# America's 4 Most Wanted Botnets

<table>
<thead>
<tr>
<th>Botnet Name</th>
<th>No. of Compromised Computers (US)</th>
<th>Description</th>
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</table>
| Zeus              | 3.6M                             | • Key-logging techniques to steal sensitive data  
• Injects fake HTML forms into online banking login pages to steal user data                                    |
| Koobface          | 2.9M                             | • Spreads via social networking sites with faked messages  
• Entices user to download codec (malware) to view video |
| TidServ           | 1.5M                             | • Spreads through spam e-mail as attachment.  
• It uses rootkit techniques to run inside common Windows services or in Windows safe mode.      |
| Trojan.Fakeavalert| 1.4M                             | • Formerly used for spamming  
• Shifted to downloading other malware                                                                       |

Source: NetworkWorld.com (July 22, 2009)
Spamalytics: An Empirical Analysis of Spam Marketing Conversion

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Summarized by Gaspar Modelo-Howard
Abstract

• Measurement study on the “conversion rate” of spam campaigns
  – Probability that an unsolicited email will elicit a “sale”
• Present a methodology using Botnet infiltration
• Analyze two spam campaigns
  – Trojan propagation
  – Online pharmaceutical marketing
• For more than 469M spam emails, authors identified
  – Number that pass thru anti-spam filters
  – Number that elicit use visits to advertised sites (response rate)
  – Number of “sales” and “infections” produced (conversion rate)
Agenda

• Introduction
• Storm Botnet
• Methodology
• Experimental Results
• Conclusions
Introduction (1)

• Hard to find person who admits to follow spams “offers”, but spam continually clogs mail servers
  – Despite years of energetic deployment of antispam technology
  – Someone must be buying
  – Key questions: how many, how often, how much?

• Problem is limited visibility into basic parameters of spam value proposition
  – Cost to send spam
  – *Probability that email sent will yield a “sale” (conversion rate)*
  – Marginal profit per sale
Introduction (2)

- There are no apparent methods for indirectly measuring spam conversion
  - Best way is to be a spammer
- Authors conducted study by “sidestepping the obvious legal and ethical problems associated with sending spam”
  - Ensuring neutral actions so users never are worse off due to researchers activities
  - Reducing harm for cases in which user property is at risk
- Method: infiltrate existing spamming botnet, modifying sent spam and directing recipients to authors’ websites
Storm Botnet (1)

- P2P botnet that propagates via spam
- Uses two protocols
  - Encrypted version of UDP-based Overnet protocol, based on Kademlia DHT (directory service)
  - Custom TCP-based protocol (C&C)
- Overnet-base protocol messages
  1. Connect
     - During bootstrap phase, node has an initial list of peer
     - Chooses OID pseudo-randomly from 128-bit address space
     - Connects to all peers in list, each available peer returns its own list
     - Node repeats steps for a few rounds
  2. Publicize
     - To let other peers know about its presence
     - Periodically searching for own OID to stay connected and learn about new close-by peers
Storm Botnet (2)

• Overnet-base protocol messages
  3. Search: Export a standard DHT (key.value) pair interface
  4. Publish: DHT keys encode a dynamically changing rendezvous code, to find others on demand

• Bot generates three keys simultaneously: previous, current and next date
  – System clock is set using NTP
  – Keys are used to connect to nodes offering C&C channel

• C&C nodes include their address and port into value and publishes pair to peers close to key
Storm Botnet (3)

- Three classes of Storm nodes
  - Worker bots
  - Proxy bots
  - Master servers
- Very small number of master servers
- If a infected host can be reached externally, becomes proxy
- C&C is pull-based, worker bots request jobs

Figure 1: The Storm botnet hierarchy.
Storm Botnet (4)

• **Spam engine in detail**
  – Bot checks if can reach SMTP server of Web-based mail provider
    • If fails, will remain active but no spam campaigns
  – If successful, finds proxy (using time-varying protocol) and sends update request (via proxy) to master
  – Master responds with spam workload task, which consists of
    • Spam template (use custom macro languages for poly messages)
    • Delivery list of e-mail addresses
    • Set of named “dictionaries”
  – Bot sends unique message for each address to its MX
    • After exhausting list, request two additional spam workloads
    • Then sends a delivery report to proxy (e-mail of recipient if successful)
Methodology (1)

- Based on botnet infiltration
  - Passively observing commands/data and actively changing elements when appropriate
- 8 proxies with gateway
  - Allows for blocking unanticipated behaviors
  - Parsing/rewriting C&C messages to bots
Methodology (2)

• **C&C protocol rewriting**
  – Click-based network element redirects potential C&C traffic to fixed IP address and port
  – User-space proxy server accepts incoming connections and impersonates the proxy bots
  – Click element injects SOCKS-style destination header into flows to associate connections

• **Measuring spam delivery**
  – Created collections of test e-mail accounts from Webmail providers, own organization (filtering appliance), and SMTP “sinks” (for control purposes)
  – Rewriter appends these addresses to workloads requests and removes them from success reports
  – E-mail accounts were periodically poll
Methodology (2)

- **Measuring click-through and conversion**
  - Study focuses on two types of campaigns, self-propagation (rogue postcard sw) and pharmacy site, representing 40% of Storm activity
  - Rewriter replaces any dictionaries with entries only containing URLs to researchers’ servers
  - Created two sites to mimic those used in campaigns
    - Pharmacy: no personal/payment information captured
    - Self-propagation: offers benign executable
    - Both sites logged all accesses and activity
Methodology (2)

• Separating users from crawlers
  – Several heuristics created to filter automated or semiautomated processes that visit sites, using blacklist
    • Hosts that access pharmacy site without using unique identifier
    • Hosts that access robots.txt
    • Hosts that make malformed requests
    • Hosts that disable javascript and do not load embedded images
    • IP addresses accessing pharmacy site with more than one unique identifier and same User-Agent field
    • Hosts that request downloaded postcard executable ten or more times
    • Hosts connecting to rogue IP addresses added to self-propagation dictionary
Methodology (3)

• Screenshot of Pharmaceutical website, operated to measure user click-through and conversion
Experimental Results (1)

- Campaign datasets

Figure 4: Number of e-mail messages assigned per hour for each campaign.

<table>
<thead>
<tr>
<th>Campaign</th>
<th>Dates</th>
<th>Workers</th>
<th>E-mails</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pharmacy</td>
<td>Mar 21 – Apr 15</td>
<td>31,348</td>
<td>347,590,389</td>
</tr>
<tr>
<td>Postcard</td>
<td>Mar 9 – Mar 15</td>
<td>17,639</td>
<td>83,665,479</td>
</tr>
<tr>
<td>April Fool</td>
<td>Mar 31 – Apr 2</td>
<td>3,678</td>
<td>38,651,124</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>469,906,992</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Campaigns used in the experiment.

Figure 5: Timeline of proxy bot workload.

Table 2: The 10 most-targeted e-mail address domains and their frequency in the combined lists of targeted addresses over all three campaigns.
Experimental Results (2)

- Spam conversion pipeline

![Spam conversion pipeline diagram]

**Figure 6:** The spam conversion pipeline.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Pharmacy</th>
<th>Postcard</th>
<th>April Fool</th>
</tr>
</thead>
<tbody>
<tr>
<td>A – Spam Targets</td>
<td>347,590,389 (100%)</td>
<td>83,655,479 (100%)</td>
<td>40,135,487 (100%)</td>
</tr>
<tr>
<td>B – MTA Delivery (est.)</td>
<td>82,700,000 (23.8%)</td>
<td>21,100,000 (25.2%)</td>
<td>10,100,000 (25.2%)</td>
</tr>
<tr>
<td>C – Inbox Delivery</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>D – User Site Visits</td>
<td>10,522 (0.00303%)</td>
<td>3,827 (0.00457%)</td>
<td>2,721 (0.00680%)</td>
</tr>
<tr>
<td>E – User Conversions</td>
<td>28 (0.0000081%)</td>
<td>316 (0.000378%)</td>
<td>225 (0.000561%)</td>
</tr>
</tbody>
</table>

Table 3: Filtering at each stage of the spam conversion pipeline for the self-propagation and pharmacy campaigns. Percentages refer to the conversion rate relative to Stage A.
Experimental Results (3)

• Time to click

Figure 7: Time-to-click distributions for accesses to the pharmacy site.
Effects of Blacklisting

Figure 8: Change in per-domain delivery rates as seen prior to a worker bot appearing in the blacklist (x-axis) vs. after appearing (y-axis). Each circle represents a domain targeted by at least 1,000 analyzable deliveries, with the radius scaled in proportion to the number of delivery attempts.
Conversion Rate Analysis (1)

• Geographic location of “conversion” hosts
  – 541 that executed self-propagation program (gray nodes)
  – 28 that visited purchase page (black nodes)
Conversion Rate Analysis (2)

Figure 10: Volume of e-mail targeting (x-axis) vs. responses (y-axis) for the most prominent country-code TLDs. The x and y axes correspond to Stages A and D in the pipeline (Figure 6), respectively.

Figure 11: Response rates (stage D in the pipeline) by TLD for executable download (x-axis) vs. pharmacy visits (y-axis).
Conclusions

• Large-scale quantitative study of spam conversion
  – Results represent a single data point and are not necessarily representative of spam as a whole
• Study helps debunk some unscientific claims related to underground economy
• After 26 days, 350 million e-mail messages, only 28 sales resulted
  – Conversation rate: 0.00001% $\rightarrow$ revenues of $2731.88$
  – Study proxy 1.5% of bots $\rightarrow$ $7000$ to $9500$ per day
• Storm campaigns can produce between 3500 and 8500 new bot per day (estimated)