deSEO: Combating Search-Result Poisoning

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Your Google is not SAFE!

SEO Poisoning - A new way to spread malware!

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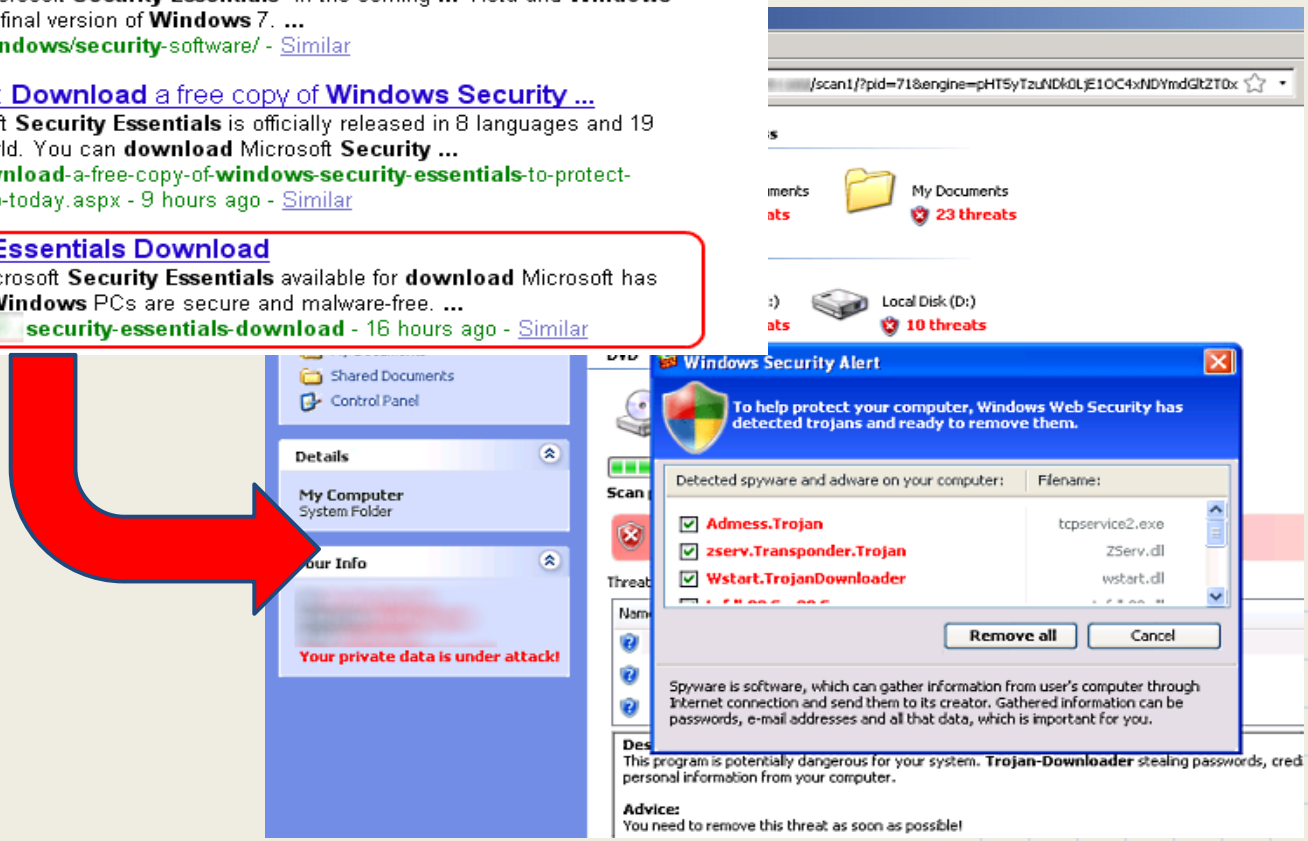


Why choose SE?

22.4% of Google searches in the top 100 results
> 50% for very-popular key phrase search in first page

Why attackers are attracted by search engines?

- Low cost
- Legitimate appearance
  - People trust Google, Bing, Yahoo, etc

Background of SE

- Page Rank
  - rank the web pages in search index
  - depends on number of incoming links and ranks of links on pages

- Features on pages
  - disclose, to prevent spammers
  - some estimated features:
    - over 200 features
    - ex. words in the title, URL, content of the page.

- Search Engine Optimization (SEO)
  - optimize Web pages so that they are ranked higher by search engines.
  - white-hat
    - created by the end user primarily
    - sitemap, appropriate headings and subheadings
    - follow guidelines recommended by SE
  - black-hat
    - EVIL!

Black-Hat SEO

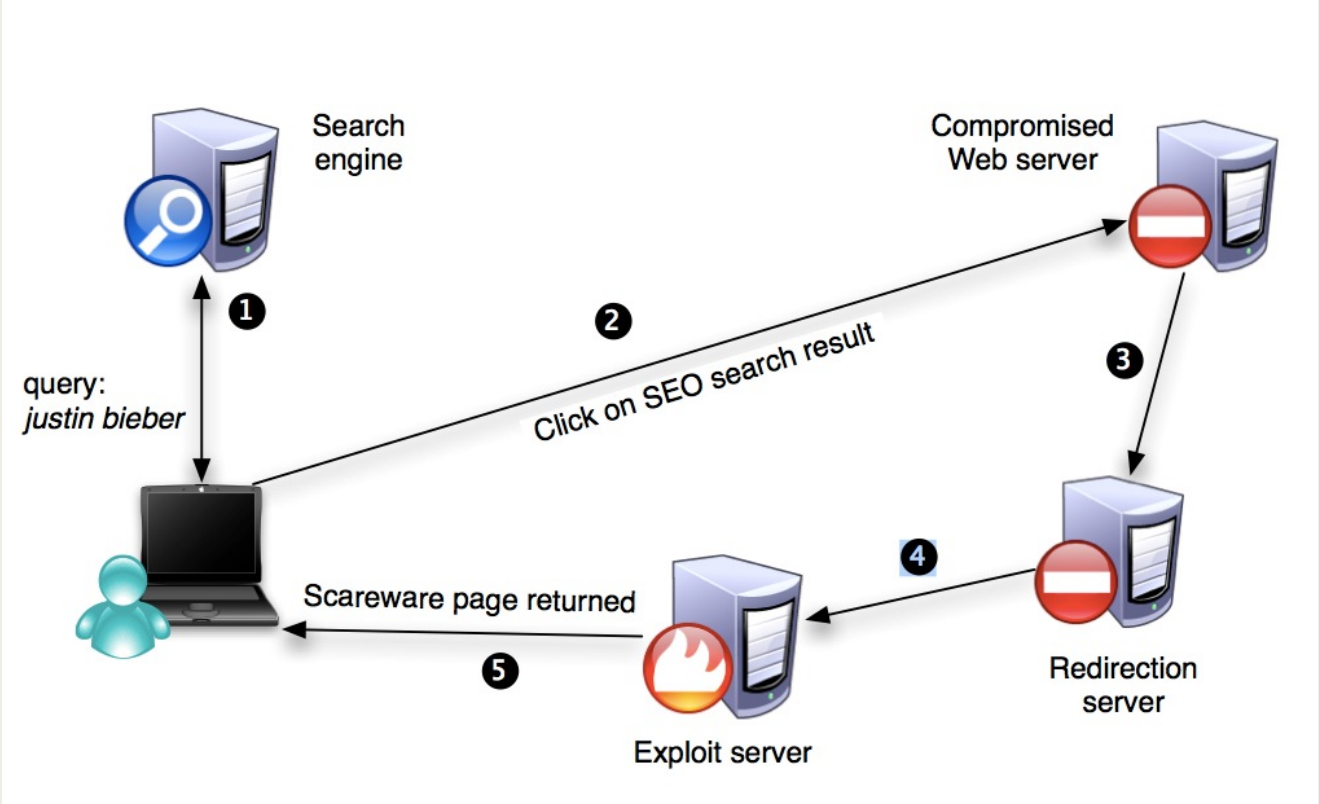
- Gaming the rankings, do not follow guidelines
  - Keyword stuffing
    - filling the page with lots of irrelevant keywords
  - Cloaking
    - providing different content to crawlers and users
  - Redirects
  - participating in link farms

- Detect Black-Hat SEO pages
  - Content of pages
  - Presence of cloaking
  - link structures leading to the pages

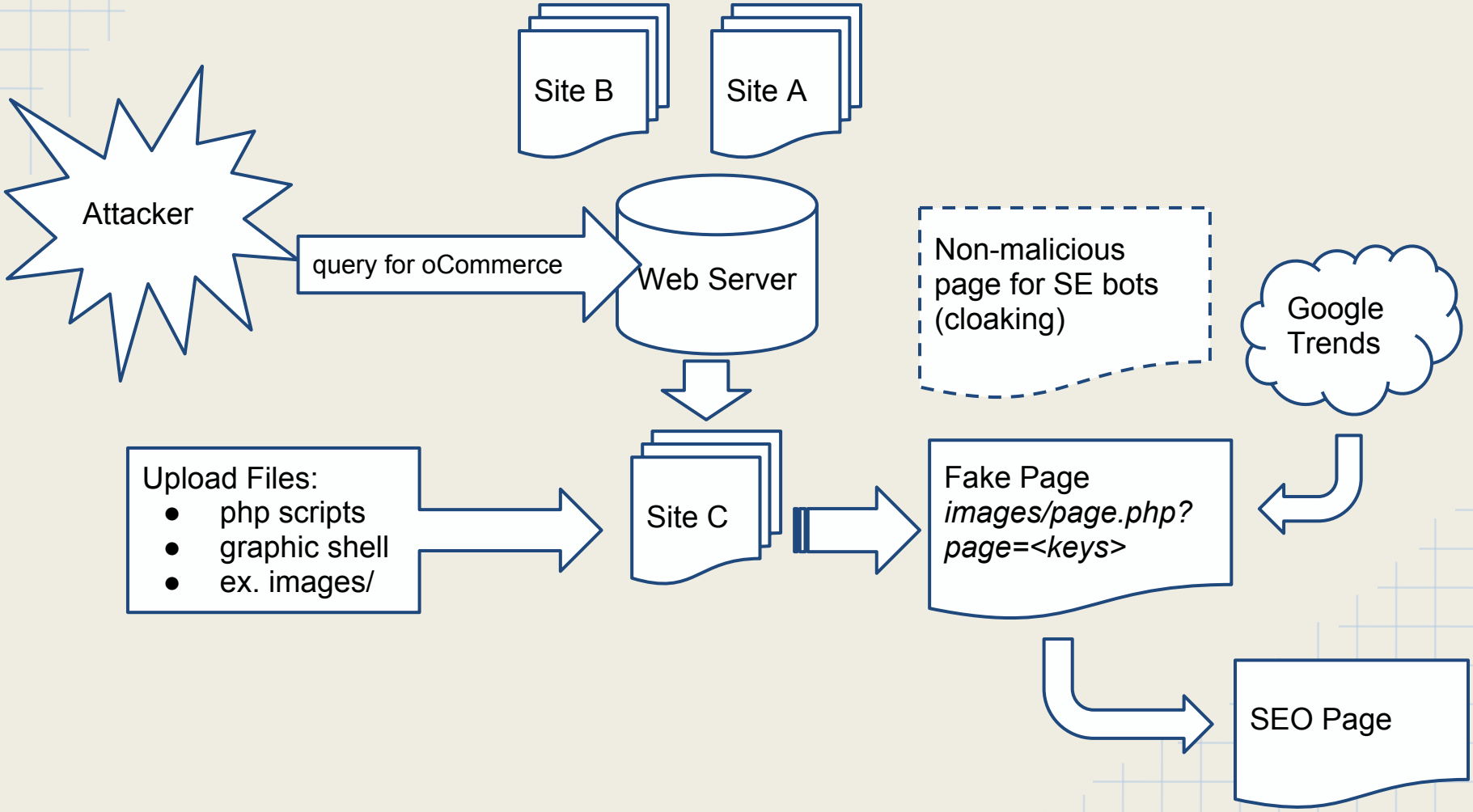
- SEO attacks studied in this paper (Trojan.FakeAV case)
  - Mixed behavior, hard to detect, less training data
    - Servers are originally legitimate
    - Main websites operate normally even after compromised

Overview of SEO Attack

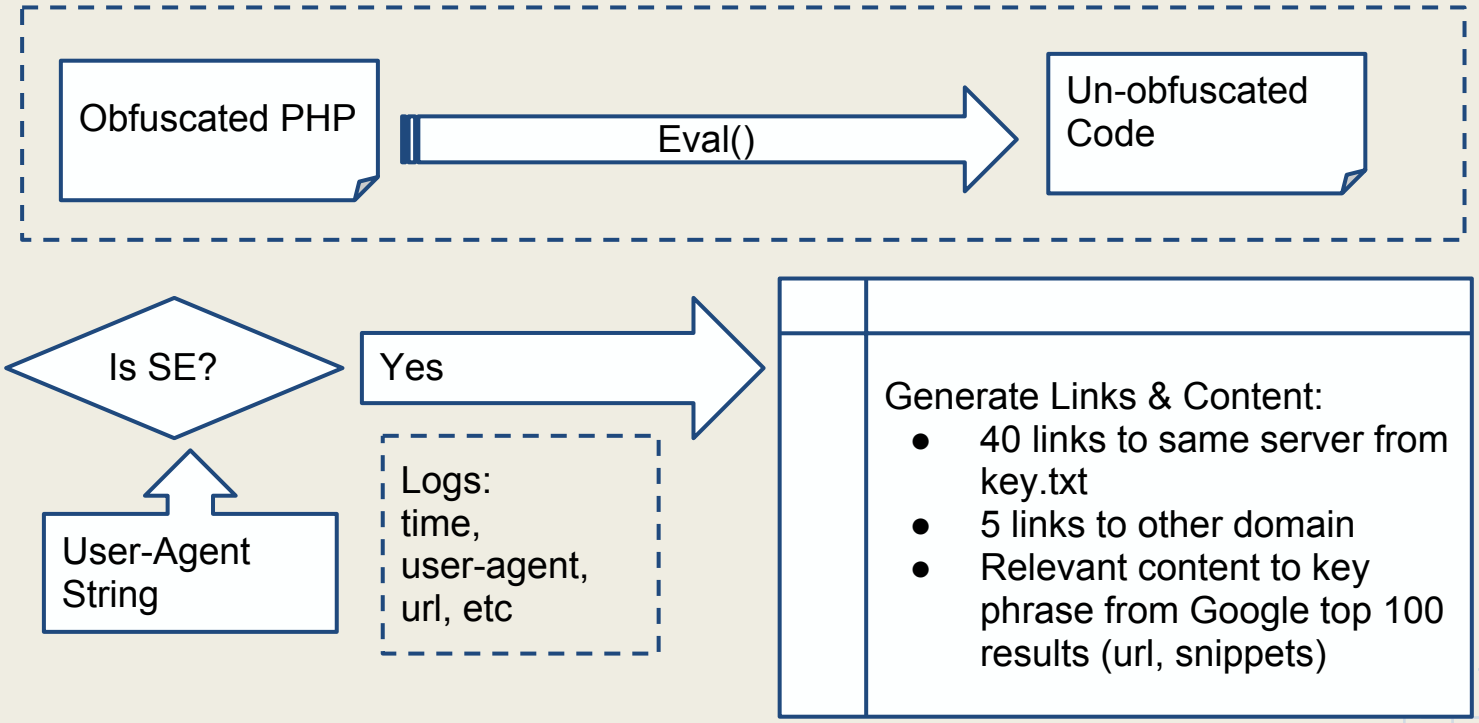
- How a victim falls into trap of SEO poisoning
- Three major players:
  - Compromised Web Server, Redirection Server, Exploit Server



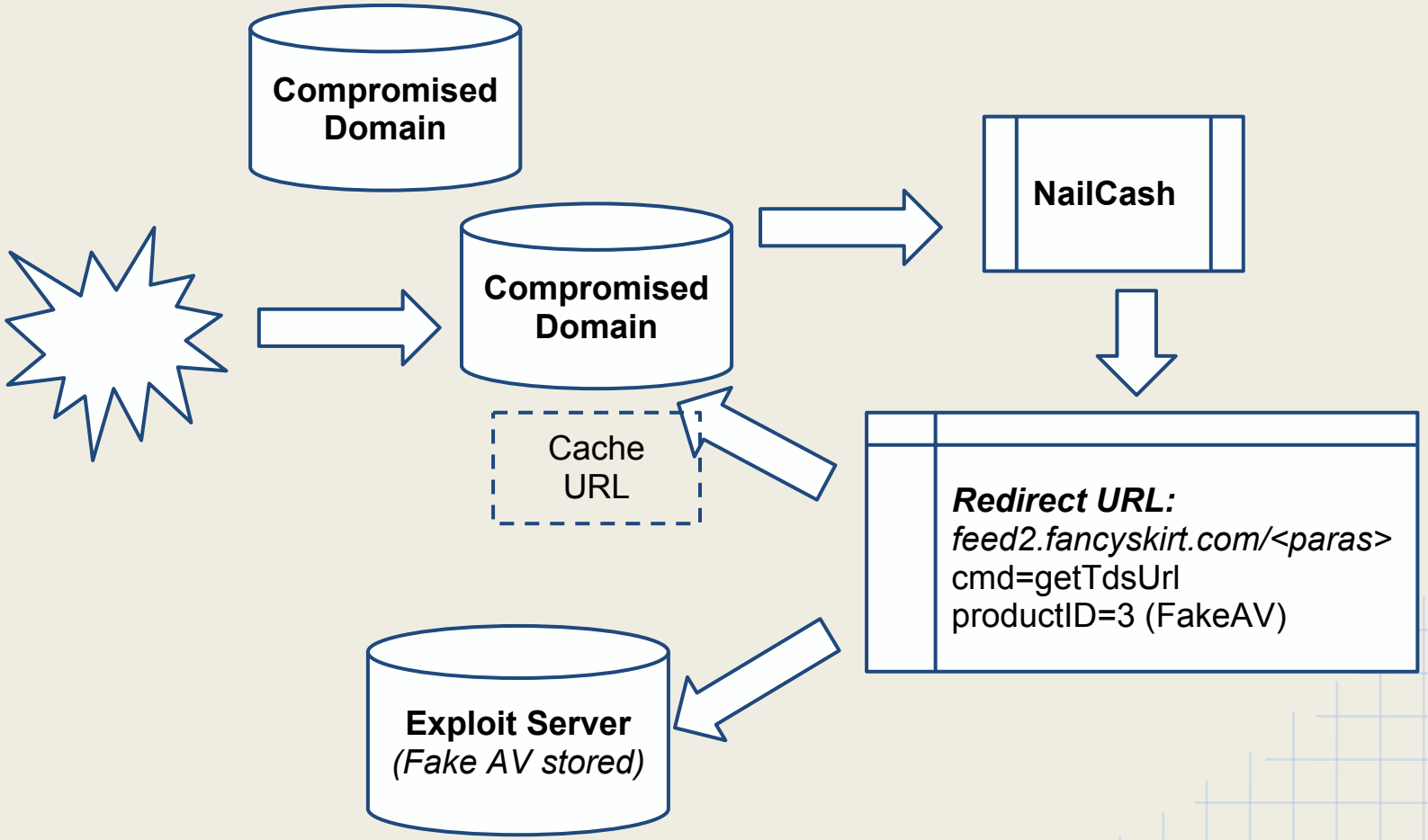
Compromised Server



SEO Page


Obfuscated PHP
Eval()
Un-obfuscated Code
Is SE?
Yes
User-Agent String
Logs: time, user-agent, url, etc
Generate Links & Content:
40 links to same server from key.txt
5 links to other domain
Relevant content to key phrase from Google top 100 results (url, snippets)

Redirecting & Exploit Server



Obversations

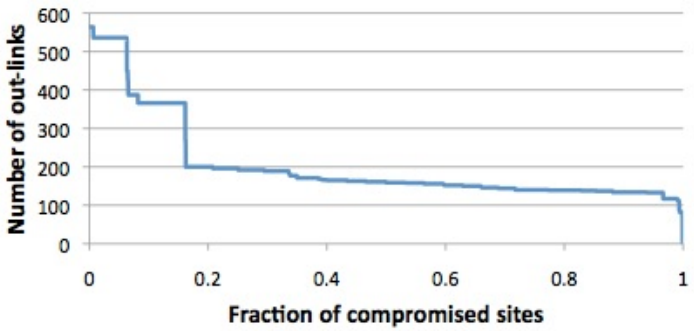


Figure 3: The number of other compromised sites each site links to. The degree distribution indicates a dense linking structure.

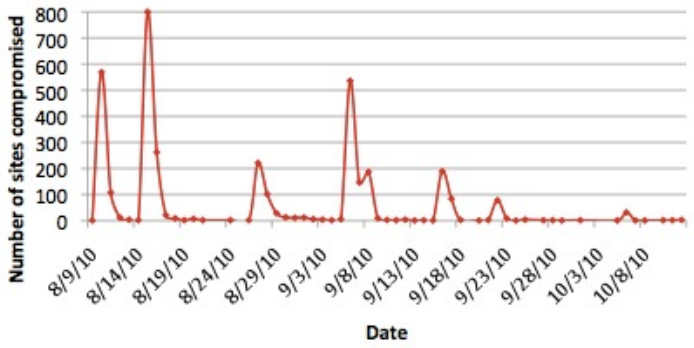


Figure 4: The number of sites compromised by the attackers each day over a period of three months.

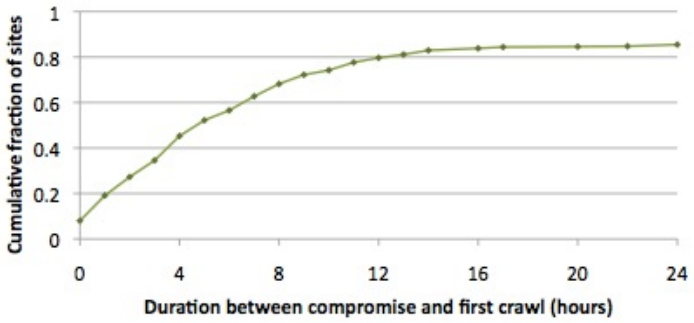


Figure 5: The interval between a site getting compromised and the SEO page getting crawled by a search engine.

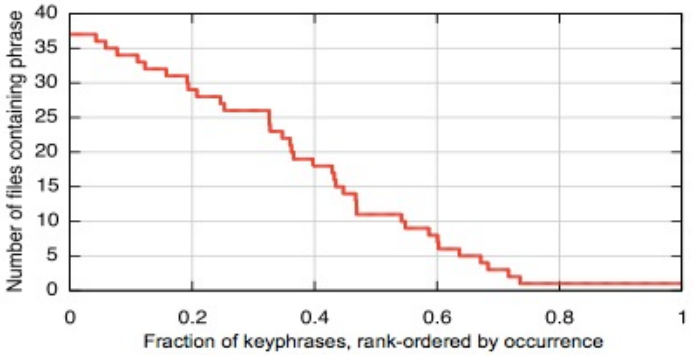


Figure 6: The frequency with which each keyphrase occurs across the compromised sites.

Observations

- Link Structure: Num. of out links less, more likely be compromised
- Time line: most at initial phase of attack
  - duration before first SE crawl: half < 4hrs; over 85% < 1day
    - SE crawlers are aggressive
    - Attacker submit to SE
- Distribution of key phrase:
  - High rank has high appearance rate
- Traffic from victims:
  - over 5000 compromised sites, over 40 million SEO pages
  - by monitoring logs of Redirect Servers (num. of visits of Fake AV)

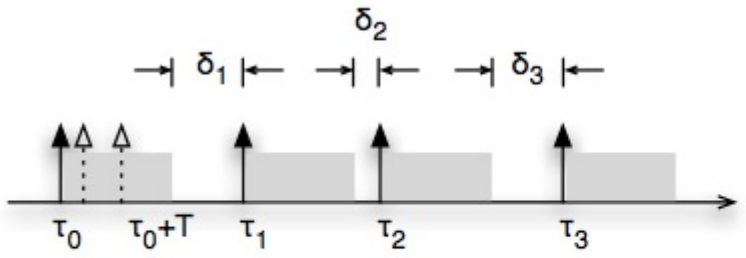
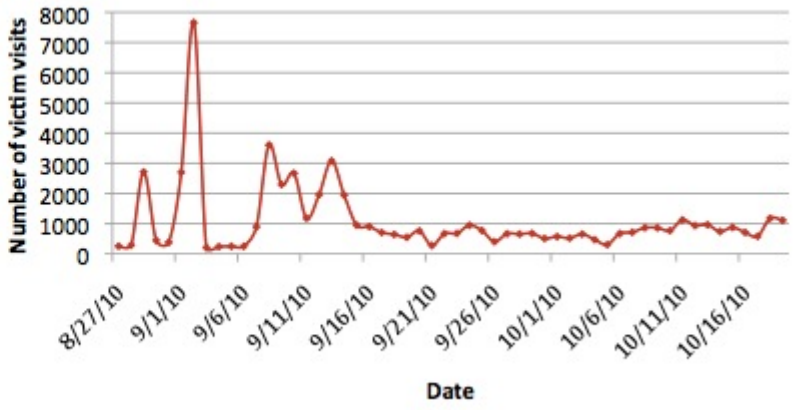


Figure 7: The arrival of requests at the redirection server.



Why SEO Attacks succeed?

- 3 key observations:
  - Generation of pages with relevant content
  - Targeting multiple popular search keywords to increase coverage
  - Creating dense link structures to boost pagerank

- deSEO focus on:
  - Websites change behavior
    - many new links are added after compromised, usually with different URL structures from the old URLs
  - Harmful URLs have similar structures
    - looking for newly created pages that share the same structure on different domains
    - help to identify group attacks

History-based Detection

- Study and compare URLs of server with snapshot history
- Example: *http://www.askania-fachmaerkte.de/images/news.php?page=lisa+roberts+gillan*
  - Do website have url : */images/news.php?page=* before?

Clustering of Suspicious Domains

- Three Lexical features from URLs:
  - String features:
    - separator between keywords, argument name, filename, subdirectory name before the keywords
  - Numerical features:
    - number of arguments in the URL, length of arguments, length of filename, length of keywords
  - Bag of words:
    - keywords

- abcd.blogspot.com v.s. blogspot.com
  - Sub-domains are preferred

- K-means++ method
  - Neither weight and threshold selection are sensitive

Group Analysis

- SEO links in one campaign share a similar page structure (not just the URL structure)
- Measure similarity of web pages
  - Compare parsed HTML structure tree
- AutoRE - signature generator system

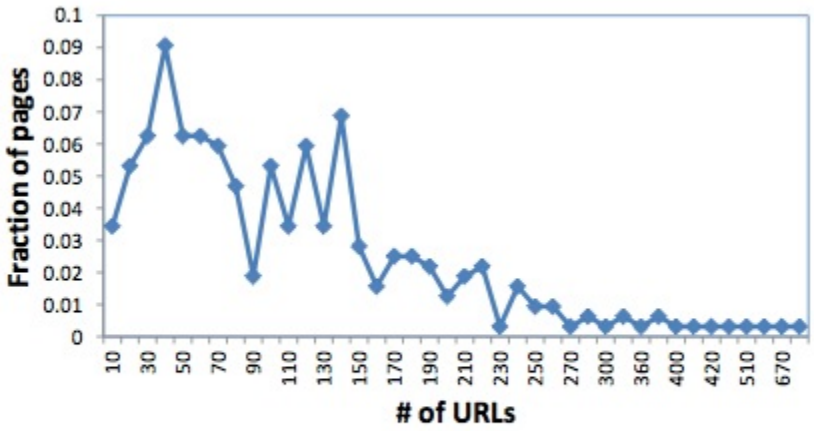


Figure 9: An example legitimate group that has diverse distribution of number of URLs in each Web page.

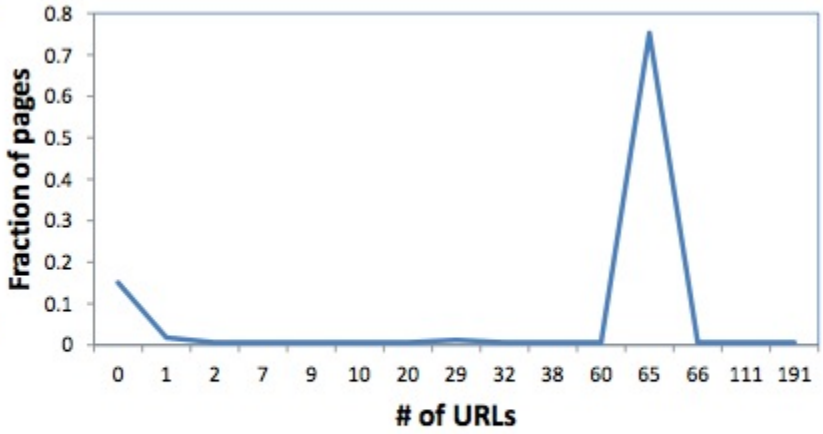


Figure 10: An example malicious group that has a similar number of URLs in each Web page.

Results

- Data sets (Bing.com):
  - June, 2010 - Historical snapshots
  - Sep, 2010
  - Jan, 2011
- Trendy keywords:
  - Google Trends, May 28th, 2010 ~ Feb, 3rd, 2011 (20/day)
- History-based Detection:
  - over 100 billion URLs at beginning
  - filter by Alex Top 10000
  - 2/3 move to next step

Month	With trendy keyword		With new structure	
	Domains	URLs	Domains	URLs
Sept 10	428,430	1,481,766	136,387	366,767
Jan 11	512,617	3,255,140	211,225	1,102,878

Table 2: History-based URL filtering.

Results

- Clustering
  - K=100 results
- Group Analysis
  - small num of groups have high peak values
  - most have small peak values
  - threshold = 0.45
  - 20 groups remain

Month	Number of groups		
	Total	Above threshold	Malicious
Sept 10	290	14	9
Jan 11	272	16	11

Table 3: Clustering and group analysis results.

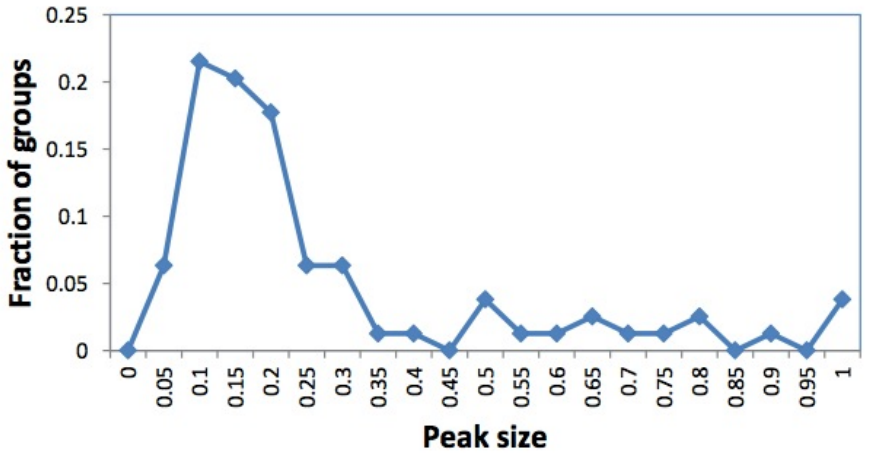


Figure 11: The distribution of peak values: percentage of pages sharing the same number of URLs within a group.

A New Attack

- Found another SEO attack that uses a different methodology
  - setting up SEO pages
  - boosting their page ranks
  - polluting the search index

- Differences b/t previous attack:
  - Not link to each other, rely on incoming links for page rank
  - Use cloaking
  - Extra level of redirection for exploit server

Study of SEO Attack

- Queries
  - Less than 5% of the top 500 Alexa Web sites ever submitted queries during the month of September 2010, while 46% of the compromised servers did
  - Queries from the IPs of compromised servers are more frequent than those of legitimate sites
- Matching Google and Bing queries

	60 trendy keywords		60 attacker poisoned keywords	
	# of matched searches	# of matched URLs	# of matched searches	# of matched URLs
Google	16	39	27	124
Bing	0	0	1	1

Table 4: Matching Google and Bing search results using derived regular expressions.