America's 4 Most Wanted Botnets

Botnet Name	No. of Compromised Computers (US)	Description
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

Chris Kanich, Christian Kreibich, Kirill Levchenko, Brandon Enright, Geoffrey Voelker, Vern Paxson, Stefan Savage

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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

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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 a 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
  4. Publish

  } Export a standard DHT (key.value) pair interface
- 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

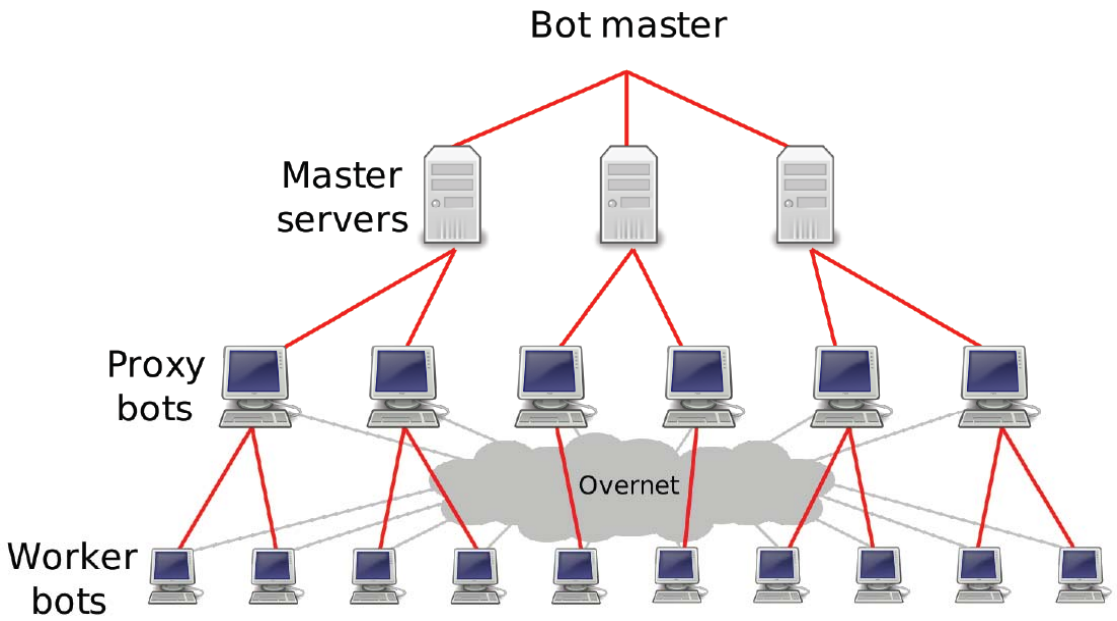


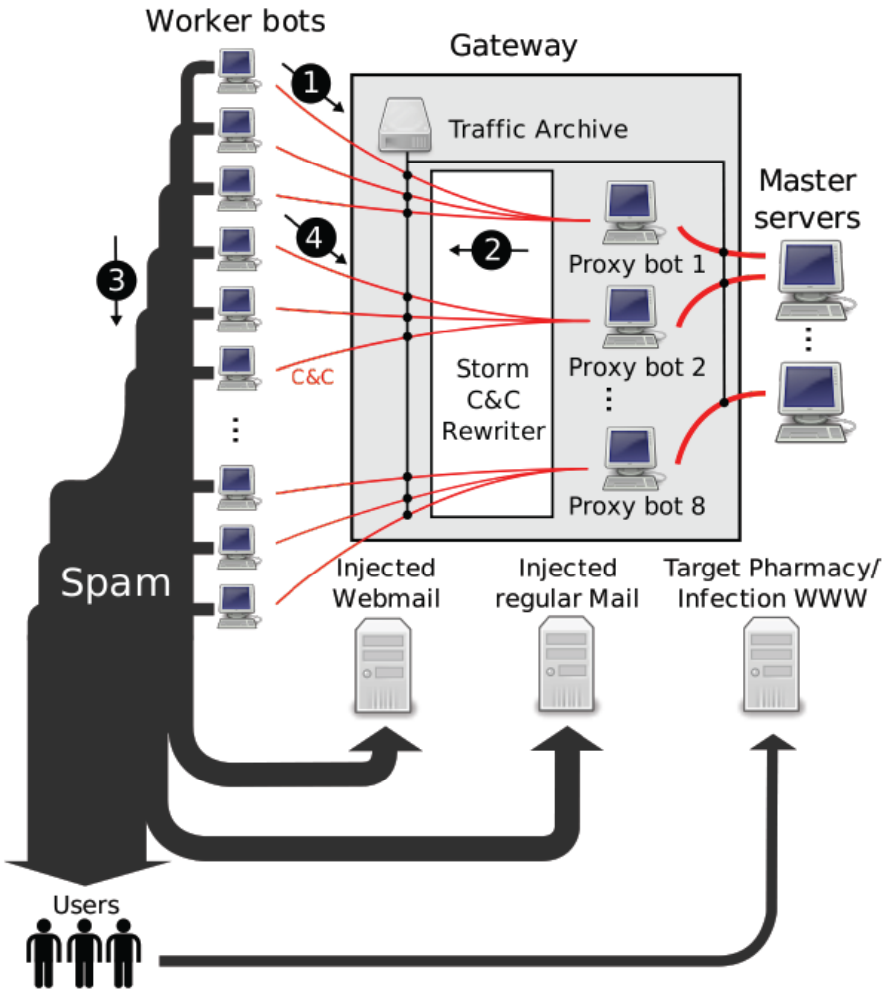
Figure 1: The Storm botnet hierarchy.

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

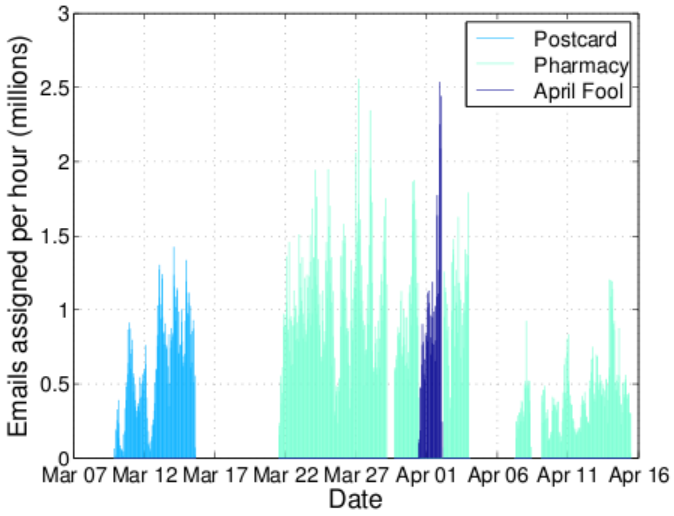


Figure 4: Number of e-mail messages assigned per hour for each campaign.

CAMPAIGN	DATES	WORKERS	E-MAILS
Pharmacy	Mar 21 – Apr 15	31,348	347,590,389
Postcard	Mar 9 – Mar 15	17,639	83,665,479
April Fool	Mar 31 – Apr 2	3,678	38,651,124
		Total	469,906,992

Table 1: Campaigns used in the experiment.

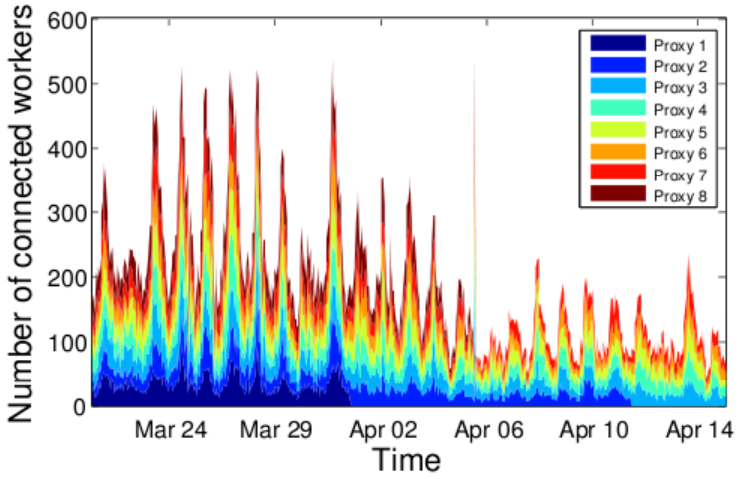


Figure 5: Timeline of proxy bot workload.

DOMAIN	FREQ.
hotmail.com	8.47%
yahoo.com	5.05%
gmail.com	3.17%
aol.com	2.37%
yahoo.co.in	1.13%
sbcglobal.net	0.93%
mail.ru	0.86%
shaw.ca	0.61%
wanadoo.fr	0.61%
msn.com	0.58%
Total	23.79%

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

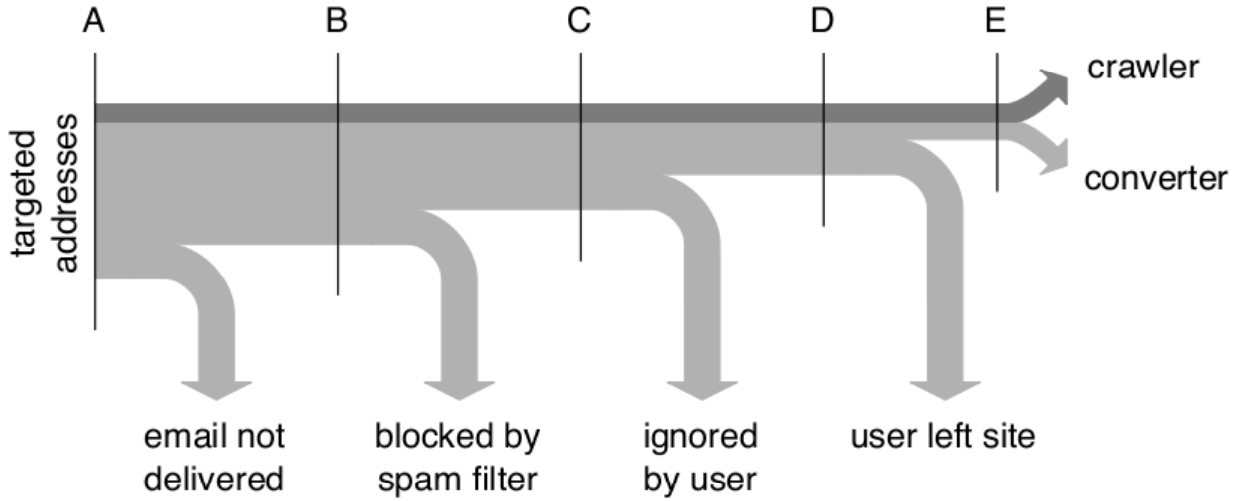


Figure 6: The spam conversion pipeline.

STAGE	PHARMACY		POSTCARD		APRIL FOOL	
A – Spam Targets	347,590,389	100%	83,655,479	100%	40,135,487	100%
B – MTA Delivery (est.)	82,700,000	23.8%	21,100,000	25.2%	10,100,000	25.2%
C – Inbox Delivery	—	—	—	—	—	—
D – User Site Visits	10,522	0.00303%	3,827	0.00457%	2,721	0.00680%
E – User Conversions	28	0.0000081%	316	0.000378%	225	0.000561%

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

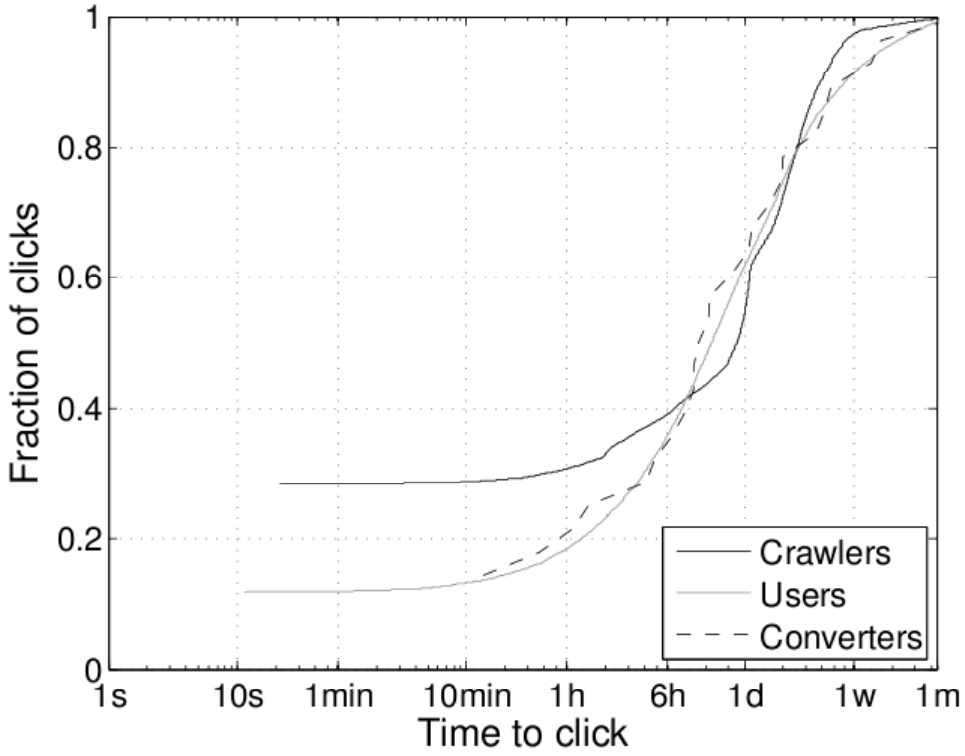


Figure 7: Time-to-click distributions for accesses to the pharmacy site.

Effects of Blacklisting

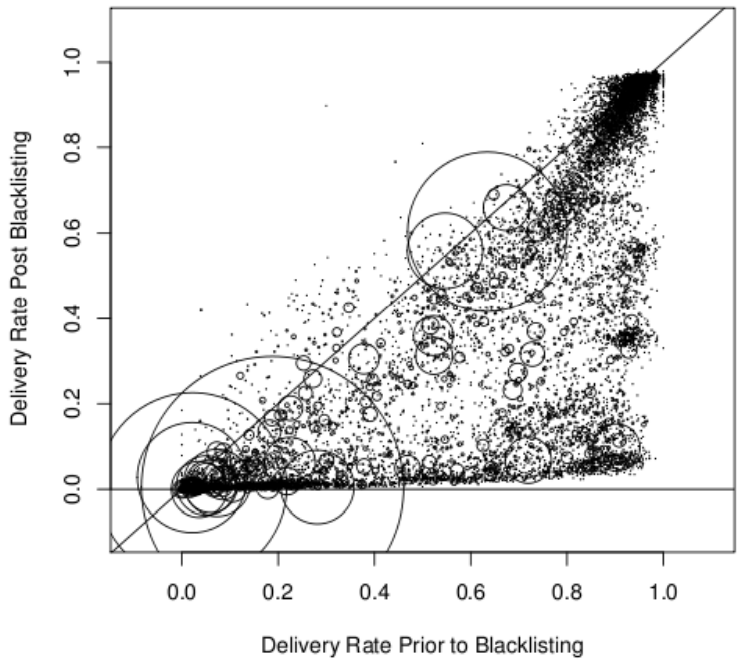
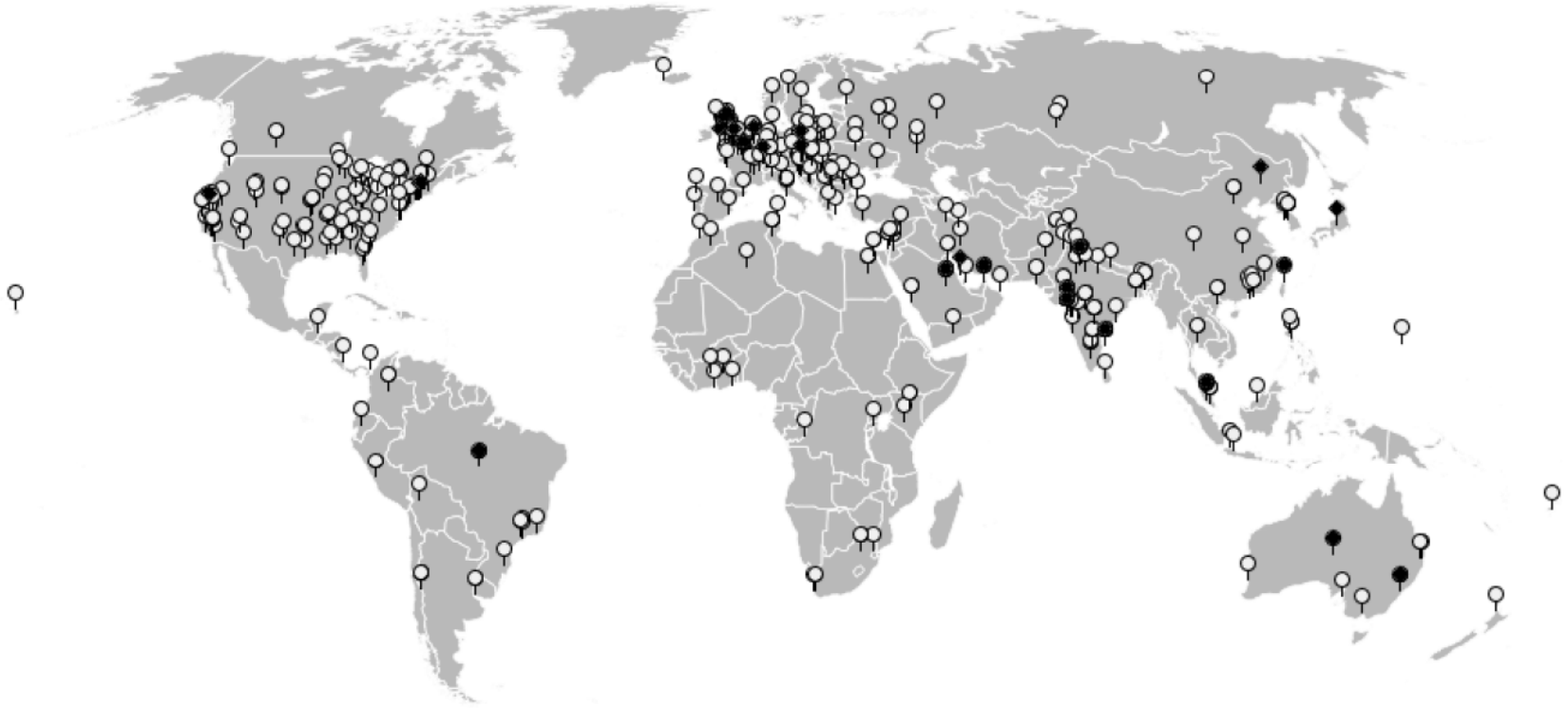


Figure 8: Change in per-domain delivery rates as seen prior to a worker bot appearing in the blacklist (x-axis) vs. after appearing (y-axis). Each circle represents a domain targeted by at least 1,000 analyzable deliveries, with the radius scaled in proportion to the number of delivery attempts.

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)

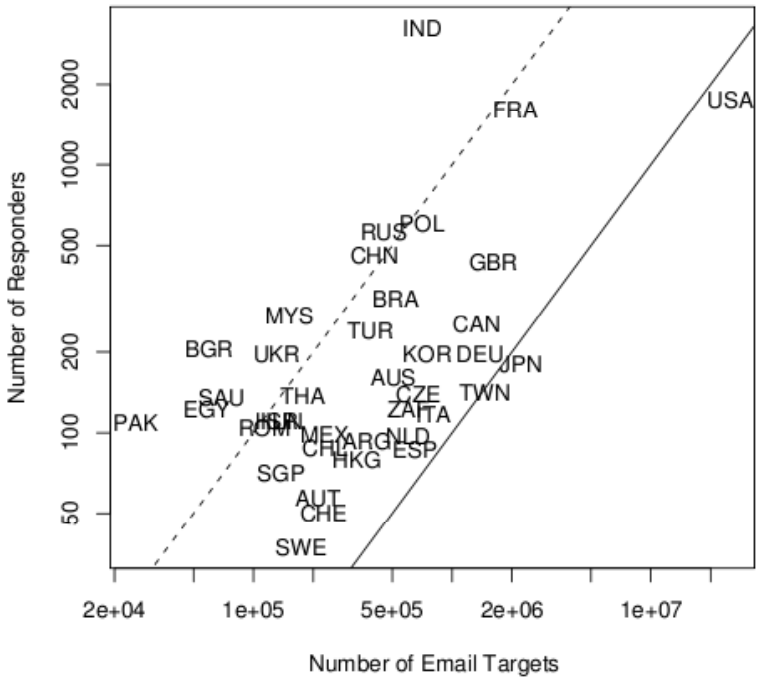


Figure 10: Volume of e-mail targeting (x-axis) vs. responses (y-axis) for the most prominent country-code TLDs. The x and y axes correspond to Stages A and D in the pipeline (Figure 6), respectively.

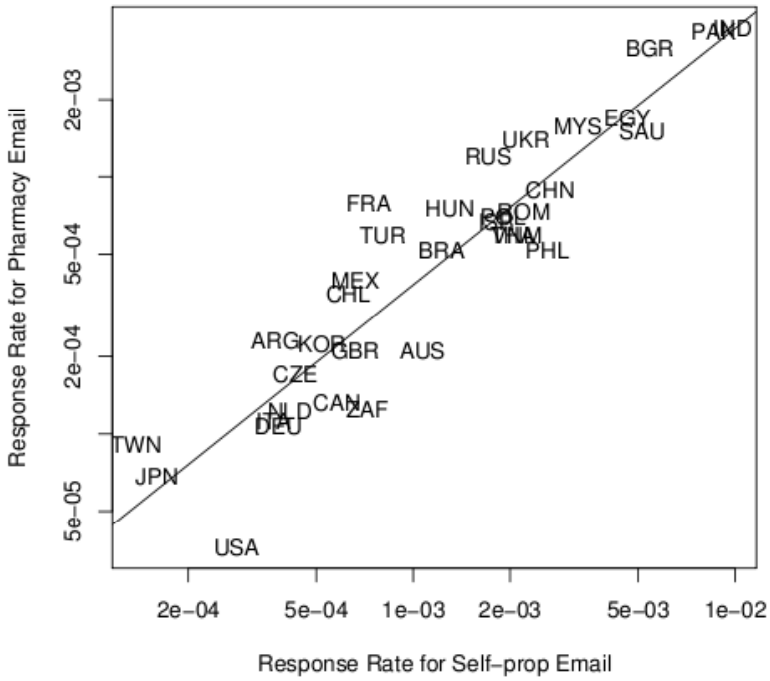


Figure 11: Response rates (stage D in the pipeline) by TLD for executable download (x-axis) vs. pharmacy visits (y-axis).

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% ⟹ revenues of $2731.88
  - Study proxy 1.5% of bots ⟹ $7000 to $9500 per day
- Storm campaigns can produce between 3500 and 8500 new bot per day(estimated)