An analysis of exploitation behaviors on the web and the role of web hosting providers in detecting them

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NDSS 2013 & WWW 2013

Behind the Scenes of Online Attacks: an Analysis of Exploitation Behaviors on the Web

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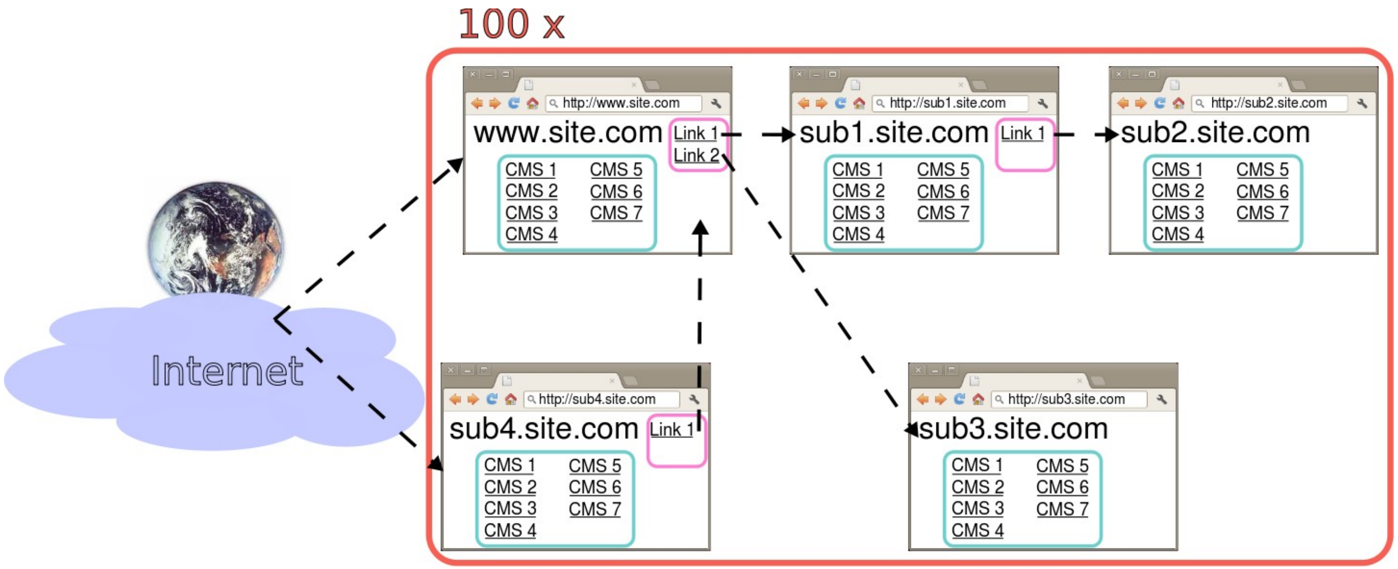
NDSS 2013

Motivations

- Studying the internals of web attacks
  - What attackers do while and after they exploit a vulnerability on a website
  - Understand why attacks are carried out (fun, profit, damaging others, etc.)
- Previous studies
  - how attacks against web sites are carried out
  - how criminals find their victims on the Internet
  - Lack of studies on the behavior of attackers (what they do during and after a typical attack)
    - Previous works used static, non functional honeypots (not exploitable)

How

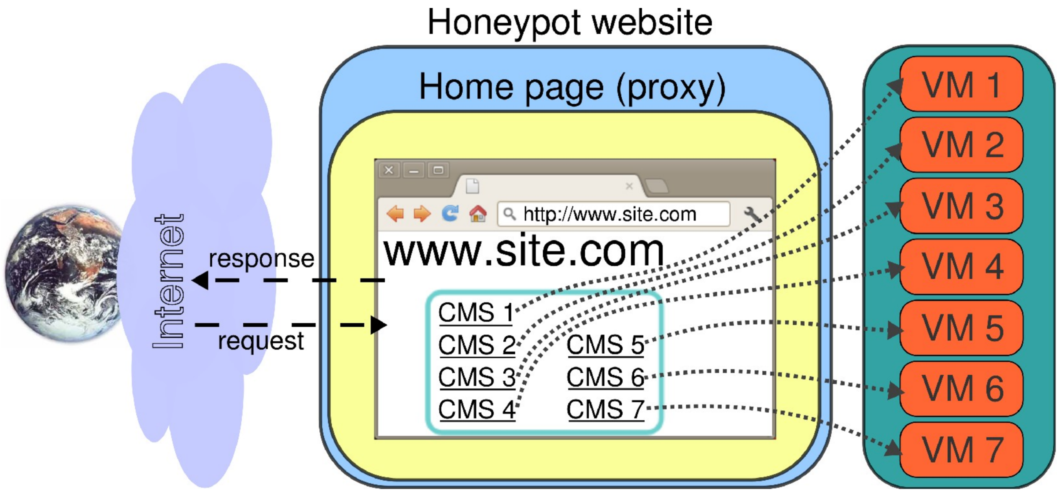
- 500 vulnerable websites deployed on the Internet



  - 100 domain names registered, with 5 subdomains each
  - Hosted on 9 of the Internet's biggest hosting providers
  - Each website contains 5 common CMSs (blog, forum, e-commerce web app, generic portal, SQL manager), 1 static website and 17 PHP web shells

Data collection

- 100 days of centralized data collection
- Allows for simple and effective management
- Each deployed website acts as a proxy
  - Redirects traffic to the real web applications installed on VMs in our premises

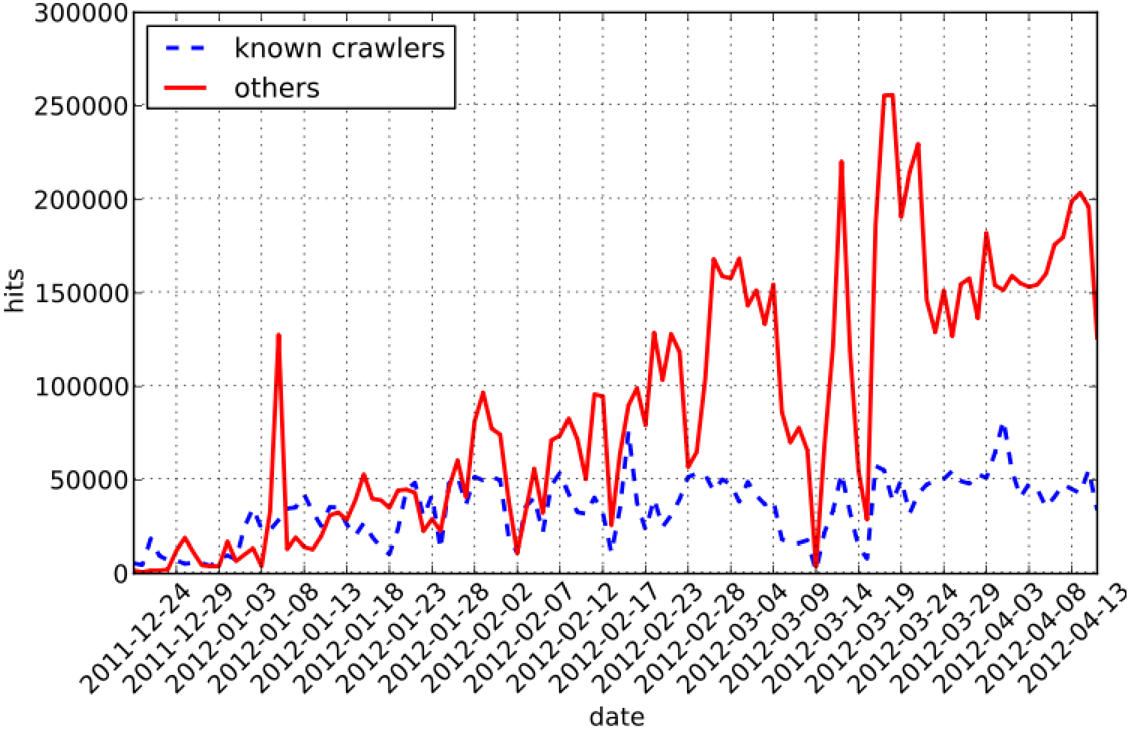


- » Easy to restore the VM state once an attack takes place
- » Full attack logs available
- » Easy to limit and tailor the attacker's privileges on the machine that hosts the vulnerable app

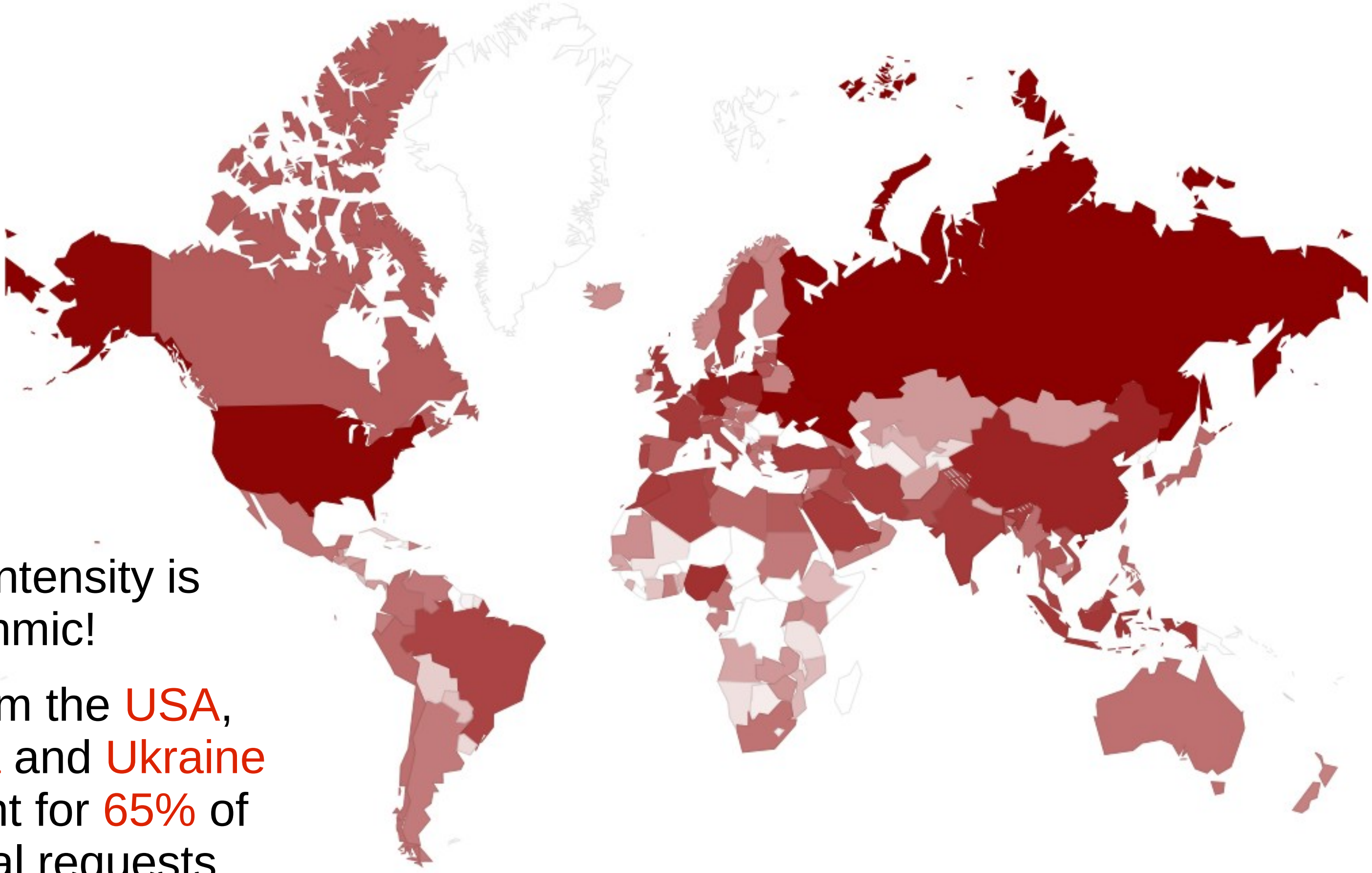
Collected data

- ~10 GB of raw HTTP requests
- In average:
  - 1-10K uploaded files every day
  - 100-200K HTTP requests/day
- First suspicious activities:
  - automated: 2h 10' after deployment
  - manual: after 4h 30'

Requests volume



Requests by country
(excluding known crawlers)



- Color intensity is logarithmic!
- IPs from the USA, Russia and Ukraine account for 65% of the total requests

Attack analysis

The four different phases

1. Discovery: how attackers find their targets
   - Referer analysis, dorks used to reach our websites, first suspicious activities

69.8% of the attacks start with a scout bot visiting the pages often disguising its User-Agent

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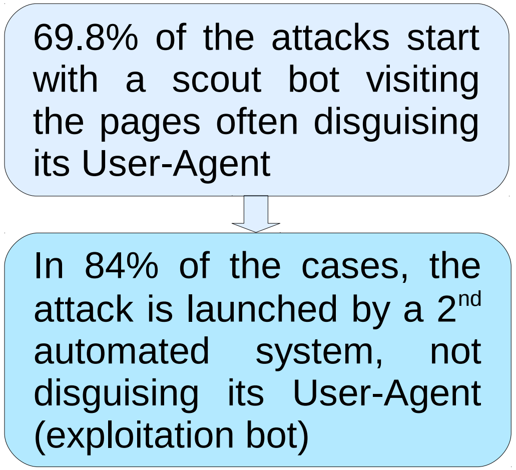
   - Automated systems and crawling patterns identification, User-Agent analysis



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In 84% of the cases, the attack is launched by a 2nd automated system, not disguising its User-Agent (exploitation bot)

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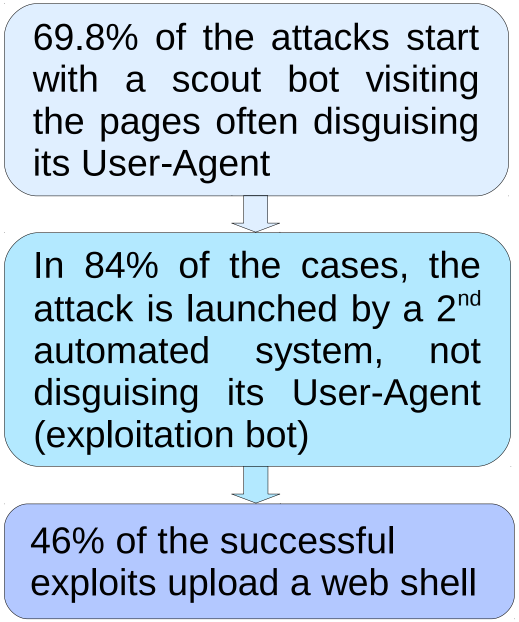
   - Analysis of forum activities: registrations, posts and URLs, geolocation, message categories



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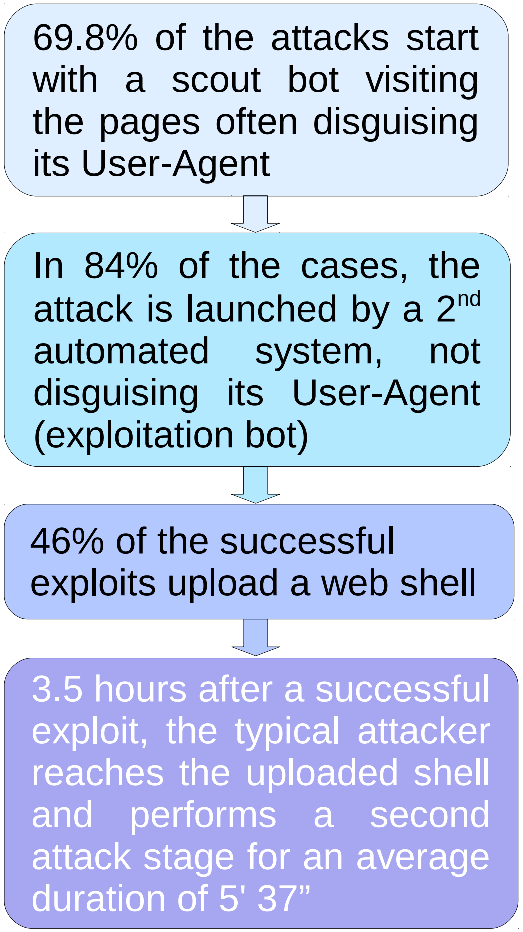
4. Post-Exploitation: second stage of the attack, usually carried out manually (optional)
   - Session identification, analysis of shell commands



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46% of the successful exploits upload a web shell

3.5 hours after a successful exploit, the typical attacker reaches the uploaded shell and performs a second attack stage for an average duration of 5' 37”

Attack analysis

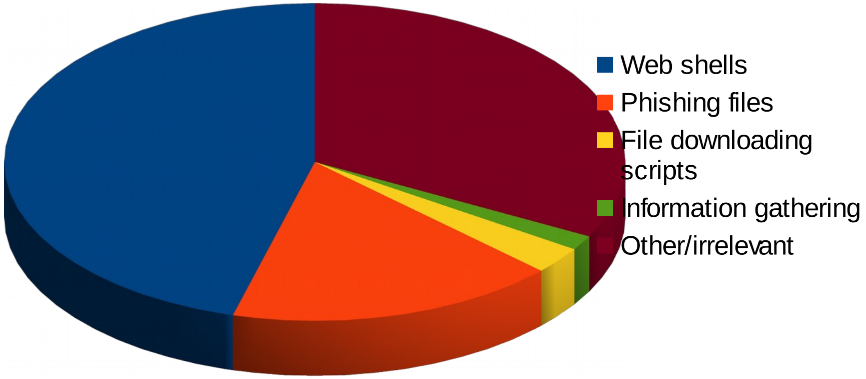
phases #1-2: discovery - reconnaissance

- Discovery: referer shows where visitors are coming from
  - Set in 50% of the cases
  - Attackers find our honeypots mostly from search engine queries (in the order: Google, Yandex, Bing, Yahoo)
    - Some visitors from 'hacking' search engines as well
  - Some visits from web mail services (spam or phishing victims) and social networks
- Reconnaissance: how were pages visited?
  - 84% of the malicious traffic was from automated systems
    - No images or style-sheets requested
    - Low inter-arrival time
    - Multiple subdomains visited within a short time frame
  - 6.8% of the requests mimicked the User-Agent string of known search engines

Attack analysis

phase #3: exploitation

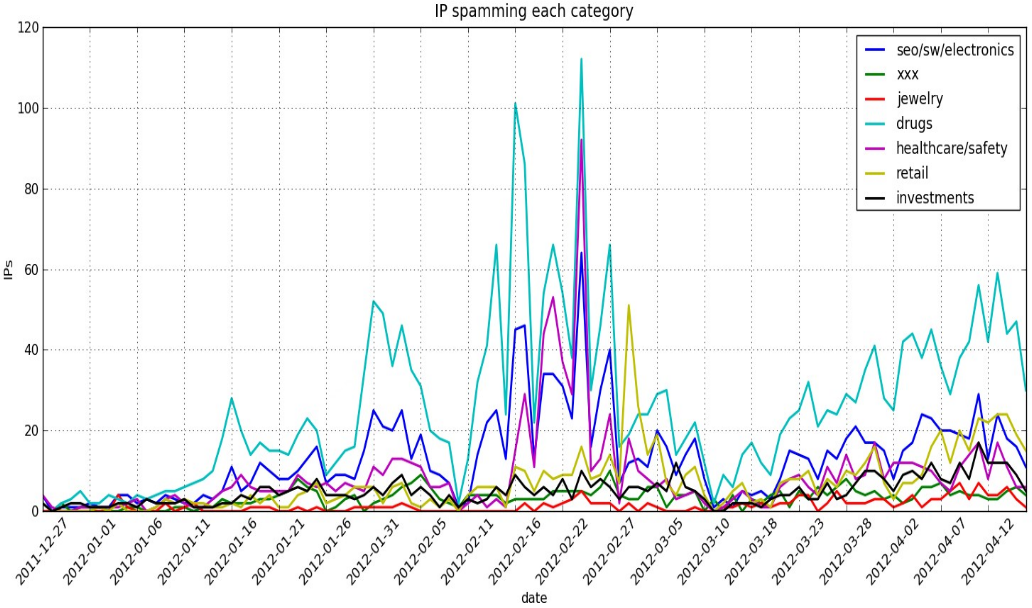
- We already know our applications' vulnerabilities
- 444 distinct exploitation sessions
  - Session = a set of requests that can be linked to the same origin, arriving within 5' from each other
  - 75% of the sessions used at least once '`libwww/perl`' as User-Agent string → scout bots and automatic attacks
- Almost one exploitation out of two uploaded a web shell, to continue the attack at a later stage (post-exploitation)



Attack analysis

phase #3: Forum activity

- Daily averages: 604 posts, 1907 registrations, 232 online users
  - One third of the IPs acting on the forum registered at least one account, but never posted any message → any business related to selling forum accounts?
- ~1% of the links posted to the forum led to malicious content[†]
- Geographical trends (active IPs)
  - 36.8% from the US
  - 24.6% from Eastern EU
- Simple message categorization
  - Keyword-based
  - Coverage: 93.5% of the forum posts (63,373)

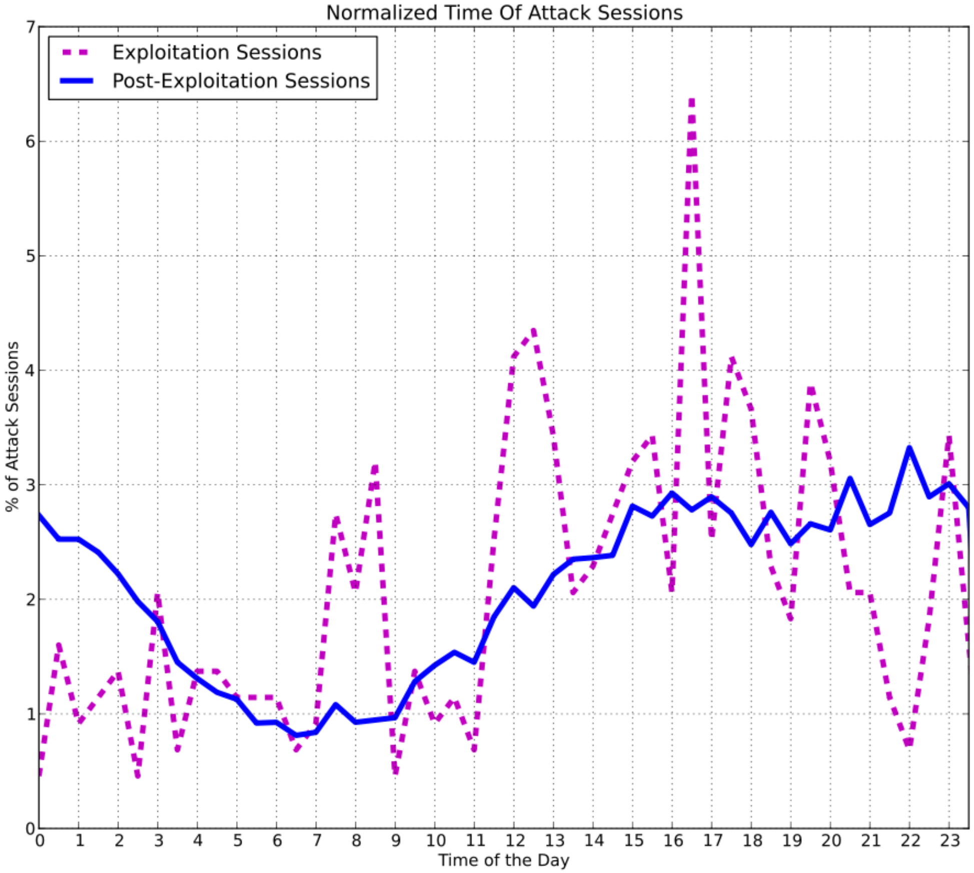


[†] According to Google SafeBrowsing and Wepawet

Attack analysis

phases #3-4

- Clear hourly trends for post-exploitation (manual) sessions



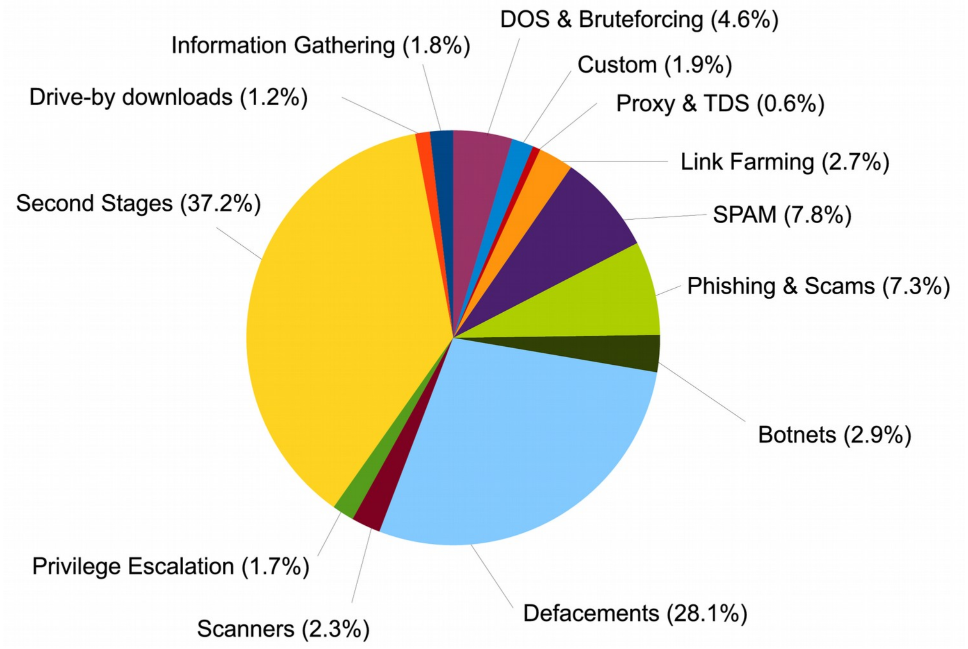
Attack analysis

phase #4: post-exploitation

- Almost 8500 interactive sessions collected
  - Known and unknown web shells
  - Average session duration: 5' 37”
    - 9 sessions lasting more than one hour
  - Parsed commands from the logs
    - 61% of the sessions upload a file to the system
    - 50% of the sessions (try to) modify existing files
      - Defacement in 13% of the cases

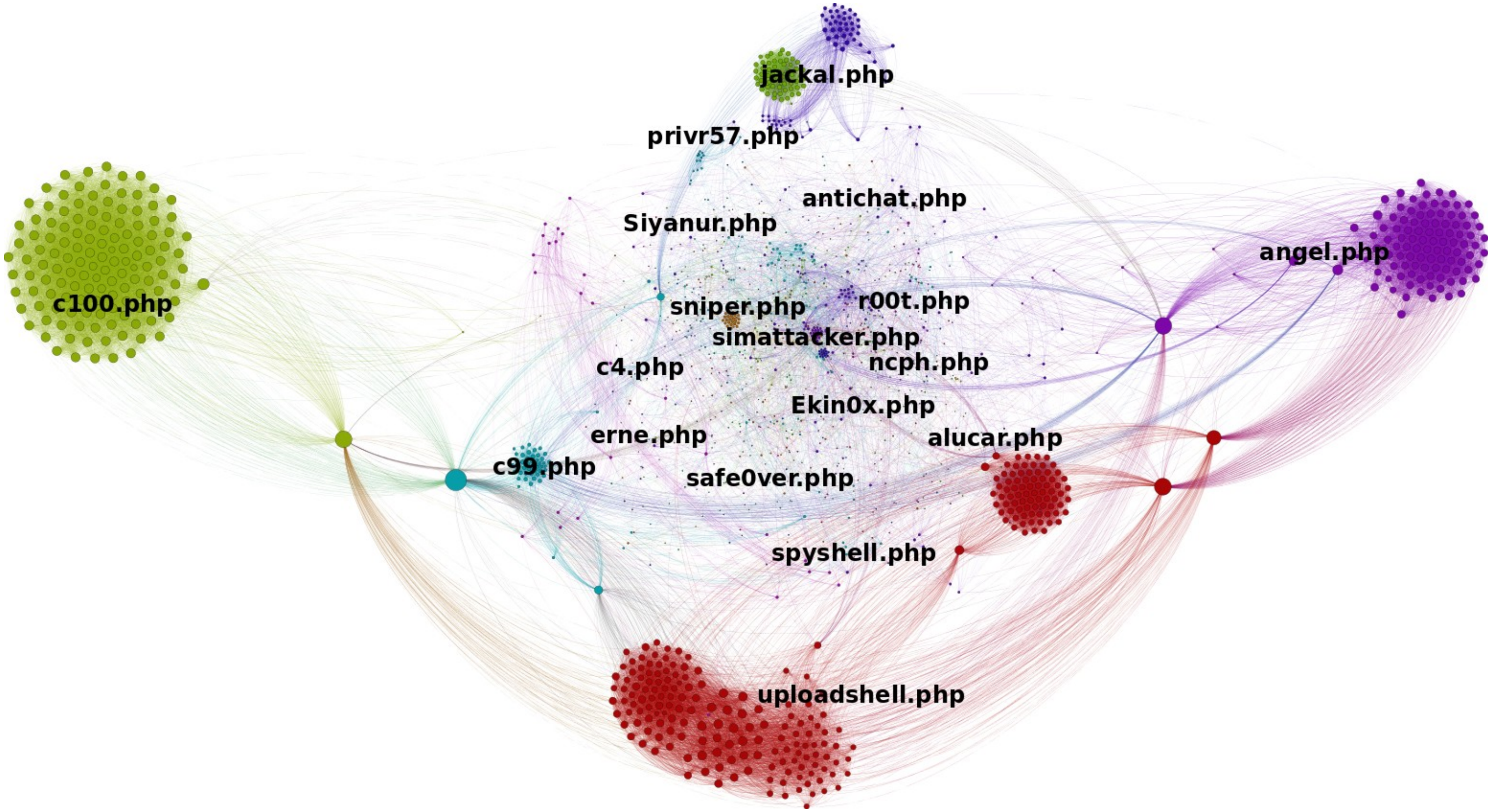
Attacker goals

- The analysis of collected files allows to understand the attackers' goals
  - » File normalization and similarity-based clustering
  - » Manual labeling of clusters



Clustering example

- Similarity clustering on web shells (ours are labeled)



Conclusions (so far)

- The study confirmed some known trends
  - Strong presence of Eastern European countries in spamming activities
  - Scam and phishing campaigns often run from African countries
  - Most common spam topic: pharmaceutical ads
- Unexpected results
  - High number of manual attacks
  - Many IRC botnets still around
  - Despite their low sophistication, these represent a large fraction of the attacks to which vulnerable websites are exposed every day

One surprising experience

- The honeypot proxies are hosted on various web hosting facilities
  - Many of them complain of the activity
  - At some point close our account

- We really don't do anything bad, we just get attacked!
  - How are they detecting this ?
  - Do they really care about their customer's security ?
  - That would be great !
- Let's check !

The Role of Web Hosting Providers in Detecting Compromised Websites

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WWW 2013

Motivations

- **Shared web hosting** is used by **millions of users**
  - Host personal and small business websites
  - Users often have little or no security background
  - Even experienced users have little control/visibility
- Millions of websites, unexperienced users, outdated/vulnerable web apps → **huge attack surface**!
- Hosting providers should play a key role in helping the user in case of a compromise
  - Is this the case?

Goal

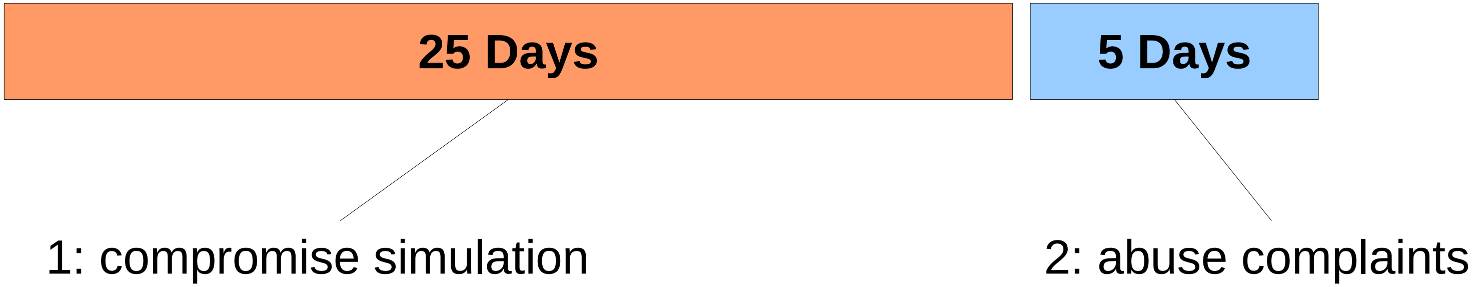
- Study how shared web hosting providers handle the security of their customers
  - By **detecting the compromise** of their websites
  - By testing their **reactions to abuse complaints**
- We also tested six **specialized security services**
  - Provided as an add-on for hosting accounts
  - Monitor security issues on websites
  - For a small fee

Testing methodology (1/2)

- **Register** multiple shared hosting accounts
- Install real web applications
- Simulate a number of **compromise scenarios**
  - Infected by botnet
  - Data exfiltration (SQL injection)
  - Phishing kit
  - Code inclusion (Drive-by-download)
  - Compromised account (upload of malicious files)
- **Tests** designed to be noisy and **easily detectable**

Testing methodology (2/2)

- Phase 1: observe the provider's reaction
- Phase 2: send **abuse complaints** regarding our websites
  - **Real complaints** about phishing and malicious executables
  - **Illegitimate complaints**, about offending or malicious content, while the account was clean



Ethical Issues

- We used real vulnerabilities, a real phishing kit, and a real drive-by javascript code
- But
  - we modified the sources to be **exploitable only by us** (special parameters)
  - **not indexable** by search engines (robot.txt)
  - malicious content was **not accessible from the web** or disabled

Tested Providers

- **12** among the **top global ones** (mostly US-based)
- **10 regional ones**
  - From Europe, US, India, Russia, Algeria, Hong Kong, Argentina, Indonesia

- 6 add-on security services
  - Less than 30 $/month subscription fee
  - Two come in *basic* and *pro* version
  - 10 days detection threshold
    (we expected them to be quick at detecting security issues)

Scenarios details

- Infected by botnet
- Data exfiltration (SQL injection)
- Phishing kit
- Code inclusion (Drive-by-download)
- Compromised account (upload of malicious files)

Bot Test Case

- Suspicious Network Activity: IRC Bot (**Bot**)

  Setup

  - Base OsCommerce installation (no modifications)
  - Two executable files (same IRC client, compiled for 32 and 64 bit architectures) and a PHP script executing the right binary depending on the machine's configuration
    - The IRC client connects to a fake IRC server (run by us), issues some IRC commands, and closes the connection

  Attack (run every hour)

  - Uploads the PHP file and the two binaries to the shared hosting account via FTP (case of an attacker using stolen credentials)
  - Launches the IRC client by issuing a request to the PHP page

SQL injection and Data Exfiltration (**SQLi**)

Setup

- OsCommerce installation mimicking a known SQL injection vulnerability
- Source code modified to return personal details and credit card numbers of fictious people

Attack (run every hour)

- Sequence of GET requests simulating an automated SQL injection tool enumerating entries in the 'customers' table of the CMS.
- Requests include several common SQL reserved words, to test if providers employ any keywork-based URL blacklisting

Remote File Upload of a Phishing Kit

Setup

- OsCommerce installation mimicking a known **Remote File Upload** vulnerability
- Performs the upload a real Bank of America **phishing kit** (disabled back-end code)

Attack

- *Attacker phase*, run every 6 hours: uploads the phishing kit by triggering the vulnerability
- *Victim phase,* every 15': simulates a victim falling prey of the phishing attack
  - The forms on the phishing pages are filled up with a set of fake personal details (manually pre-generated)

Compromised Account
(upload of known malicious files)

Setup

- Static HTML page with random English sentences and some pictures
- Two **known malicious files** (PHP and executable)
  - *c99.php*: a real c99 web shell
  - *sb.exe*: Ramnit worm
  - Both detected by most antiviruses

Attack

- **Uploads** the two malicious files to the shared hosting account **via FTP** (attacker using stolen credentials)
- Run every 6 hours

Web Shell

- File Upload and Code Injection using Web Shell (**SH**)

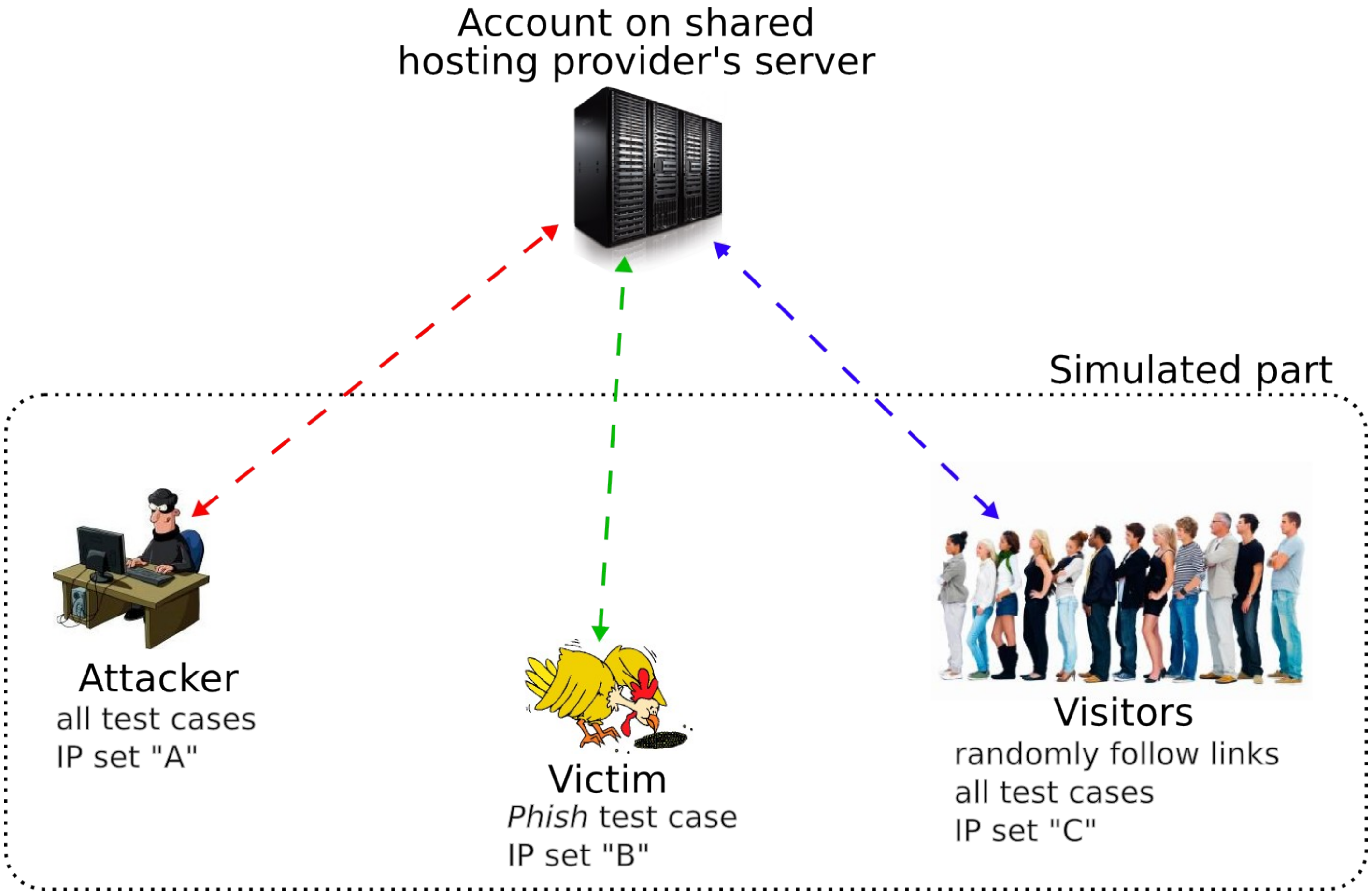
  Setup

  - OsCommerce installation mimicking a known Remote File Upload vulnerability
  - Source code modified to allow the file upload only when the request contains a secret keyword
    - We upload a known php web shell (c99)
  - The web shell is modified to allow only injecting some malicious drive-by code on the website's home page
    - Malicious JS code disabled by a dynamic check (still detected by AVs)

  Attack (run every hour)

  - Performs the upload of the web shell
  - simulates somebody using the the shell to access known files
  - injects the malicious drive-by download in the home page

Experiment scheme



Results

- Registration <= Surprise
- Attack prevention
- Compromise detection
- Response to abuse complaints

Results: registration

- Some providers **discourage abusive** user **registrations**
  - Phone calls, ID scan, 3rd party fraud protection services
- **Global providers** are **more cautious** than regional ones
  - 58% of them manually verified at least one of our accounts (10% for regional)
- **Three regional** providers have a very simple **“1-step” signup process**
  - Never verified our information upon registration

Results: prevention and detection

- Attack **prevention** measures work to some extent
  - **URL blacklists** to block SQL injections and File Uploads
    - SQLi, SH, Phish in ~30% of the cases
  - Connection and OS-level **filtering** are effective (Bot)
  - Some providers seem to employ the same (commercial) rule sets for blocking attacks

- Attack **detection results** are quite **disappointing**
  - **Only one provider** was able to detect **one** of our attacks
  - Received alert for **test AV after 17 days** it was running

Results

- **Prevention**

Tests	**SQLi**	**SH**	**Phish**	**Bot**	**AV**
Fully blocked	**0**	4	6	18	-
Partially blocked	7	2	0	2	-
Not blocked	13	**16**	16	2	-

Results: abuse complaints

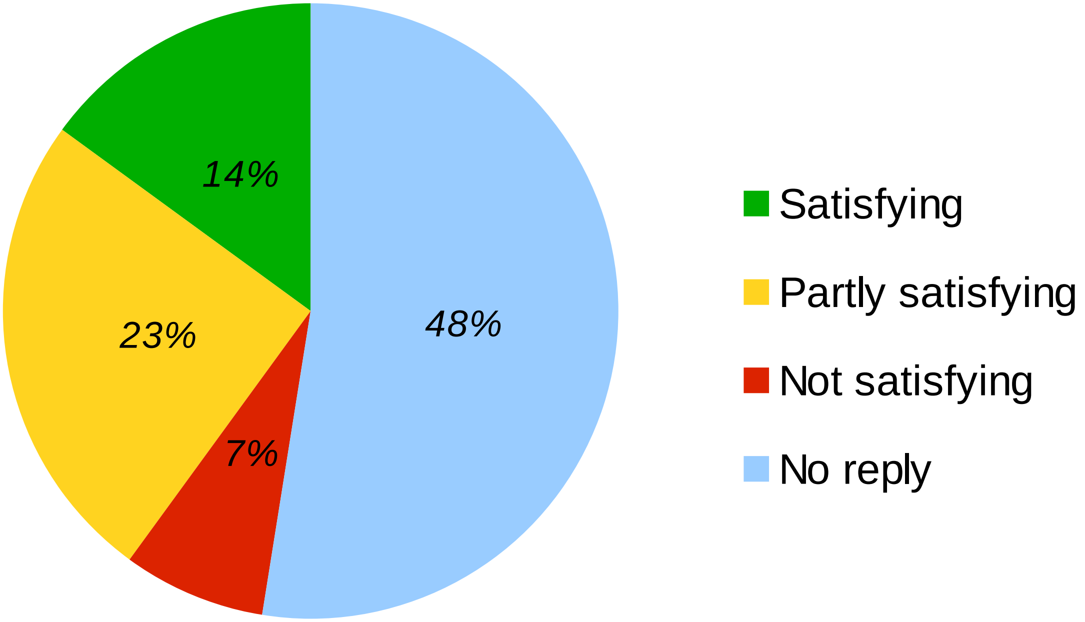
- **50%** of the tested providers **never replied** to any notification

- **64%** of the replies arrived **within one day** from the notification

- Average response delay:
  - **28h** for **global** providers
  - **79h** for **regional** providers

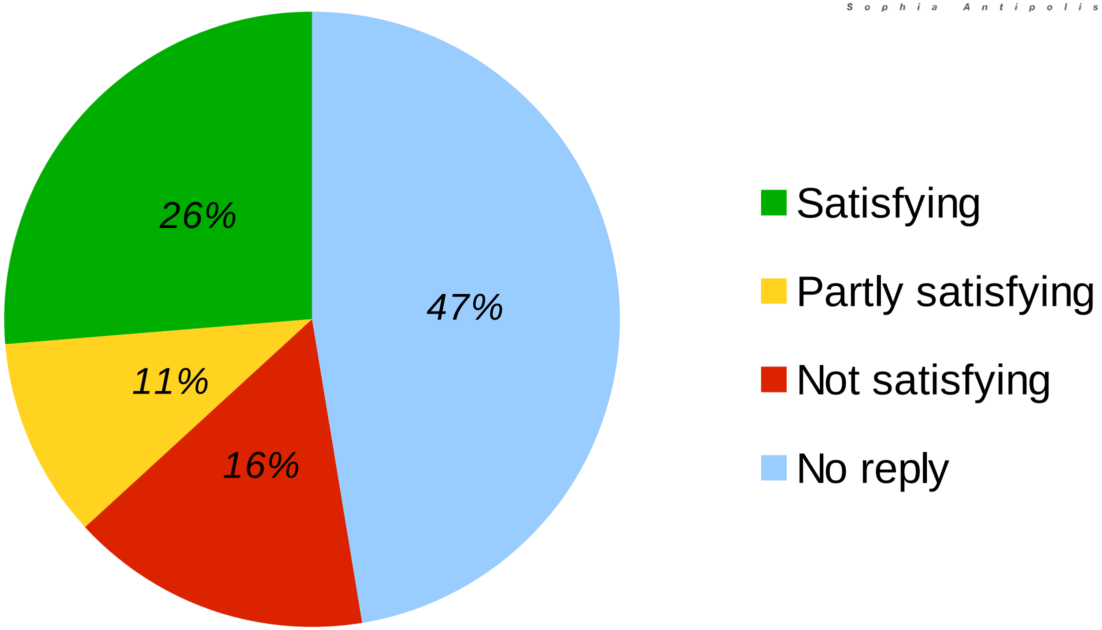
- Wide variety of reactions...

Real abuse notification handling



- **Only 3** providers **out of 22** handled them well
- Some **overreact** (e.g., two of them terminated the user's account)
  - Others sent an ultimatum to the user, but then did not check whether the user did anything to clean up the account

Illegitimate abuse notification handling



- **14** providers **out of 19** tested behaved well
  - » **Over estimation** (some did not answer)
- 3 (regional) providers believed the complaint without checking
  - – completely **wrong decisions** (e.g., account suspension, file removal)

Detection by Security add-on Services

- Some of the services we tested had a partnership with a **URL blacklisting service**

  → We intentionally got our malicious pages blacklisted

- **Five out of six** services did **not detect anything**

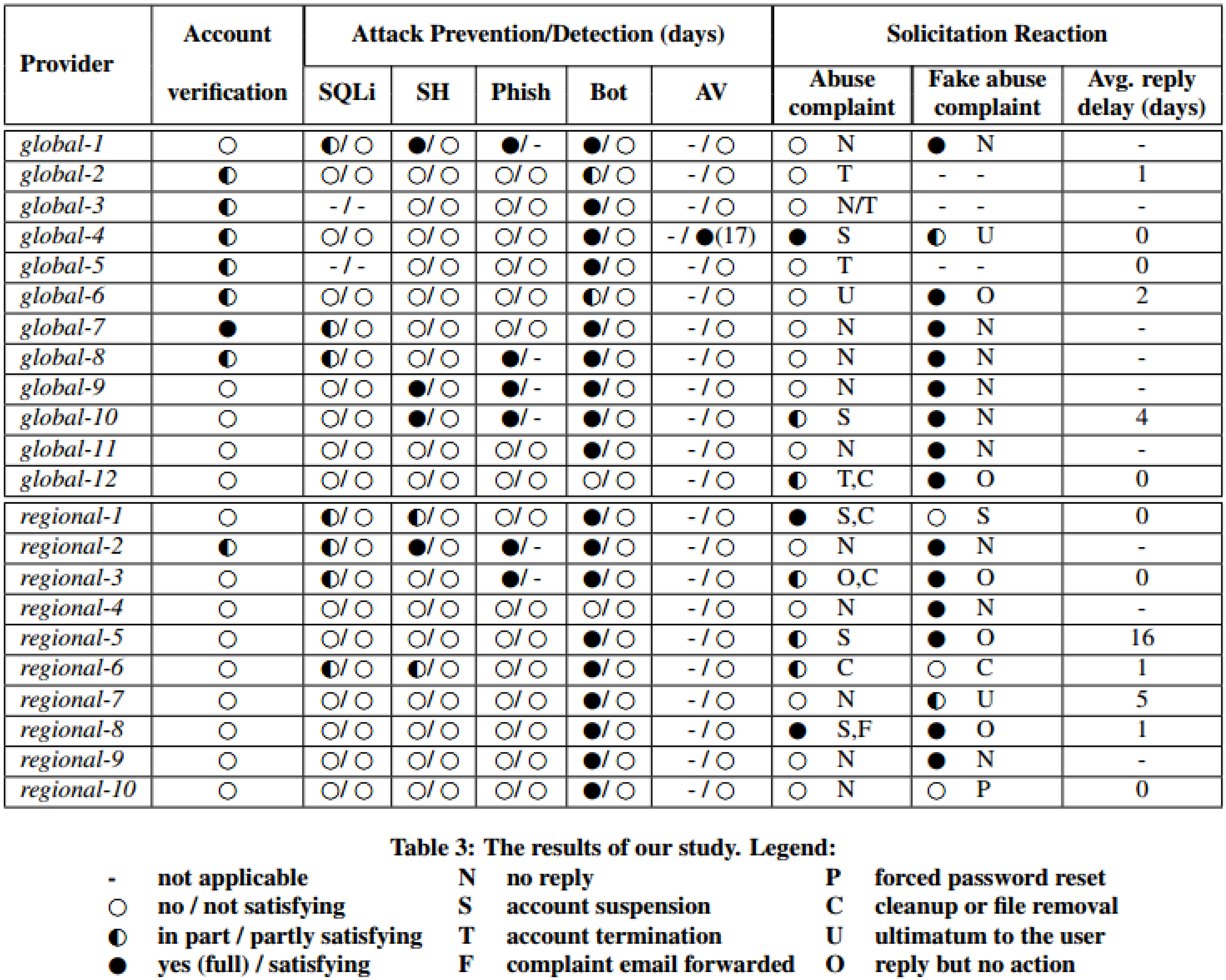
- One detected
  - the malicious files (through an antivirus scan)
    but they did **NOT notify the user**
  - the blacklisted malicious page

Conclusions

- Quite a **lot of effort** is spent in **preventing** malicious **registrations**
  - Especially from **global** providers
  - Revenue protection...
- Most providers employ **basic** mechanisms to **prevent** some kinds of **attack** (e.g., URL blacklists)
- Almost **zero effort** in **detecting obvious** signs of **compromise**
- **Cheap security services are useless**
- **Half of the companies responded** to complaints
  - Only 14% in the appropriate way

Thank you

?



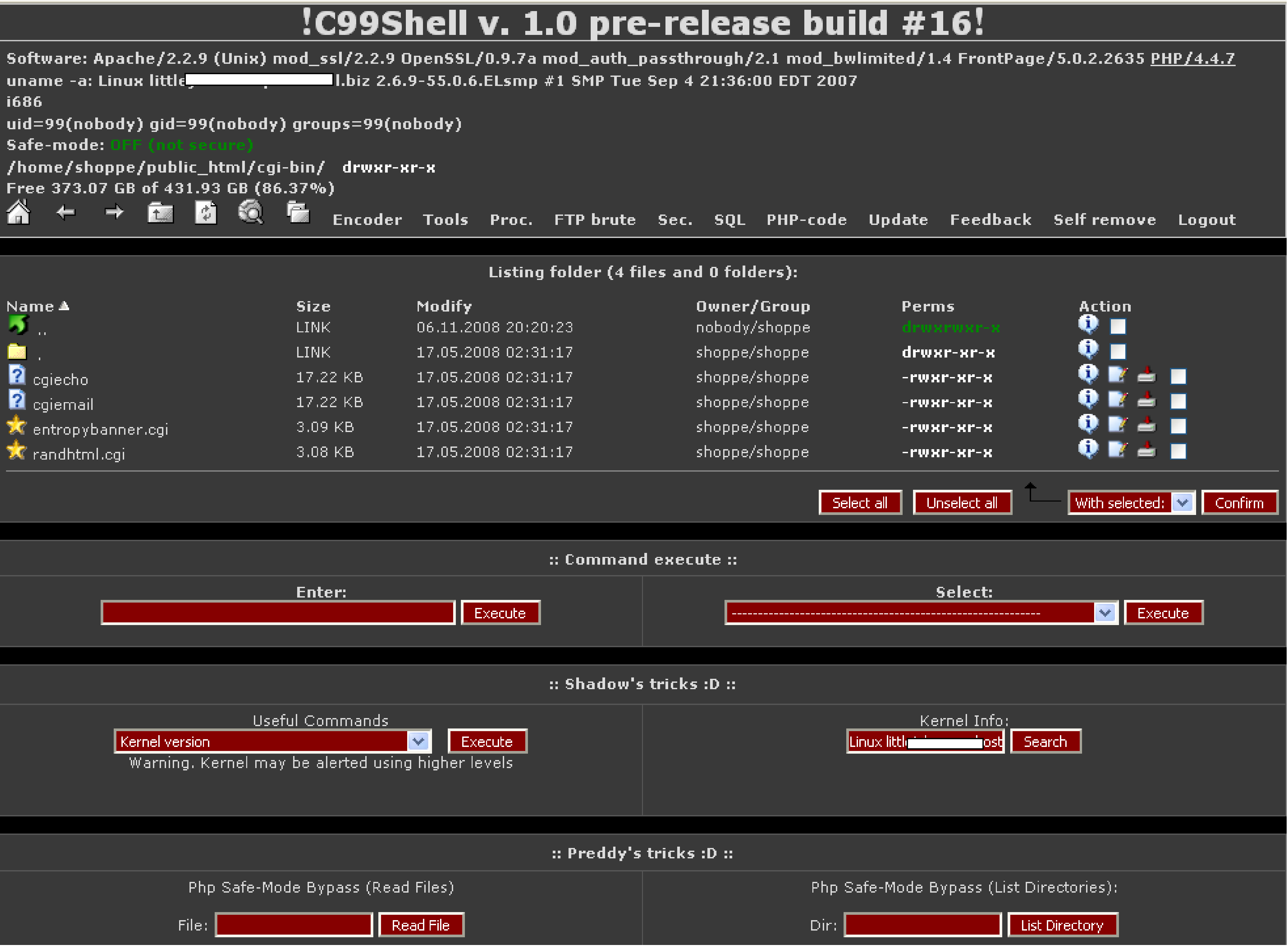
Provider	Account	Attack Prevention/Detection (days)					Solicitation Reaction		
	verification	SQLi	SH	Phish	Bot	AV	Abuse complaint	Fake abuse complaint	Avg. reply delay (days)
global-1	○	◐/ ○	●/ ○	●/ -	●/ ○	- / ○	○ N	● N	-
global-2	◐	○/ ○	○/ ○	○/ ○	◐/ ○	- / ○	○ T	- -	1
global-3	◐	- / -	○/ ○	○/ ○	●/ ○	- / ○	○ N/T	- -	-
global-4	◐	○/ ○	○/ ○	○/ ○	●/ ○	- / ●(17)	● S	◐ U	0
global-5	◐	- / -	○/ ○	○/ ○	●/ ○	- / ○	○ T	- -	0
global-6	◐	○/ ○	○/ ○	○/ ○	◐/ ○	- / ○	○ U	● O	2
global-7	●	◐/ ○	○/ ○	○/ ○	●/ ○	- / ○	○ N	● N	-
global-8	◐	◐/ ○	○/ ○	●/ -	●/ ○	- / ○	○ N	● N	-
global-9	○	○/ ○	●/ ○	●/ -	●/ ○	- / ○	○ N	● N	-
global-10	○	○/ ○	●/ ○	●/ -	●/ ○	- / ○	◐ S	● N	4
global-11	○	○/ ○	○/ ○	○/ ○	●/ ○	- / ○	○ N	● N	-
global-12	○	○/ ○	○/ ○	○/ ○	○/ ○	- / ○	◐ T,C	● O	0
regional-1	○	◐/ ○	◐/ ○	○/ ○	●/ ○	- / ○	● S,C	○ S	0
regional-2	◐	◐/ ○	●/ ○	●/ -	●/ ○	- / ○	○ N	● N	-
regional-3	○	◐/ ○	○/ ○	●/ -	●/ ○	- / ○	◐ O,C	● O	0
regional-4	○	○/ ○	○/ ○	○/ ○	○/ ○	- / ○	○ N	● N	-
regional-5	○	○/ ○	○/ ○	○/ ○	●/ ○	- / ○	◐ S	● O	16
regional-6	○	◐/ ○	◐/ ○	○/ ○	●/ ○	- / ○	◐ C	○ C	1
regional-7	○	○/ ○	○/ ○	○/ ○	●/ ○	- / ○	○ N	◐ U	5
regional-8	○	○/ ○	○/ ○	○/ ○	●/ ○	- / ○	● S,F	● O	1
regional-9	○	○/ ○	○/ ○	○/ ○	●/ ○	- / ○	○ N	● N	-
regional-10	○	○/ ○	○/ ○	○/ ○	●/ ○	- / ○	○ N	○ P	0

Table 3: The results of our study. Legend:

-	not applicable	N	no reply	P	forced password reset
○	no / not satisfying	S	account suspension	C	cleanup or file removal
◐	in part / partly satisfying	T	account termination	U	ultimatum to the user
●	yes (full) / satisfying	F	complaint email forwarded	O	reply but no action

Honeypot Websites

- Honeypot pages linked to our homepages in order to be easily reachable by search engine bots
  - Search engine indexing is a key factor for attracting automated (attack) bots
- Installed vulnerable apps:
  - Blog (Wordpress)
  - Forum (SMF)
  - E-commerce application (osCommerce)
  - Generic portal CMS (Joomla)
  - Database management CMS (phpMyAdmin)
  - 17 common PHP web shells + static website (defacements)



!C99Shell v. 1.0 pre-release build #16!

```
Software: Apache/2.2.9 (Unix) mod_ssl/2.2.9 OpenSSL/0.9.7a mod_auth_passthrough/2.1 mod_bwlimited/1.4 FrontPage/5.0.2.2635 PHP/4.4.7
uname -a: Linux little[redacted]l.biz 2.6.9-55.0.6.ELsmp #1 SMP Tue Sep 4 21:36:00 EDT 2007
i686
uid=99(nobody) gid=99(nobody) groups=99(nobody)
Safe-mode: OFF (not secure)
/home/shoppe/public_html/cgi-bin/  drwxr-xr-x
Free 373.07 GB of 431.93 GB (86.37%)
```

Listing folder (4 files and 0 folders):

Name ▲	Size	Modify	Owner/Group	Perms	Action
..	LINK	06.11.2008 20:20:23	nobody/shoppe	drwxrwxr-x	□
.	LINK	17.05.2008 02:31:17	shoppe/shoppe	drwxr-xr-x	□
cgiecho	17.22 KB	17.05.2008 02:31:17	shoppe/shoppe	-rwxr-xr-x	□
cgiemail	17.22 KB	17.05.2008 02:31:17	shoppe/shoppe	-rwxr-xr-x	□
entropybanner.cgi	3.09 KB	17.05.2008 02:31:17	shoppe/shoppe	-rwxr-xr-x	□
randhtml.cgi	3.08 KB	17.05.2008 02:31:17	shoppe/shoppe	-rwxr-xr-x	□

:: Command execute ::

Enter:

Select: --

:: Shadow's tricks :D ::

Useful Commands: Kernel version

Warning. Kernel may be alerted using higher levels

Kernel Info: Linux littl[redacted]ost

:: Preddy's tricks :D ::

Php Safe-Mode Bypass (Read Files)

File:

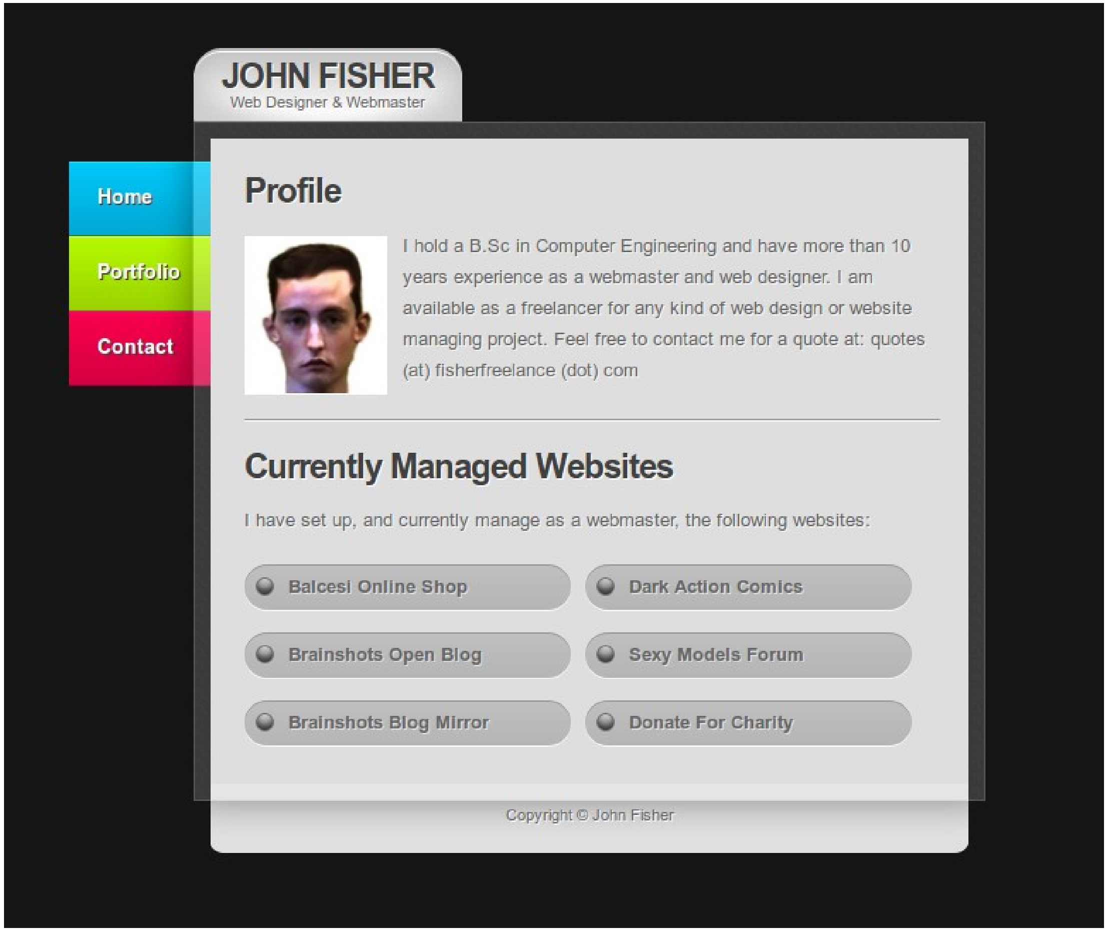
Php Safe-Mode Bypass (List Directories):

Dir:

Containment

- Avoid external exploitation and privilege escalations
  - Only 1 service (apache) exposed to the Internet
    - run as unprivileged user
  - Up to date software and security patches
- Avoid using the honeypot as a stepping stone for attacks
  - Blocked all outgoing traffic (except for IRC)
- Avoid hosting illegal content (mitigated)
  - Preventing the modification of directories, html and php files (chmod)
  - Regular restore of each VM to its original snapshot
- Avoid promoting illegal goods or services
  - Code showing content of user posts and comments commented out for each CMS
    - users and search engines are shown blank messages

Home page



JOHN FISHER
Web Designer & Webmaster

Profile

I hold a B.Sc in Computer Engineering and have more than 10 years experience as a webmaster and web designer. I am available as a freelancer for any kind of web design or website managing project. Feel free to contact me for a quote at: quotes (at) fisherfreelance (dot) com

Currently Managed Websites

I have set up, and currently manage as a webmaster, the following websites:

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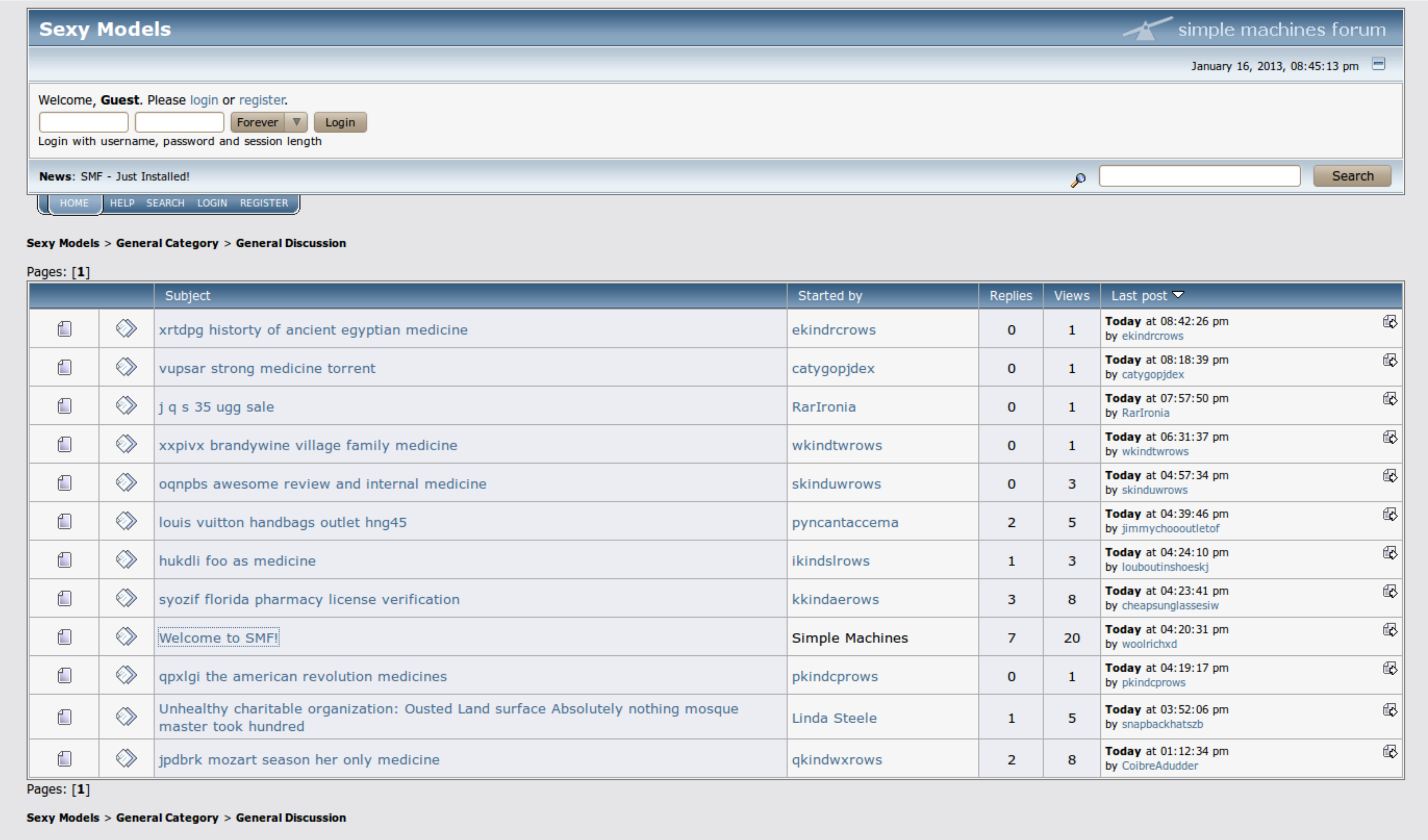
Forum



Sexy Models

January 16, 2013, 08:45:13 pm

Welcome, **Guest**. Please login or register.

Login with username, password and session length

News: SMF - Just Installed!

Sexy Models > **General Category** > **General Discussion**

Pages: [**1**]

		Subject	Started by	Replies	Views	Last post
		xrtdpg historty of ancient egyptian medicine	ekindrcrows	0	1	**Today** at 08:42:26 pm by ekindrcrows
		vupsar strong medicine torrent	catygopjdex	0	1	**Today** at 08:18:39 pm by catygopjdex
		j q s 35 ugg sale	RarIronia	0	1	**Today** at 07:57:50 pm by RarIronia
		xxpivx brandywine village family medicine	wkindtwrows	0	1	**Today** at 06:31:37 pm by wkindtwrows
		oqnpbs awesome review and internal medicine	skinduwrows	0	3	**Today** at 04:57:34 pm by skinduwrows
		louis vuitton handbags outlet hng45	pyncantaccema	2	5	**Today** at 04:39:46 pm by jimmychooooutletof
		hukdli foo as medicine	ikindslrows	1	3	**Today** at 04:24:10 pm by louboutinshoeskj
		syozif florida pharmacy license verification	kkindaerows	3	8	**Today** at 04:23:41 pm by cheapsunglassesiw
		Welcome to SMF!	Simple Machines	7	20	**Today** at 04:20:31 pm by woolrichxd
		qpxlgi the american revolution medicines	pkindcprows	0	1	**Today** at 04:19:17 pm by pkindcprows
		Unhealthy charitable organization: Ousted Land surface Absolutely nothing mosque master took hundred	Linda Steele	1	5	**Today** at 03:52:06 pm by snapbackhatszb
		jpdbrk mozart season her only medicine	qkindwxrows	2	8	**Today** at 01:12:34 pm by CoibreAdudder

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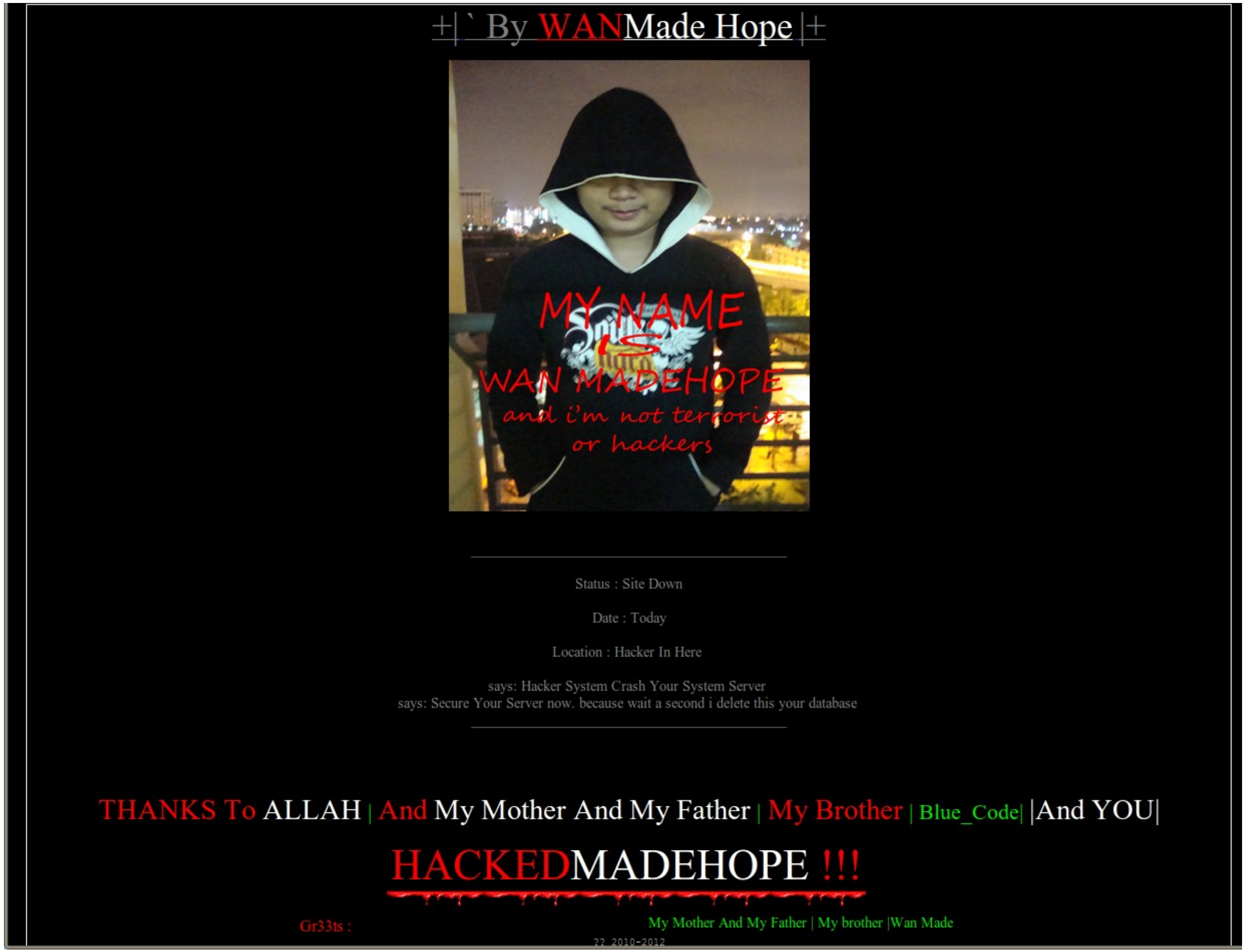
Defacement



+|` By WANMade Hope |+

Status : Site Down

Date : Today

Location : Hacker In Here

says: Hacker System Crash Your System Server
says: Secure Your Server now. because wait a second i delete this your database

THANKS To ALLAH | And My Mother And My Father | My Brother | Blue_Code| |And YOU|

HACKEDMADEHOPE !!!

Gr33ts : My Mother And My Father | My brother |Wan Made

?? 2010-2012

Conclusions

- Need for a better protection of shared hosting accounts
  - Shared hosting is where most of the web attacks and malware campaigns spread
  - Everybody would benefit from providers adopting stronger security measures
    - … whether or not security scans/IDS systems are part of their TOS (often not the case)
  - We showed this can be easily accomplished even by using common open source solutions
    - Effective and easy to deploy

Legal

- The TOS of tested providers did not include anything related to detecting and notifying customers about compromises of their websites
  - The client can't do almost anything to protect himself, the provider is the only one who can

Test case detection by state-of-the-art tools

Test	SQLi	SH	Phish	Bot	AV
ModSecurity base rule set	🟢	🟢	🟢	🟢	-
ModSecurity OWASP rule set	🔴	🟡	🟢	🟢	-
High severity IDS alerts	⚠ (5)	⚠ (2)	⚠ (2)	0	0
Antivirus detection	🟢	🔴	🟢	🟢	🔴

Tests executed against an installation of SecurityOnion Linux, which includes, among other tools, the Bro IDS, Snort and Sguil.