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

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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 x

- 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 by country (excluding known crawlers)

- Color intensity is logarithmic!
- IPs from the USA, Russia and Ukraine account for 65% of the total requests
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
1. **Discovery**: how attackers find their targets
   - Referer analysis, dorks used to reach our websites, first suspicious activities

2. **Reconnaissance**: how pages were visited
   - Automated systems and crawling patterns identification, User-Agent analysis

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

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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3. **Exploitation**: attack against the vulnerable web app
   - Exploits detection and analysis, exploitation sessions, uploaded files categorization, and attack time/location normalization
   - Analysis of forum activities: registrations, posts and URLs, geolocation, message categories

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**Attack analysis**

The four different phases

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

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46% of the successful exploits upload a web shell
Attack analysis
The four different phases

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   - Exploits detection and analysis, exploitation sessions, uploaded files categorization, and attack time/location normalization
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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

![Pie chart with various attacker goals]

- Second Stages (37.2%)
- Defacements (28.1%)
- Phishing & Scams (7.3%)
- SPAM (7.8%)
- Link Farming (2.7%)
- Proxy & TDS (0.6%)
- Custom (1.9%)
- DOS & Bruteforcing (4.6%)
- Privilege Escalation (1.7%)
- Scanners (2.3%)
- Botnets (2.9%)
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

25 Days

1: compromise simulation

5 Days

2: abuse complaints
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 fictitious 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 keyword-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

Attacker
- all test cases
- IP set "A"

Victim
- Phish test case
- IP set "B"

Visitor
- randomly follow links
- all test cases
- IP set "C"

Account on shared hosting provider's server
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**

<table>
<thead>
<tr>
<th>Tests</th>
<th>SQLi</th>
<th>SH</th>
<th>Phish</th>
<th>Bot</th>
<th>AV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully blocked</td>
<td>0</td>
<td>4</td>
<td>6</td>
<td>18</td>
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<tr>
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<tr>
<td>Not blocked</td>
<td>13</td>
<td>16</td>
<td>16</td>
<td>2</td>
<td>-</td>
</tr>
</tbody>
</table>
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
<table>
<thead>
<tr>
<th>Provider</th>
<th>Account verification</th>
<th>Attack Prevention/Detection (days)</th>
<th>Solicitation Reaction</th>
<th>Avg. reply delay (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SQLi</td>
<td>SH</td>
<td>Phish</td>
</tr>
<tr>
<td>global-1</td>
<td>○</td>
<td>●/○</td>
<td>●/○</td>
<td>●/-</td>
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<tr>
<td>global-2</td>
<td>○</td>
<td>○/○</td>
<td>○/○</td>
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<td>global-3</td>
<td>○</td>
<td>●/-</td>
<td>○/○</td>
<td>○/○</td>
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<td>global-4</td>
<td>○</td>
<td>○/○</td>
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<td>global-5</td>
<td>○</td>
<td>●/-</td>
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<td>global-6</td>
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<td>global-7</td>
<td>●</td>
<td>○/○</td>
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<td>●/○</td>
<td>●/-</td>
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<td>○/○</td>
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<td>○</td>
<td>○/○</td>
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</table>

Table 3: The results of our study. Legend:

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

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)fisherfreelanco(dot)com

Currently Managed Websites

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

- Balcesi Online Shop
- Dark Action Comics
- Brainshots Open Blog
- Sexy Models Forum
- Brainshots Blog Mirror
- Donate For Charity

Copyright © John Fisher
Forum
Defacement

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

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>ModSecurity base rule set</td>
<td><img src="Green" alt="Green" /></td>
<td><img src="Green" alt="Green" /></td>
<td><img src="Green" alt="Green" /></td>
<td><img src="Green" alt="Green" /></td>
<td>-</td>
</tr>
<tr>
<td>ModSecurity OWASP rule set</td>
<td><img src="Red" alt="Red" /></td>
<td><img src="Yellow" alt="Yellow" /></td>
<td><img src="Green" alt="Green" /></td>
<td><img src="Green" alt="Green" /></td>
<td>-</td>
</tr>
<tr>
<td>High severity IDS alerts</td>
<td><img src="Warning" alt="Warning" /> (5)</td>
<td><img src="Warning" alt="Warning" /> (2)</td>
<td><img src="Warning" alt="Warning" /> (2)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Antivirus detection</td>
<td><img src="Green" alt="Green" /></td>
<td><img src="Red" alt="Red" /></td>
<td><img src="Green" alt="Green" /></td>
<td><img src="Green" alt="Green" /></td>
<td><img src="Red" alt="Red" /></td>
</tr>
</tbody>
</table>

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