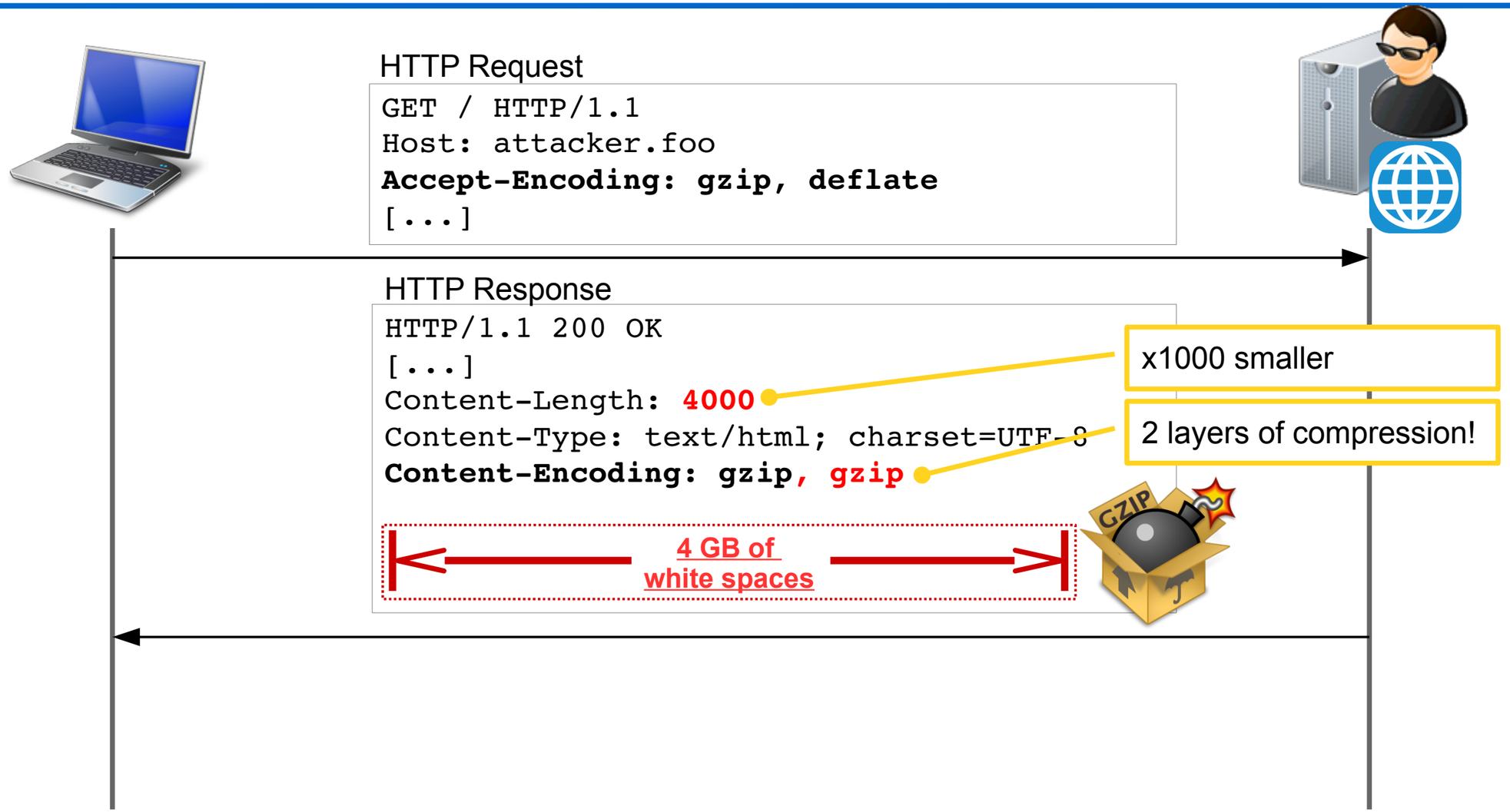
Compression rate ~1:1000

4 GB of white spaces

Decompress

See: Geoff Jones http://blog.cyberis.co.uk/2013/08/vulnerabilities-that-just-wont-die.html

Compression Bombs against Web Browsers #2



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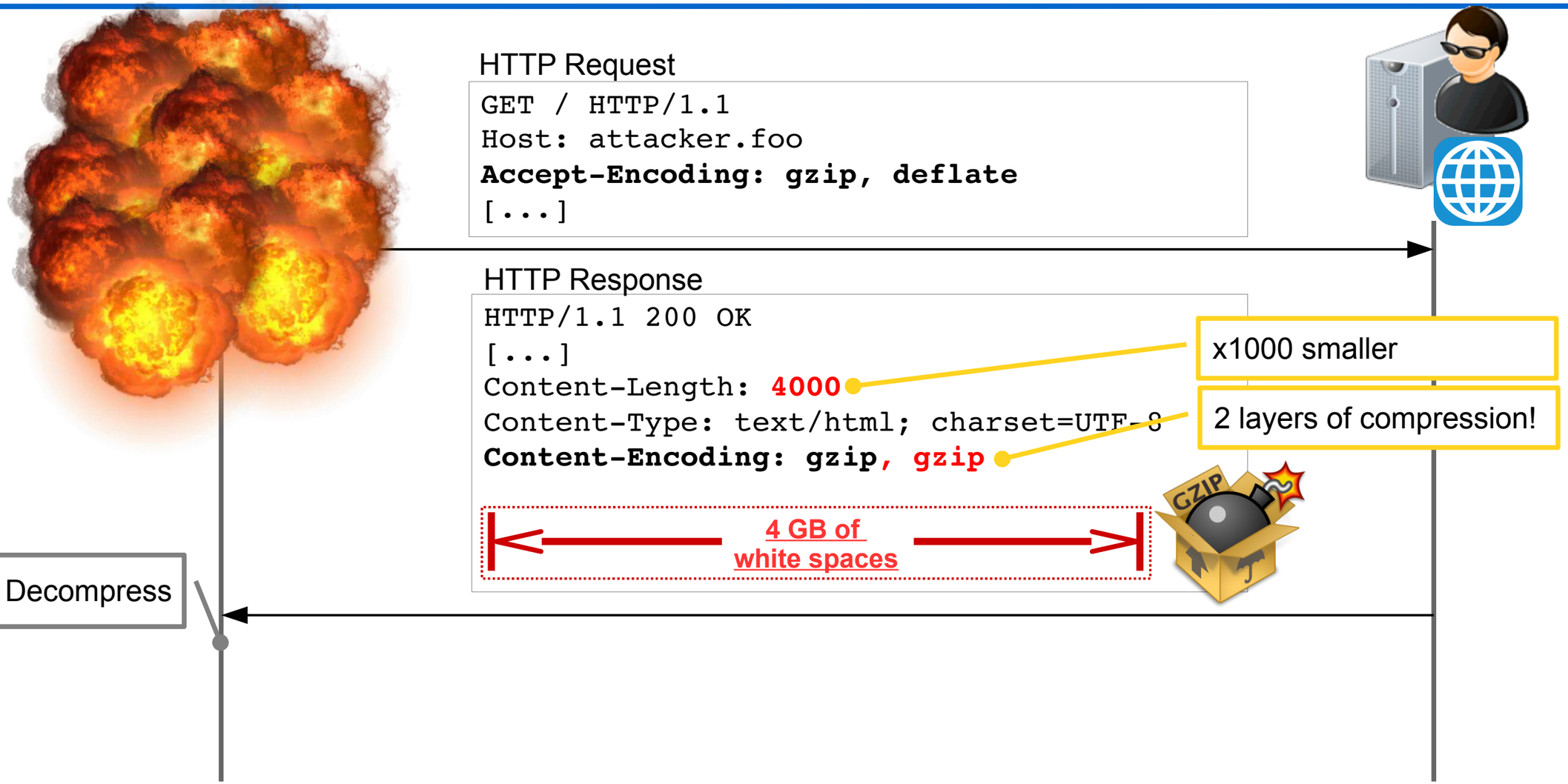

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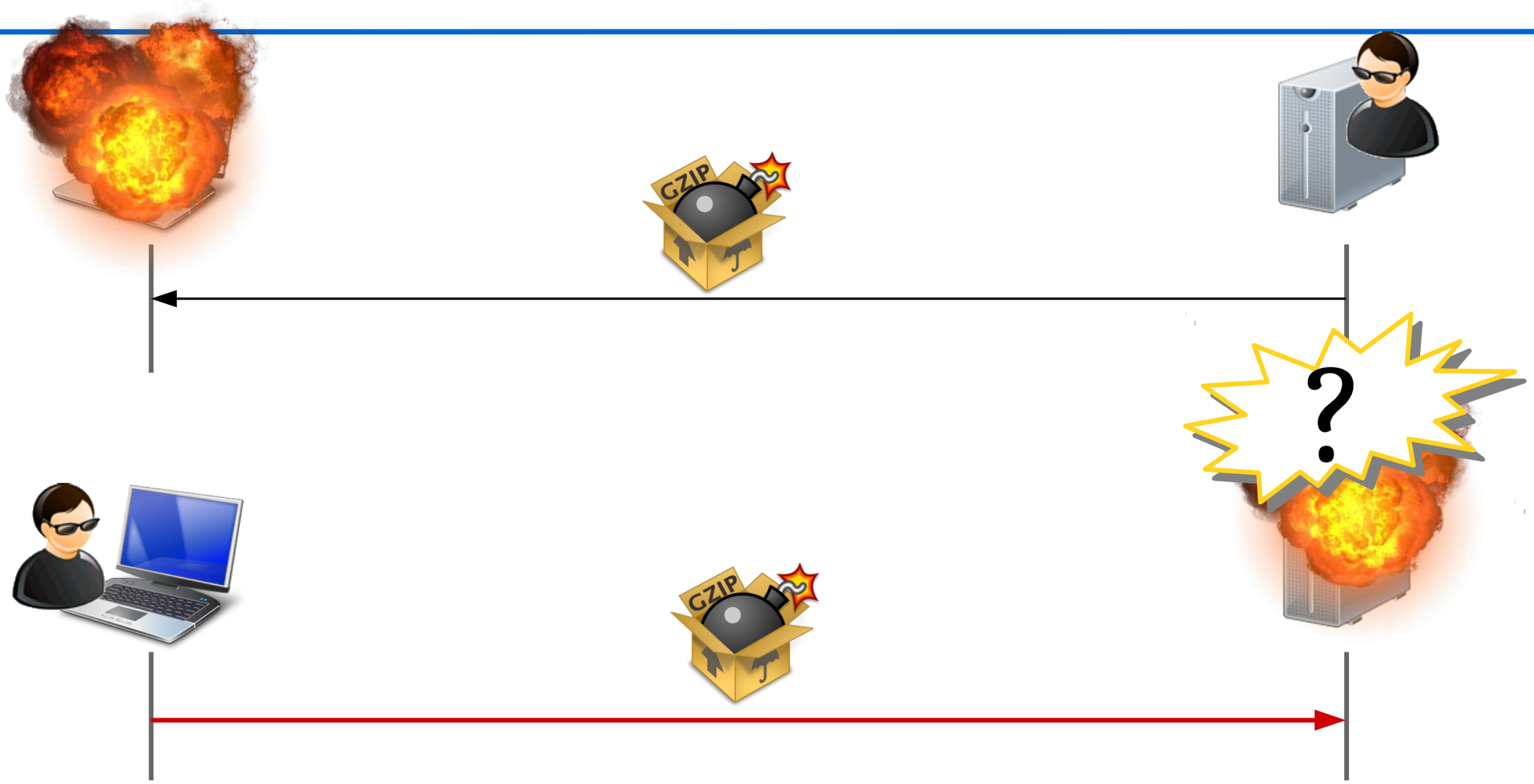
HTTP (Response) Compression Bombs

"Vulnerabilities that just won't die - Compression Bombs"
by Geoff Jones
http://blog.cyberis.co.uk/2013/08/vulnerabilities-that-just-wont-die.html

	Internet Explorer	Firefox	Chrome/Chromium	Safari	Opera
1TBx4 HTML	Not supported	See 3	See 6	Not supported	See 10
1TB HTML	See 1	See 3	See 6	See 9	See 11
1TBx4 FILE	Not supported	See 4	See 7	Not supported	See 12
1TB FILE	See 2	See 5	See 7	See 9	See 12
1TB SDCH	Not supported	Not supported	See 8	Not supported	Not supported

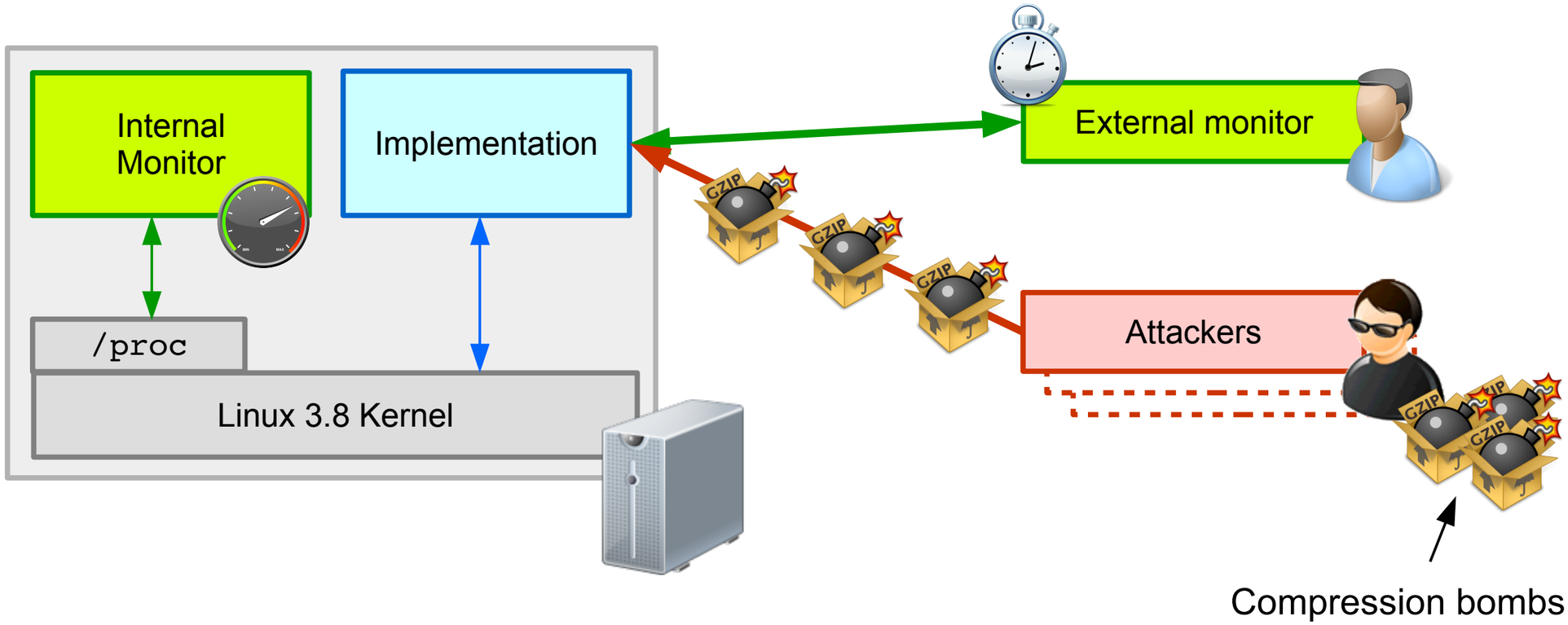
Most are still vulnerable!

How about servers?



Experiments

- Case studies:
  - HTTP, XMPP, and IMAP servers
- Testbed:



HTTP (request) Compression Bomb (SOAP)

- Case studies:
  - HTTP, XMPP, and
- Testbed:

```
POST /index.html HTTP/1.1
Content-Encoding: gzip
\r\n
<soapenv:Envelope>
<soapenv:Body>[...]</soapenv:Body>
</soapenv:Envelope>
\r\n
```

compressed

4 GB of white spaces

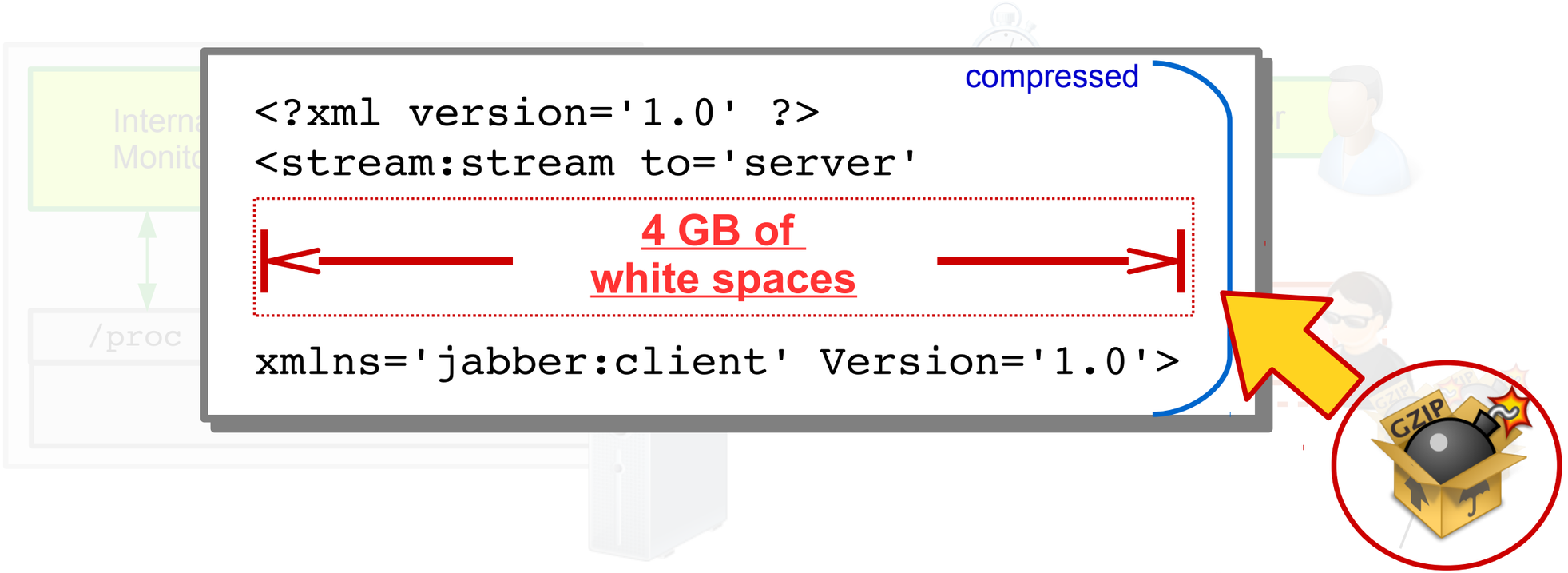
Same for JSON

Compression bombs

~4 MB, ~1:1000 compr. ratio

XMPP Compression Bomb

- Case studies:
  - HTTP, XMPP, and IMAP servers
- Testbed:



Compression bombs

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IMAP Compression Bomb

- Case studies:
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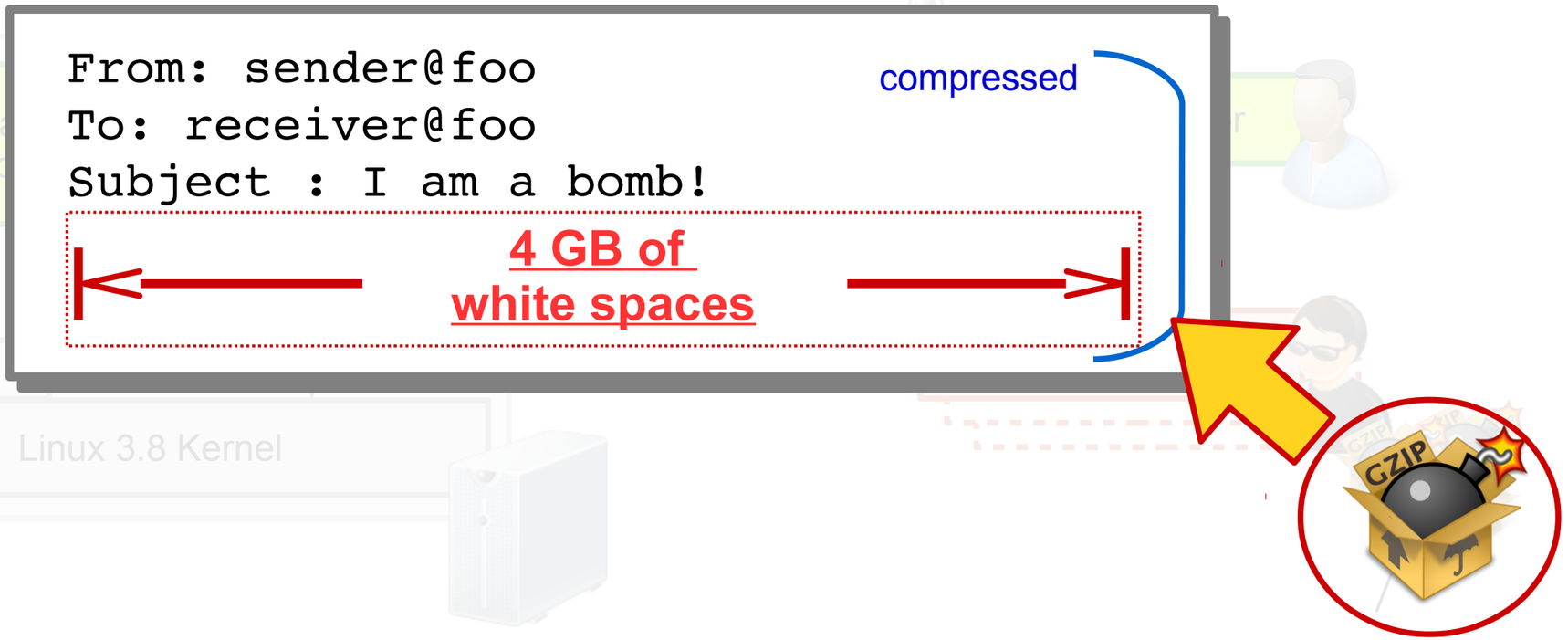


Compression bombs

~4 MB, ~1:1000 compr. ratio

Compression Bombs Everywhere

Protocol	Network Service
XMPP	OpenFire
	Prosody
	Tigase
	Ejabberd, jabberd2
HTTP	Apache HTTPD + mod_deflate
	+ mod-php, CSJRPC, mod-gsoap, mod-dav
	Apache Tomcat + 2Way/Webutilities filter
	+ Apache CXF
	+ json-rpc, lib-json-rpc
	+ Axis2/ +jsonrpc4j
	Axis 2 standalone
	gSOAP standalone
IMAP	Dovecot, Cyrus

Compression Bombs Everywhere

Protocol	Network Service
XMPP	OpenFire CVE-2014-2741
	Prosody CVE-2014-2744/ -2745
	Tigase CVE-2014-2746
	Ejabberd, jabberd2
HTTP	Apache HTTPD + mod_deflate CVE-2014-0118
	+ mod-php, CSJRPC, mod-gsoap, mod-dav
	Apache Tomcat + 2Way/Webutilities filter Notif. devel
	+ Apache CXF CVE-2014-0109/ -0110
	+ json-rpc, lib-json-rpc Notif. devels
	+ Axis2/ +jsonrpc4j
	Axis 2 standalone
	gSOAP standalone Notif. devel
IMAP	Dovecot, Cyrus

Pitfalls

Pitfalls

1. Implementation

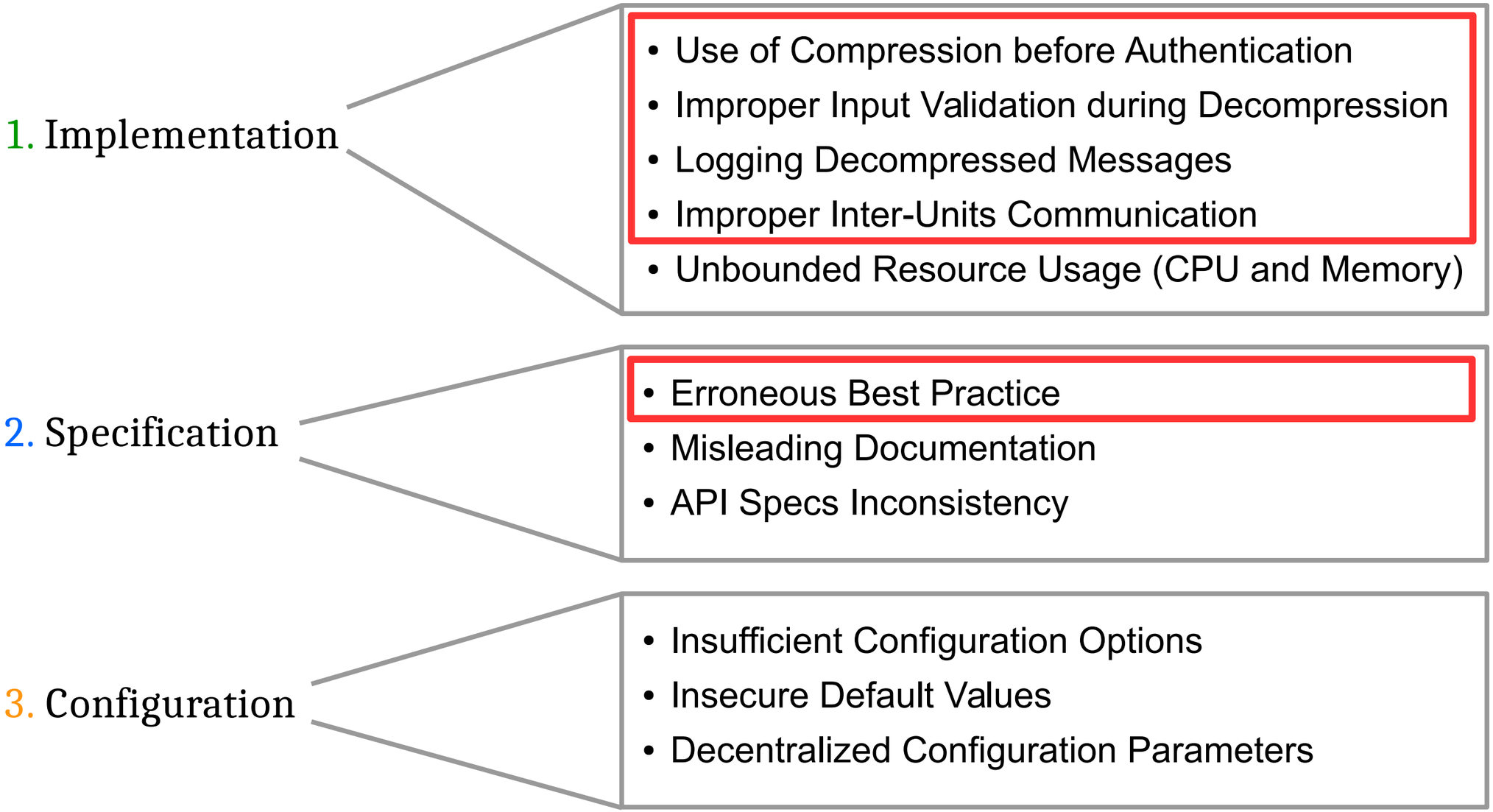
2. Specification

3. Configuration

Pitfalls

1. Implementation
   - Use of Compression before Authentication
   - Improper Input Validation during Decompression
   - Logging Decompressed Messages
   - Improper Inter-Units Communication
   - Unbounded Resource Usage (CPU and Memory)
2. Specification
   - Erroneous Best Practice
   - Misleading Documentation
   - API Specs Inconsistency
3. Configuration
   - Insufficient Configuration Options
   - Insecure Default Values
   - Decentralized Configuration Parameters

Pitfalls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Check out our paper!

http://trouge.net/gp/papers/compr_usenix15.pdf

3. Configuration
   - Insufficient Configuration Options
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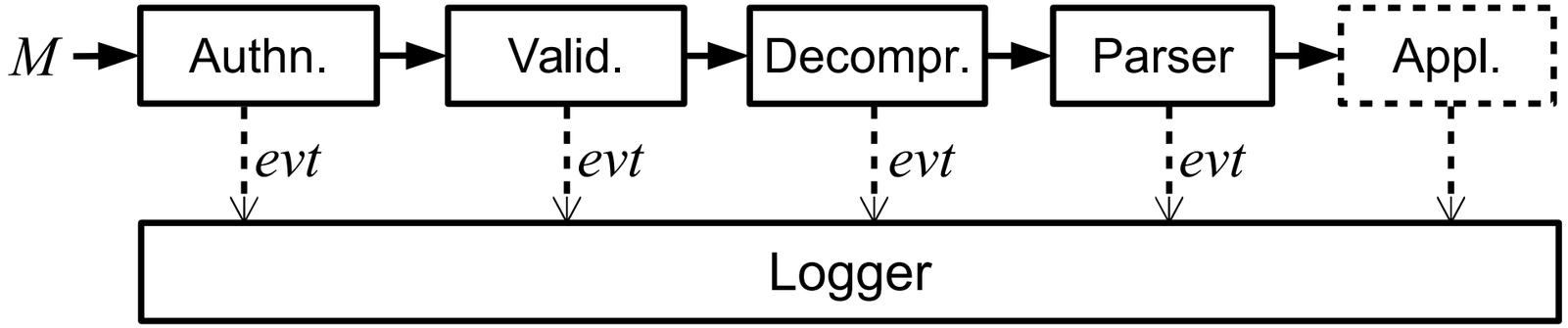
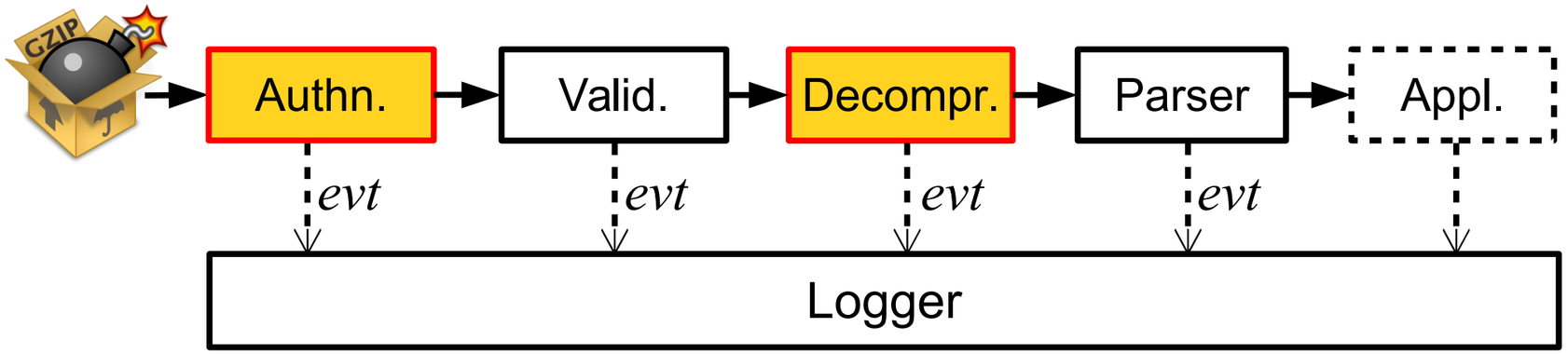
Pitfalls at Implementation level



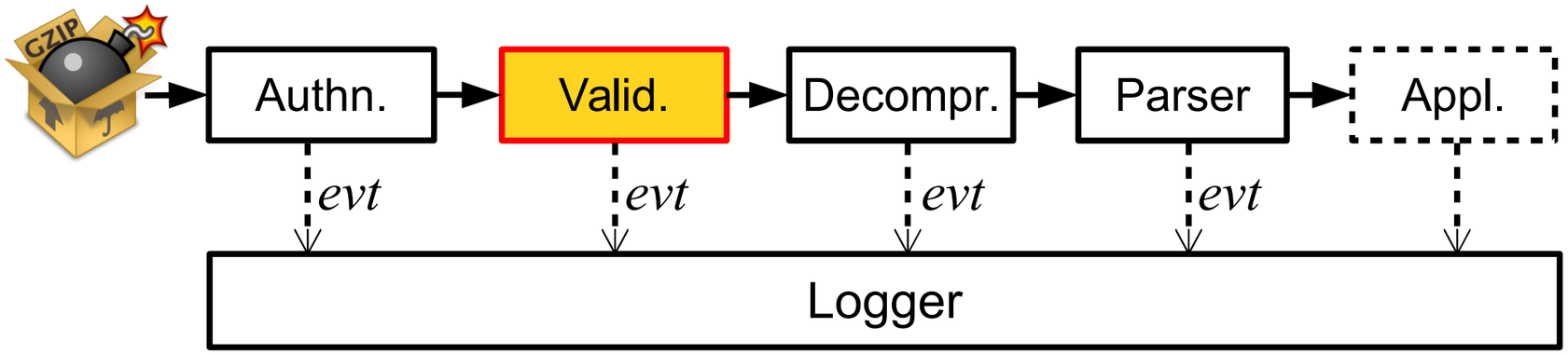
- Abstract message processing pipeline extracted from our case studies

Compression before Authentication



- Inconsistent best practice
  - Mandatory in SSL/TLS, recommended in XMPP, and undefined in IMAP and HTTP
  - Implementation may diverge from the specs, i.e., OpenSSH
- Developers may underestimate the risk or overlook recommendations
- Prosody accepted compressed messages before user authentication CVE-2014-2744
  - ➔ DoS by unauthenticated attackers

Improper Input Validation during Decompression



- 3 ways to validate a message:

mistake

  - Compressed message size
    - mod-deflate: If (compr. size > `LimitRequestBody`) → Reject CVE-2014-0118
    - ➔ However, hard to assess message size from its compressed form (1 MB compr → 1 GB decompr.)

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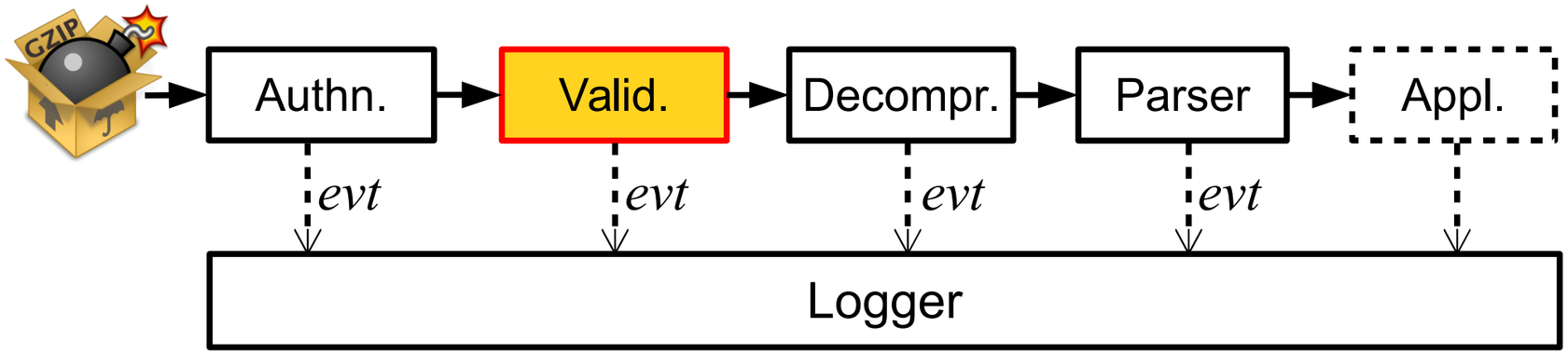

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risky

- Decompression ratio
  - Patched mod-deflate: if (decompr ratio > threshold) → Reject
  - ➔ Problem of ratio selection

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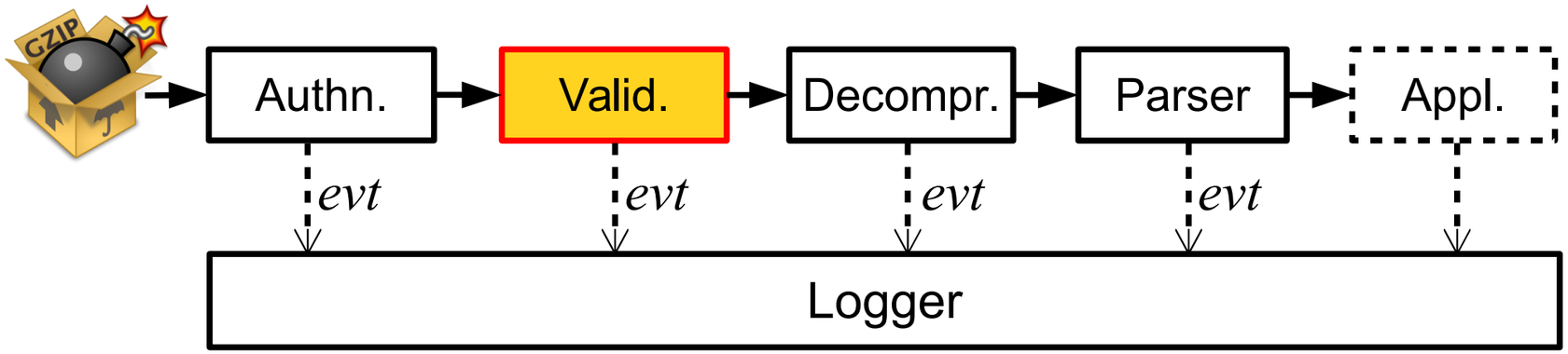

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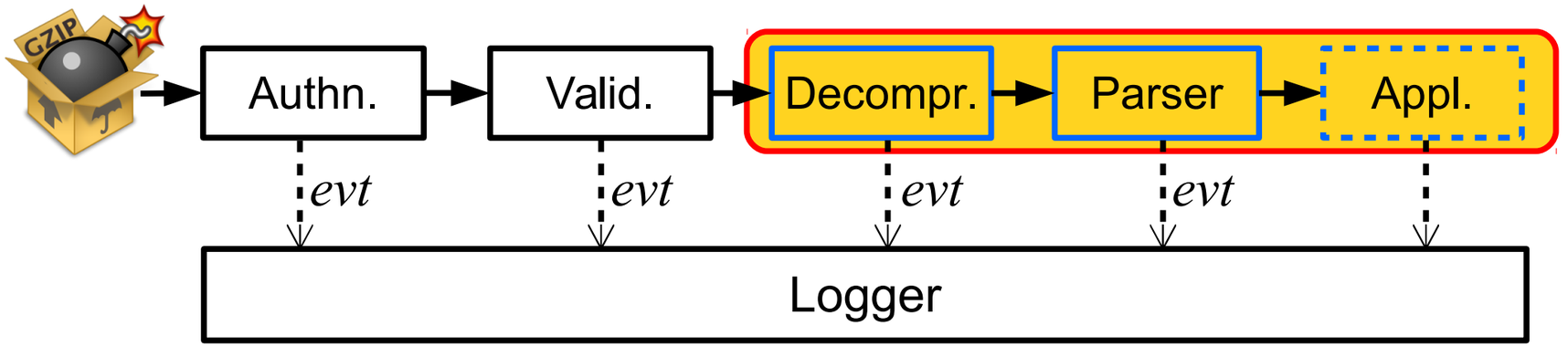
mistake
- Compressed message size
  - mod-deflate: If (compr. size > `LimitRequestBody`) → Reject CVE-2014-0118
  - ➔ However, hard to assess message size from its compressed form (1 MB compr → 1 GB decompr.)

risky
- Decompression ratio
  - Patched mod-deflate: if (decompr ratio > threshold) → Reject
  - ➔ Problem of ratio selection

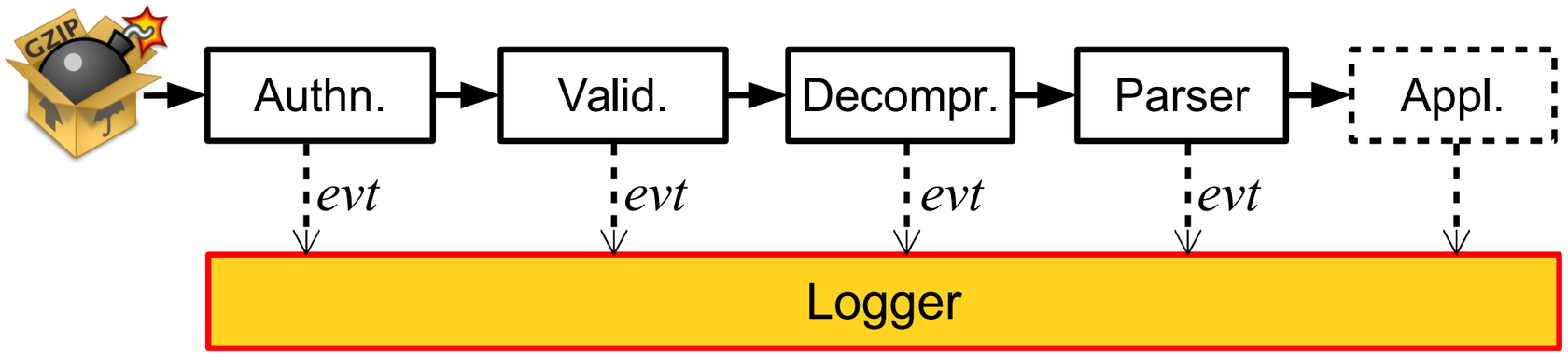
correct
- Decompressed message size
  - mod-deflate + mod-dav: If (decompr. size > `LimitXMLRequestBody`) → Reject

Improper Inter-Units Communication



- Upon exception, the pipeline halts and rejects message
- mod-php and mod-gsoap limit the size of incoming (decompressed) message
- … but had no means to halt mod-deflate
  - ➔ mod-deflate keeps on decompressing data
    - Problem addressed in CVE-2014-0118

Logging Decompressed Messages

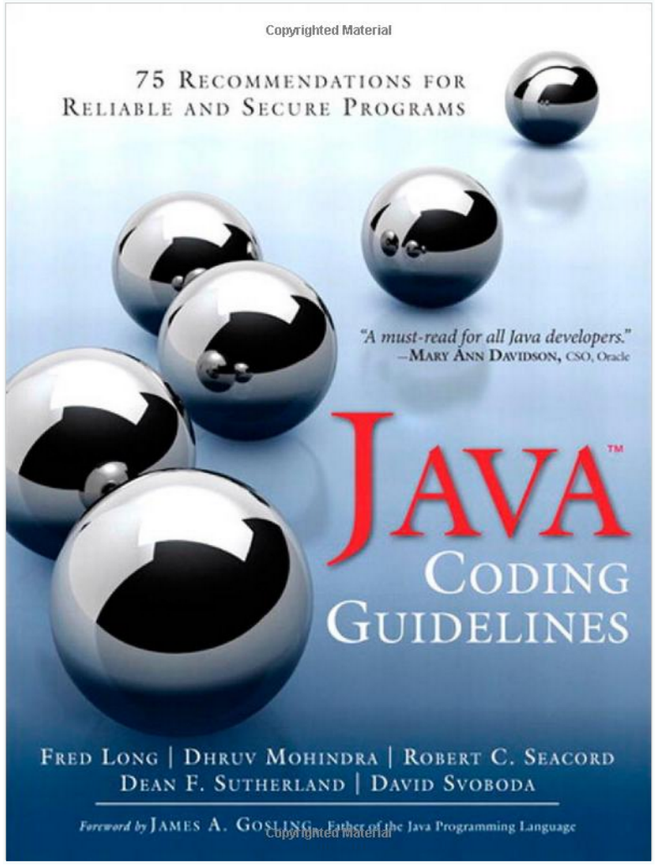


- Frequency and verbosity of log events can cause DoS
- If exception is caused by compressed data, the needed resources may be underestimated
- Upon invalid requests, Apache CXF logs first 100KB of incoming message
  - However, first it decompresses the entire message on a file, then logs the first 100KB

➔ DoS due to disk space exhaustion CVE-2014-0109/ -0110

Erroneous Best Practices (Spec. level)

- Only one code pattern specific for data compression
  - Rule: “IDS04-J. Safely extract files from ZipInputStream”



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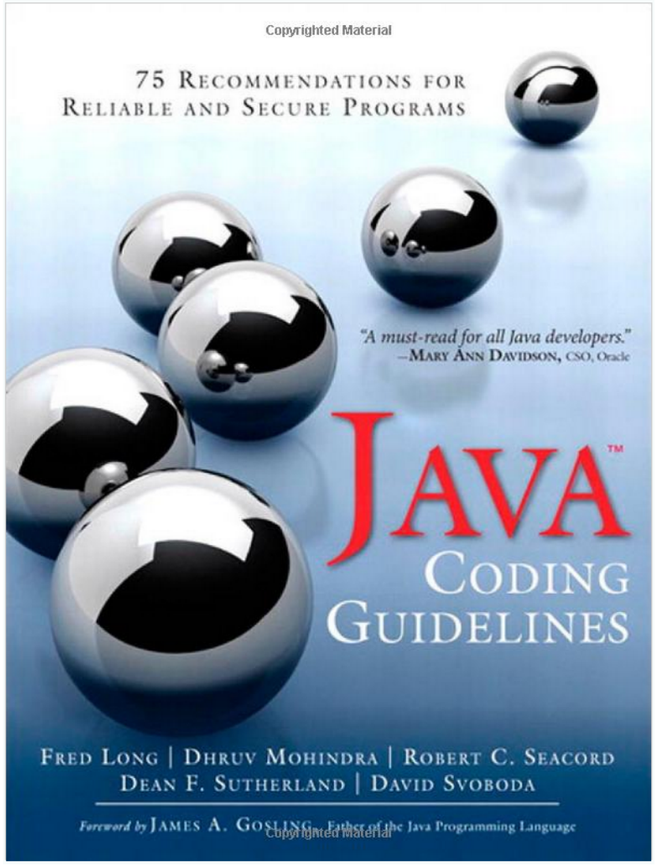

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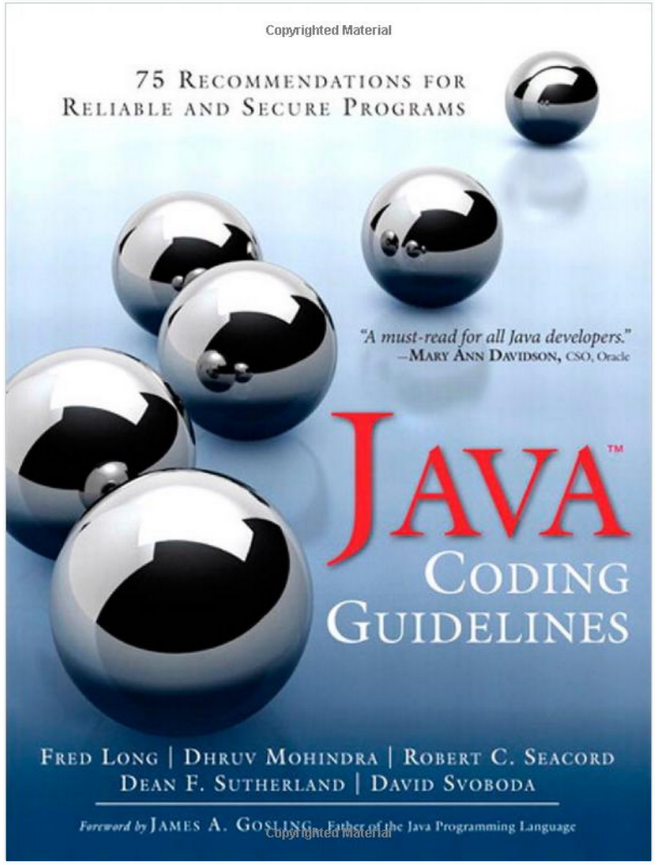

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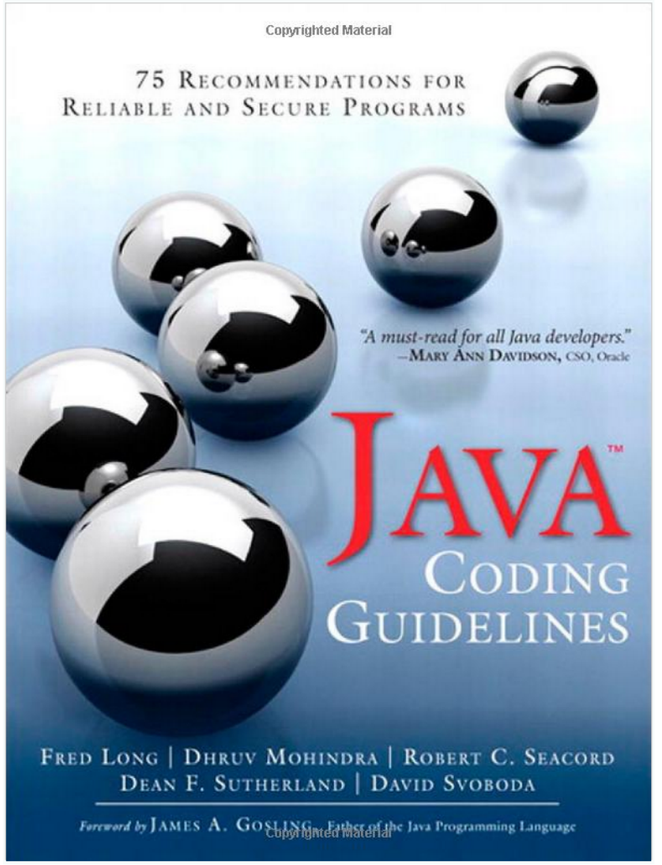

- `.getSize()` returns ZIP file header with uncompressed size

- but ZIP headers not integrity protected!
  - ➔ DoS countermeasure bypass Notif. Authors

Conclusion

Conclusion/Takeaway

- Compression bombs are back
  - ➔ New vulnerabilities in popular network services
- ~20 years after the zip bombs, developers still unaware of the risks of handling data compression
  - ➔ 12 pitfalls which can be used by developers to build more secure services