Inflight Modifications of Content: Who are the Culprits?

- *Chao Zhang*
- Keith W. Ross

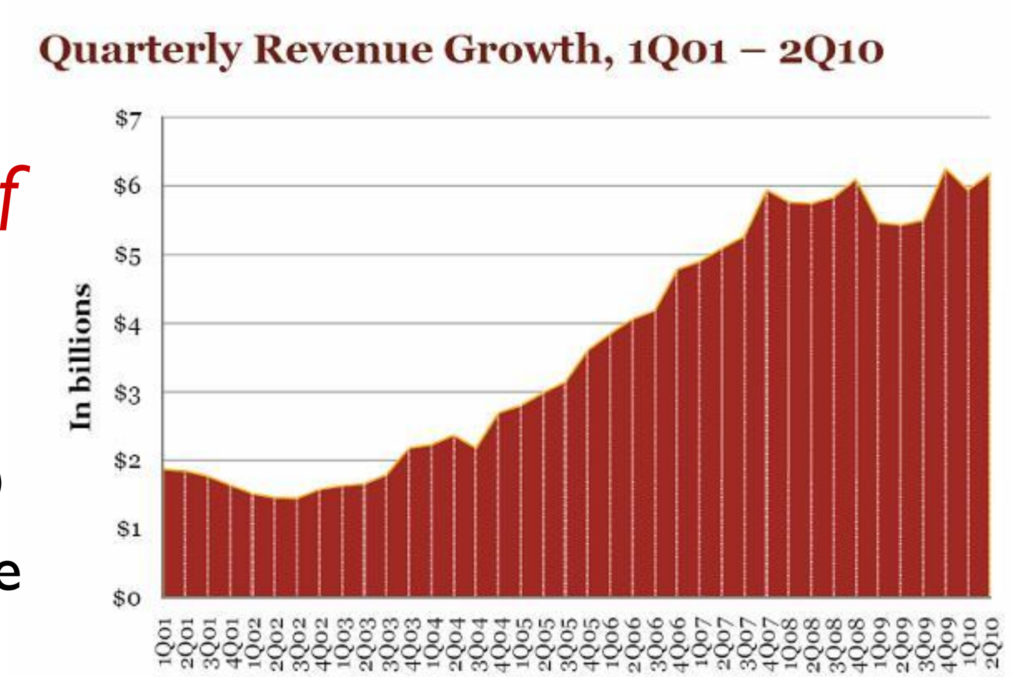
Polytechnic of NYU

- Cheng Huang
- David A. Maltz
- Jin Li

Microsoft Research

Motivation

- Online advertising becomes main source of revenue
- *High revenue attracts eyes of third-party*
  - Bahama botnet stealing traffic from Google *(blog.clickforensics.com, Sep 17, 2009)*
  - Web Tripwires demonstrate inflight modification *(NSDI, 2008)*



http://mashable.com/2010/10/12/

Contribution

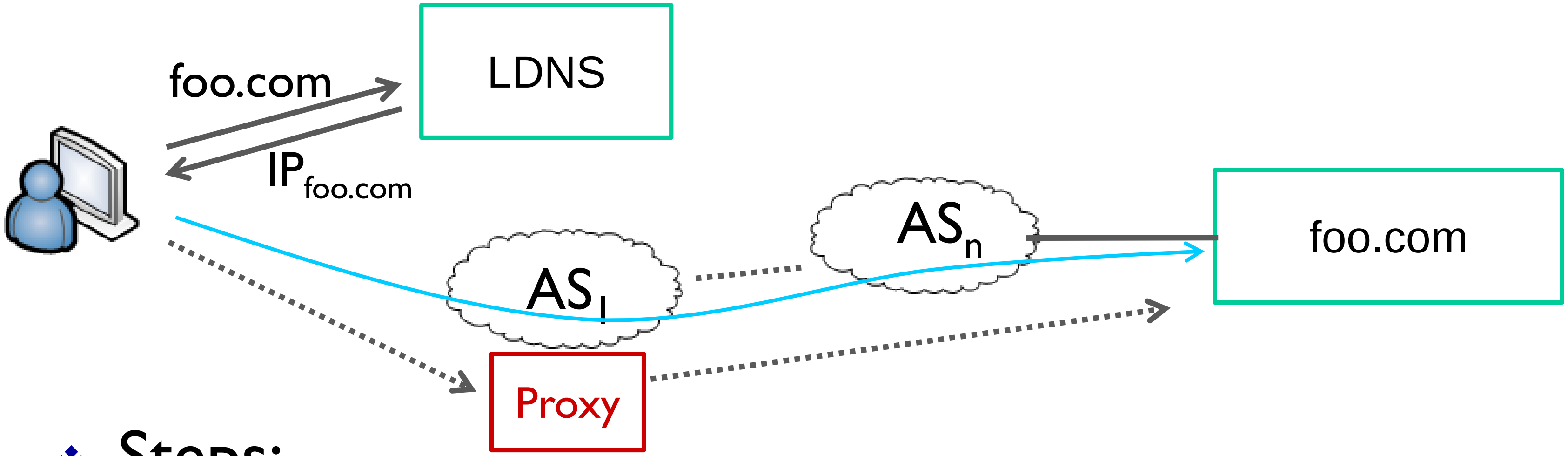
- *Nearly 2% clients from US are affected by inflight modification*
- *44 LDNS in 9 ISPs redirect clients to malicious servers*

ISP	# of cmpmzd LDNS	affected clients (%)
Hughes Network Systems	14	95.5
Frontier Communications	13	92.7
Cavalier Telephone	7	87.0
FiberNet of West Virginia	1	70.3
Spacenet, Inc.	1	97.8
Onvoy	3	76.1
WideOpenWest	3	68.6
Cincinnati Bell Telephone	1	92.6
South Dakota Network	1	88.5

Outline

- *Identifying the Inflight Modification*
- Digging the Root Causes
- Summary

Processing of Fetching a Page



- Steps:
  - DNS resolution
  - HTTP request to foo.com
  - Content to client
- Sometimes, clients are redirected to web

Q: Do Proxies Modify Pages?

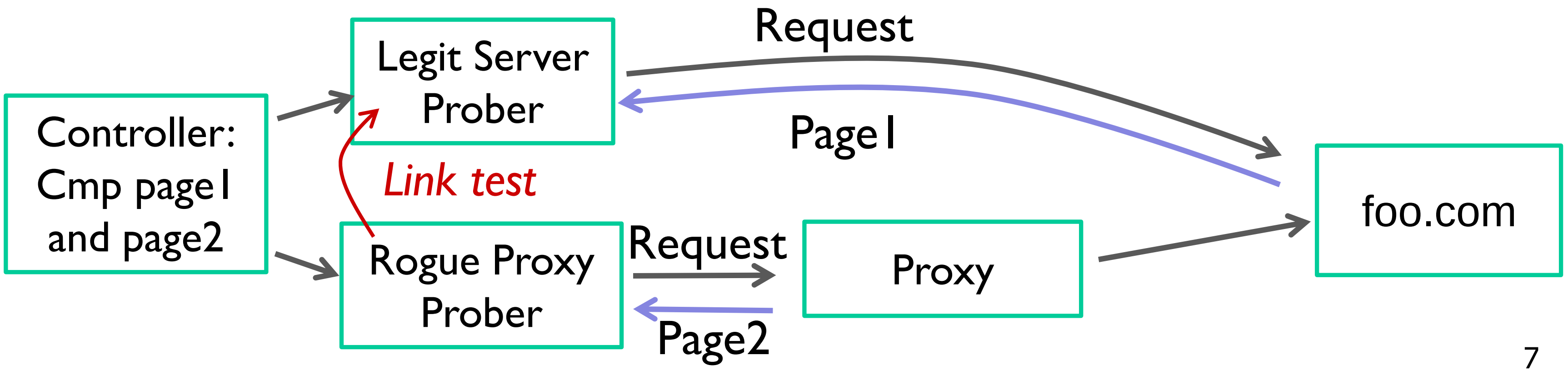
Collecting Proxies List

- Instrument clients in the wild
- Each client reports:
  - Its IP
  - The IPs of foo.com returned by the LDNS
- In two months, we collected
  - I5M unique clients
  - 4,437 proxies for foo.com

Q: Which proxy servers are modifying the content?

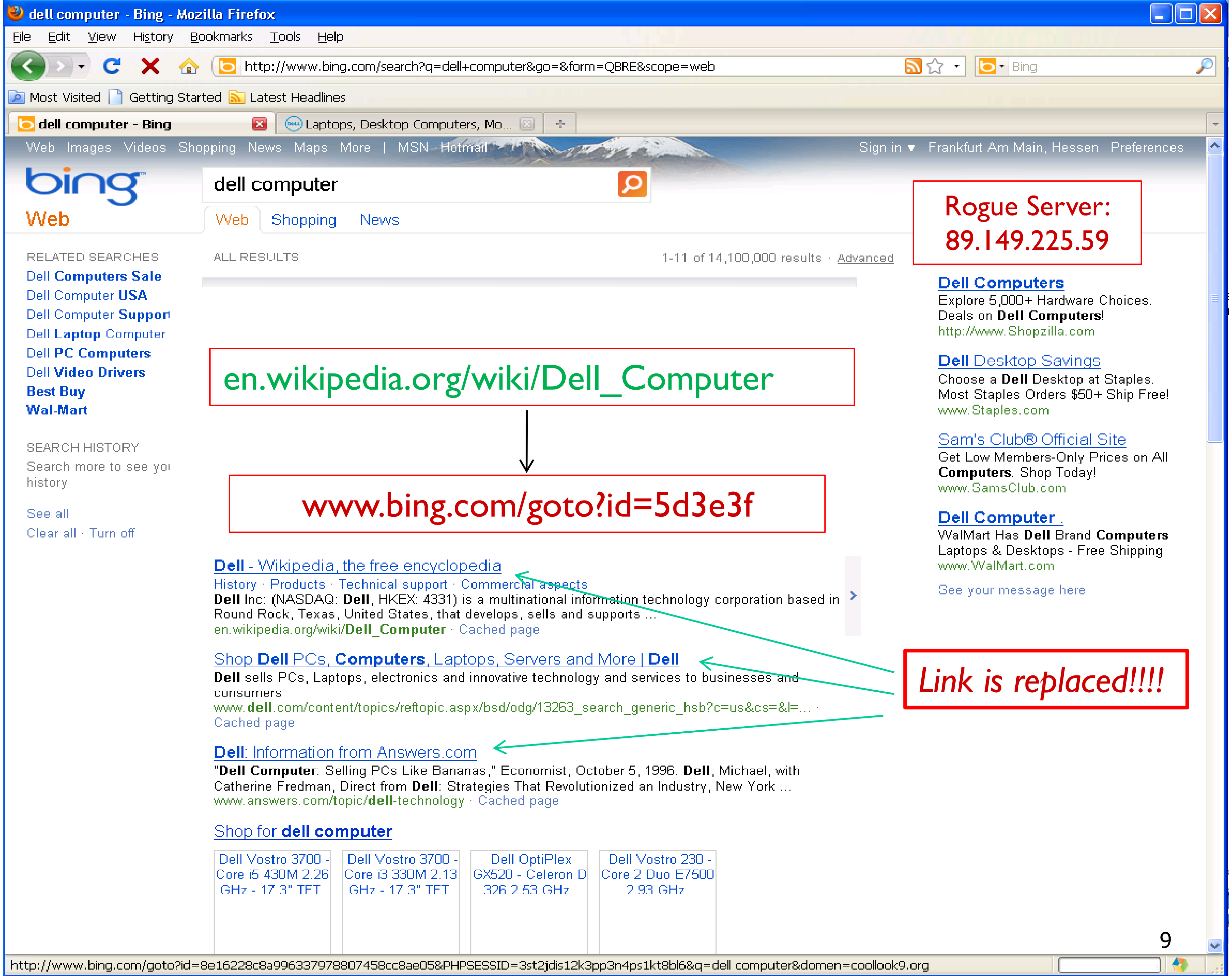
Identifying Rogue Proxies: Revealer Framework

- Fetch pages from two servers, compare
- Benign, if content is the same
- *Different content doesn't necessarily mean that the proxy is malicious*
  - *Search result page with ads*
  - different ads can be identified by links
  - test the link again by emulate user click
- Capture all HTTP traffic
  - Analyze abnormal redirection



Types of Modifications

- *Modify search result links*
- Modify advertisements links
- Insert JavaScript
- Redirect requests



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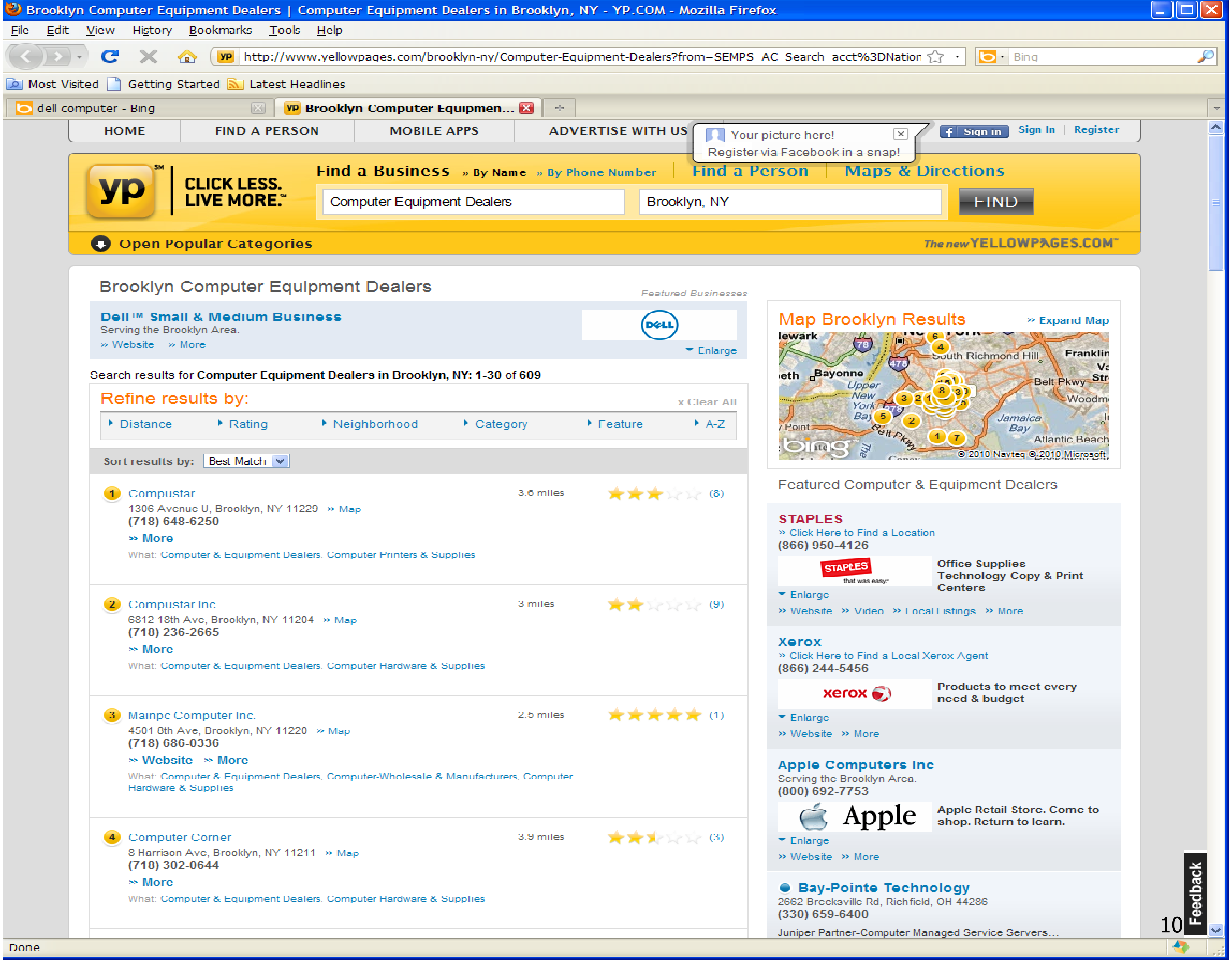

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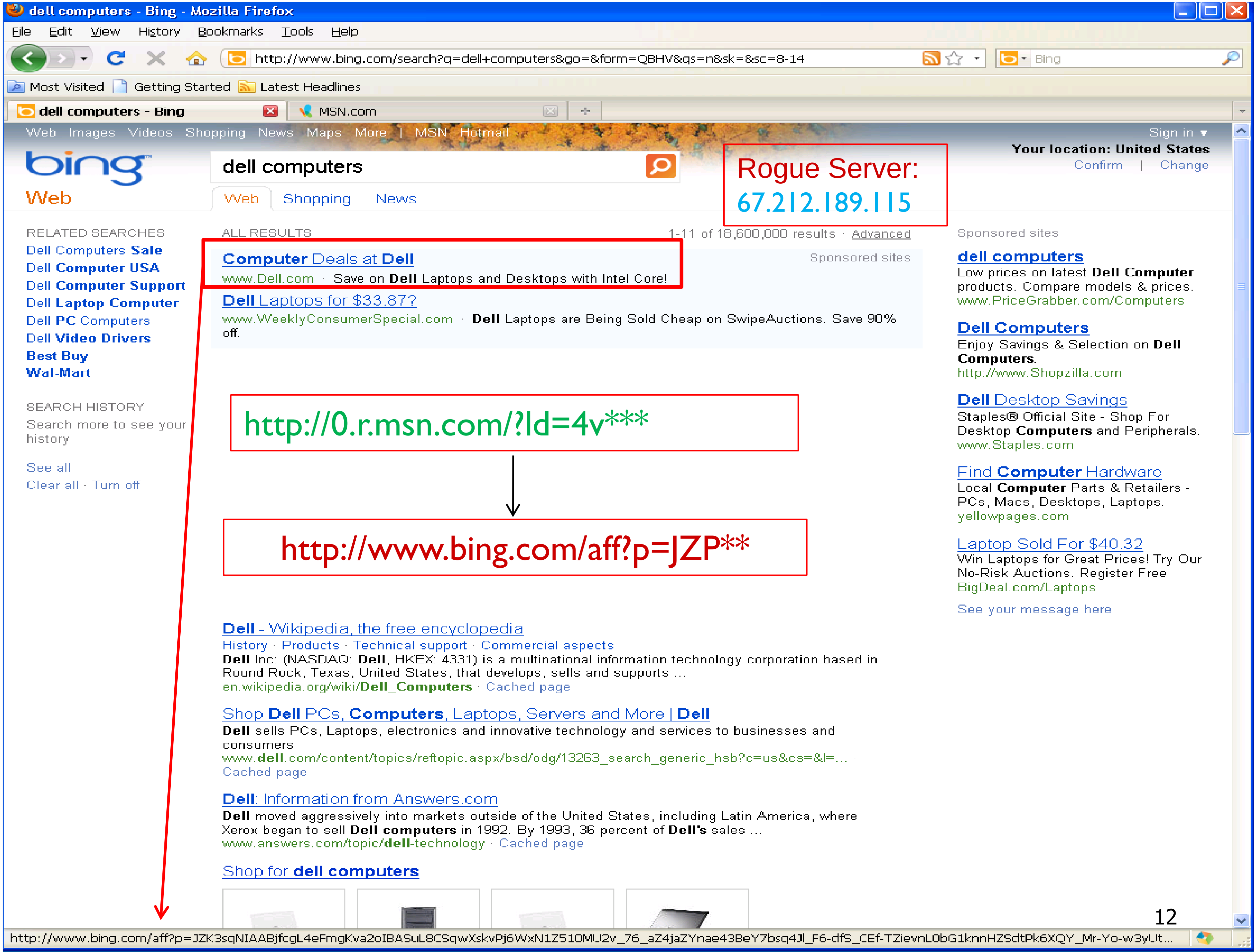
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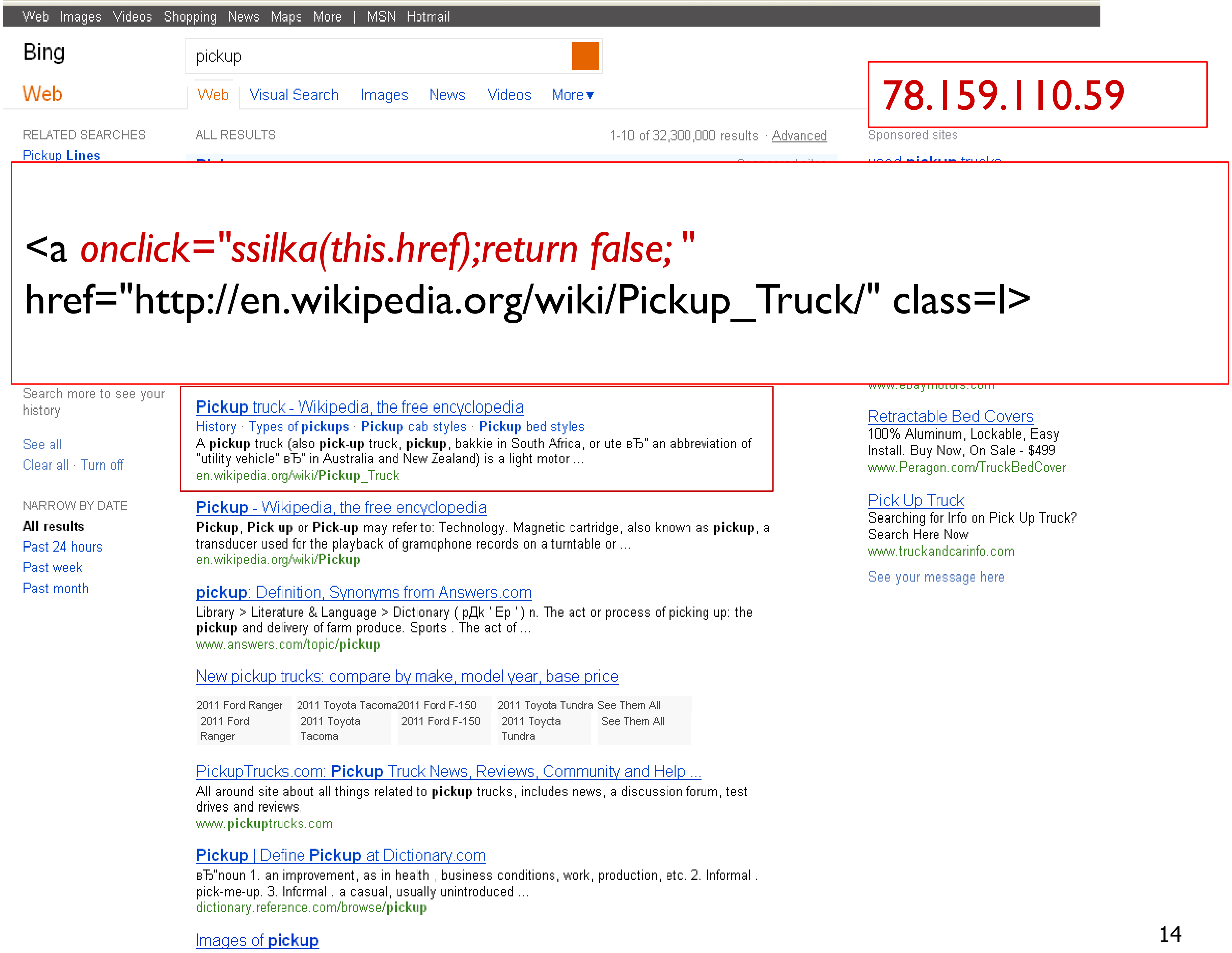

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Types of Modifications

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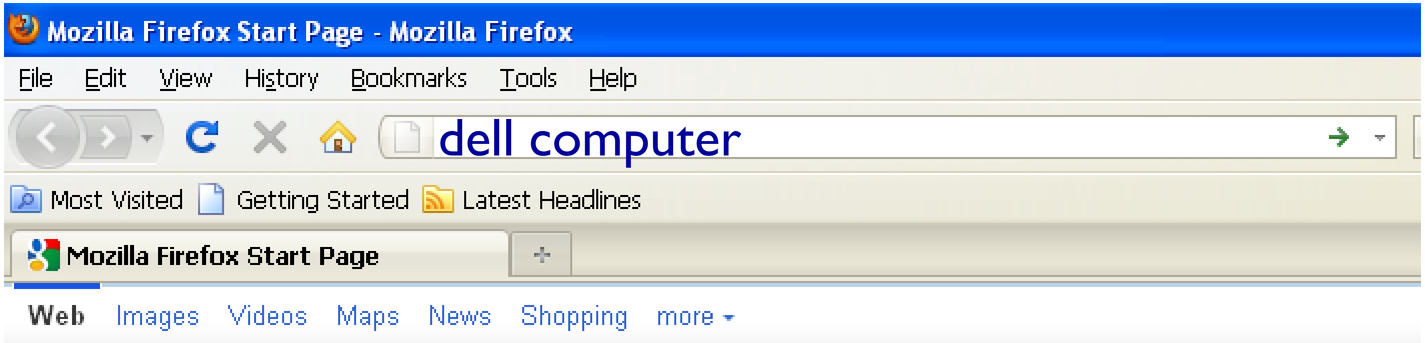
- Modify advertisements links
- Insert JavaScript
- *Redirect requests*

Redirect Requests

- Redirect search requests originating from *Address Bar*



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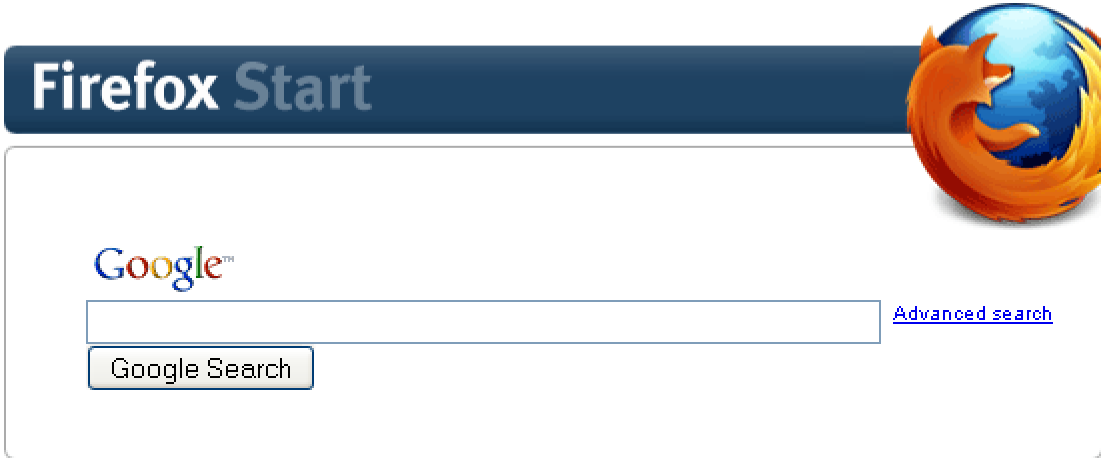
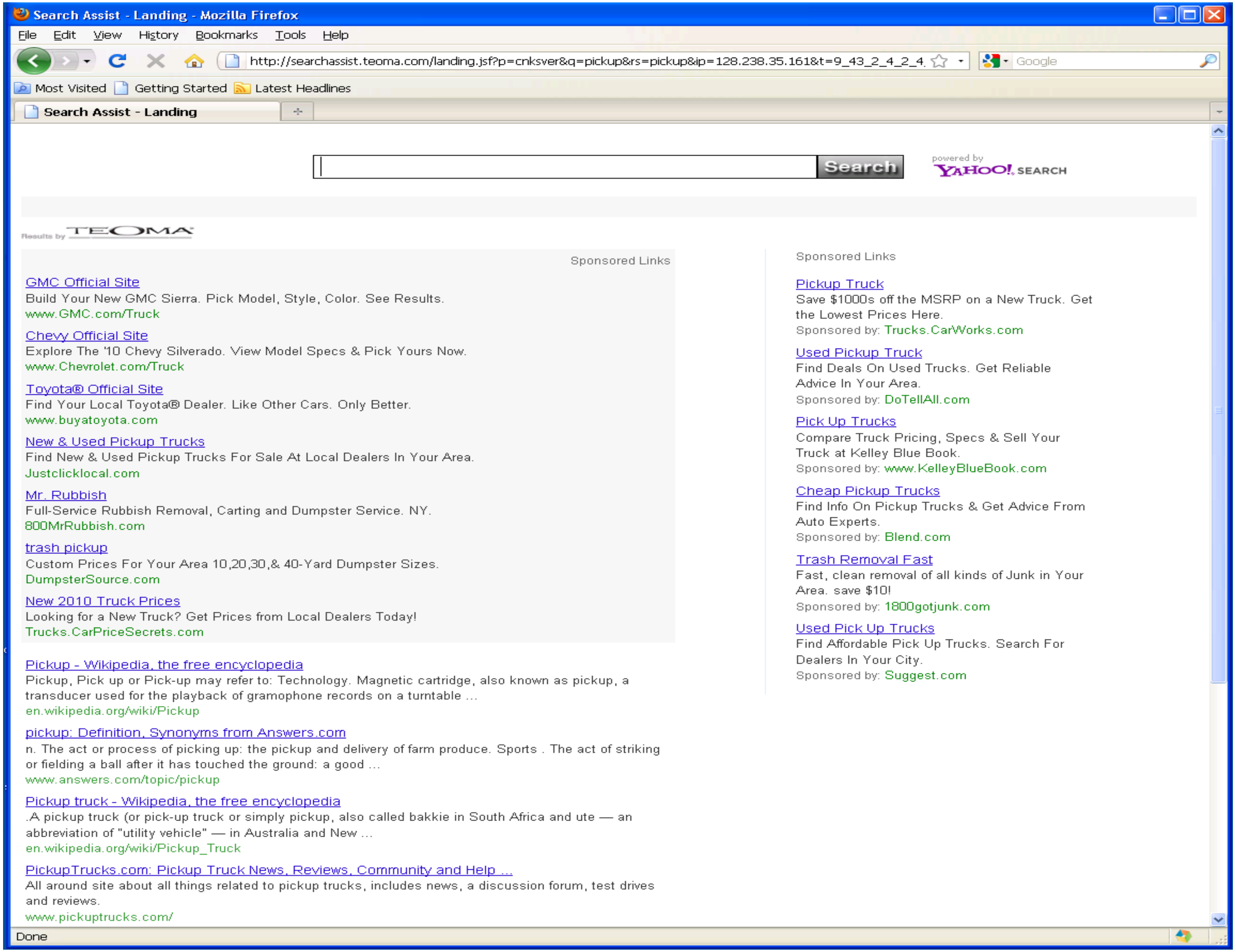


Redirect to a Different Search Engine



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Redirect Requests

- Two types of redirection
  - Redirect to a different search engine
  - *Insert additional rounds of redirection*

Normal	With Modification
www.google.com/search?ie=UTF-8****	www.google.com/search?ie=UTF-8***
www.dell.com	wwww13.notfoundhelp.net/search?***
	www.kqzyfj.com/click****
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Online ad companies

Scale of Rogue Servers

- Total # of rogue servers: 349

Type	# of Servers
Modify search result links	41
Modify ad links	80
JavaScript injection	72
Redirect requests from address bar	154

- 15M unique clients worldwide
  - 1% were directed to malicious servers
  - *2% clients from US are affected*

Identifying the Inflight Modification :Summary

- Collect thousands of proxies from wild
- Develop a framework to determine whether a proxy modify content
- Find 4 types of modifications
- 2% clients from US are affected

Outline

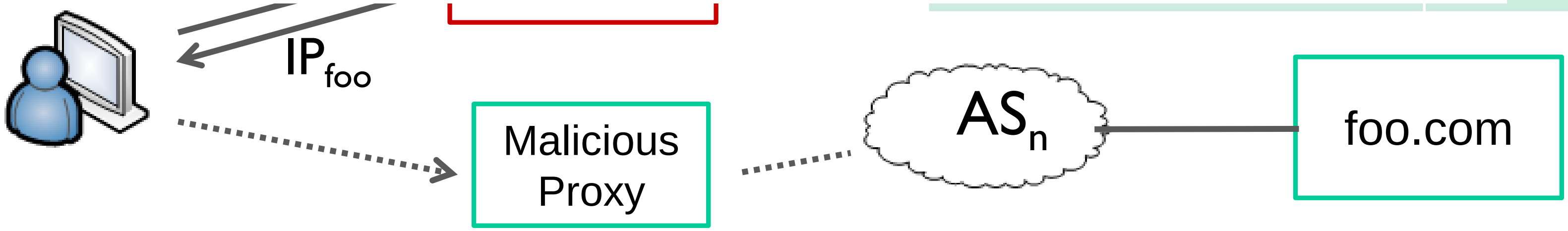
- Identifying the Inflight Modification
- *Digging the Root Causes*
- Summary

Narrow Down Horizon

- Active probing the malicious web servers
- Only accept a few domains
- Clients only connect to malicious servers when accessing particular sites

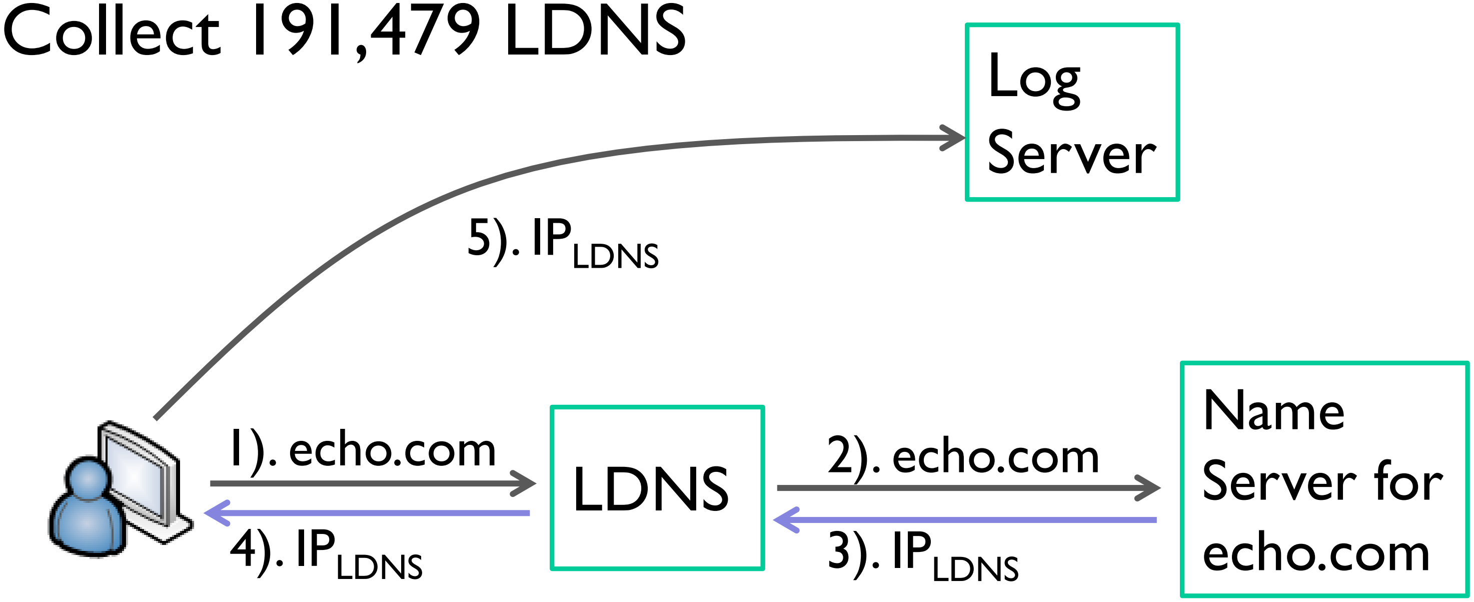
Web Service	Accept
Bing.com	✓
Google.com	✓
Search.yahoo.com	✓
Youtube.com	✗
Facebook.com	✗
Akamai.com	✗
limelightnetworks.com	✗
	✗
	✗

Q: DNS Resolution is Compromised?



Collect LDNS

- Create echo.com
- Name server for echo.com returns source IP of DNS query
- Collect 191,479 LDNS

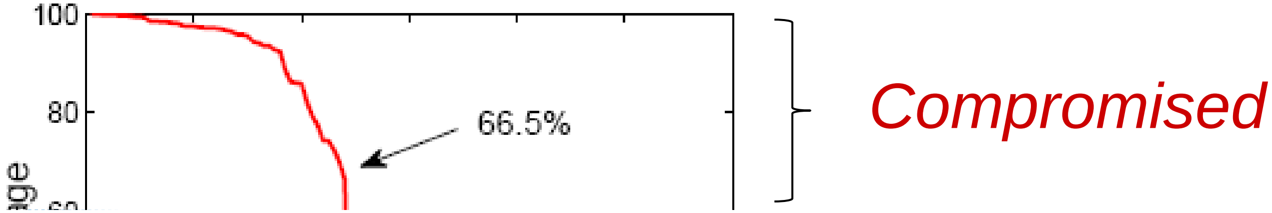


LDNS Analysis

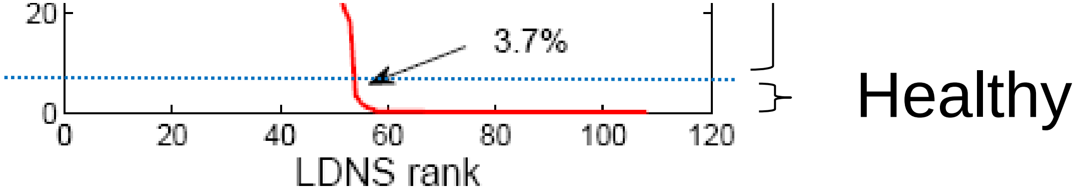
- *Which LDNS are compromised?*
- Who is behind?
- Does LDNS discriminate among users?
- Does public DNS help?

Which LDNS are compromised?

- Group by /24 prefix, remove ones with clients < 50
- Get 108 LDNS prefixes
- Aggregate all clients that use the same LDNS
- Calculate the percentage of affected clients
- *48 out of 108 LDNS are compromised*



Q: Who operates these LDNS?



Who is Behind?

- Not all LDNS are deployed by ISPs
- Define: *an LDNS deployed by ISP if more than 50% clients using it from the same ISP.*
- *44 / 48 compromised LDNS are official.*

ISP	# of cmpmzd LDNS	affected clients (%)
Hughes Network Systems	14	95.5
Frontier Communications	13	92.7
Cavalier Telephone	7	87.0
FiberNet of West Virginia	1	70.3
Spacenet, Inc.	1	97.8
Onvoy	3	76.1
WideOpenWest	3	68.6
		92.6
		88.5

A small # of ISPs operate these LDNS!

Do the LDNS Discriminate among Users?

- Will clients from other ISPs be affected if they use those compromised LDNS?

ISP	affected external clients (%)
Hughes Network Systems	82.0
Frontier Communications	97.9
Cavalier Telephone	84.7
FiberNet of West Virginia	---
Spacenet, Inc.	---
Onvoy	69.7

Compromised LDNS servers indiscriminately redirect all clients to the malicious servers!

Are clients forced to connect to malicious servers?

- In other words, will public DNS work in these ISP?

ISP	Ratio of affected external clients
Hughes Network Systems	0.2
Frontier Communications	0.1
Cavalier Telephone	0.0
FiberNet of West Virginia	0.0
Spacenet, Inc.	0.0
Onvoy	1.2
WideOpenWest	0.0

Using Public DNS Improves Service Availability!

Summary

- Find four types of modifications
  - Insert abnormal redirection in HTTP request
- Inflight modification is popular
  - Nearly 2% clients from U.S. are affected
- Most of affected clients are from 9 small-to-medium size ISPs
  - Some LDNS in ISPs direct clients to rogue servers
- Public DNS would help bypass modification