Financial Lower Bounds of Online Advertising Abuse

ELECTRICAL [+] COMPUTER

ENGINEERING

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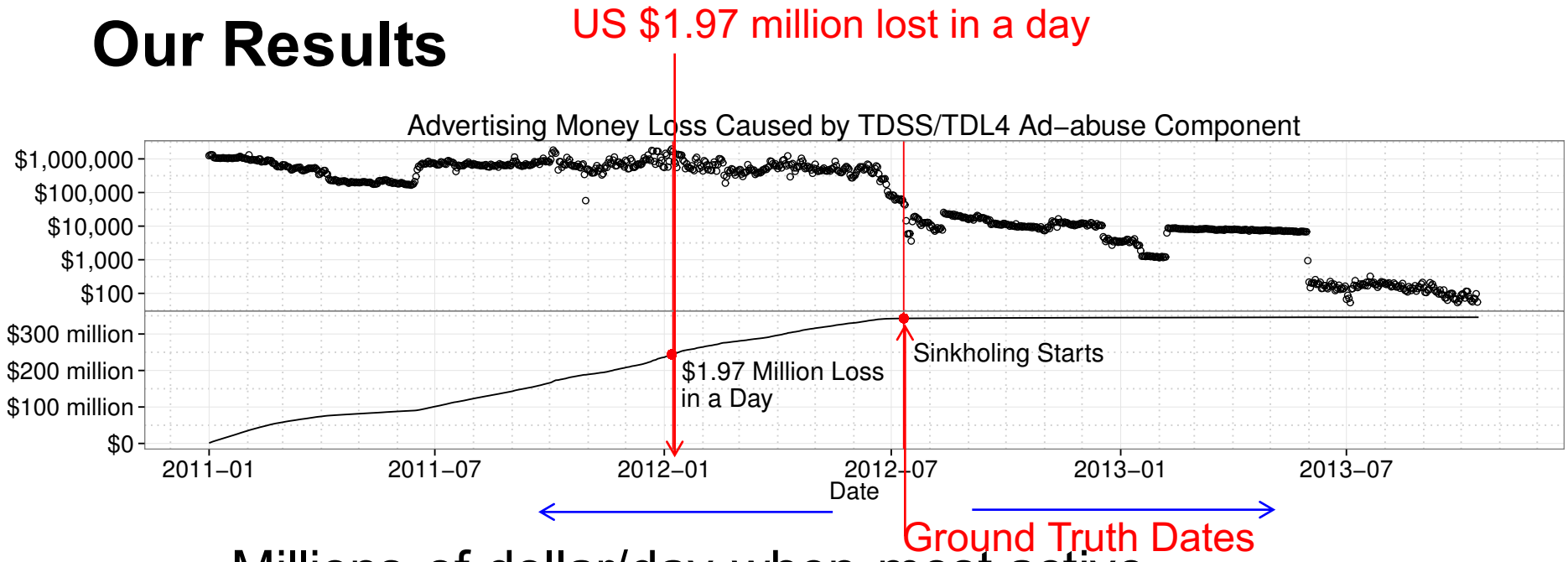
Monetization using Ads

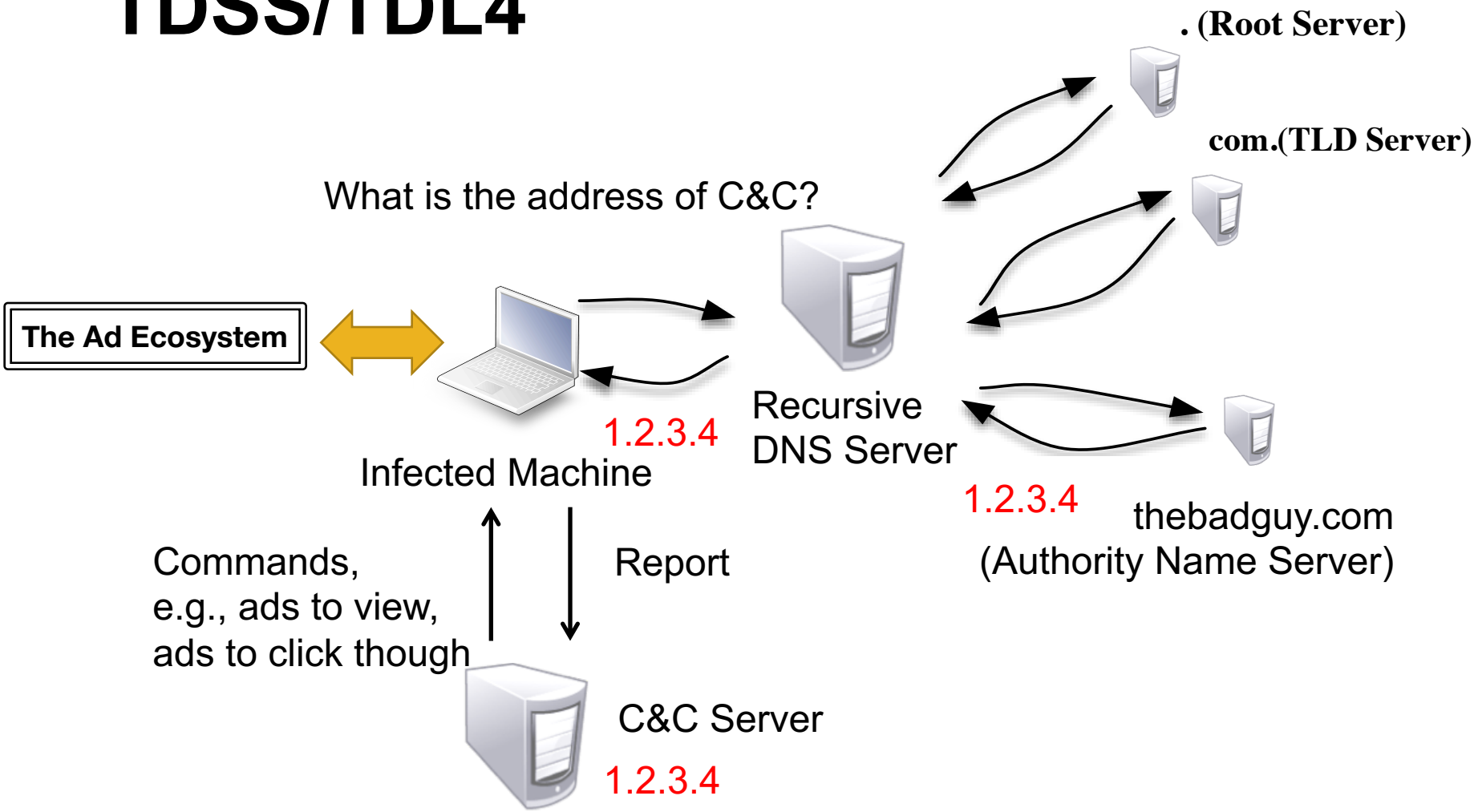
- Enable other malicious activities.
- Impression fraud.
  - Extremely hard to be detected.
- Methodology to track abuse in the long term.
  - We do not participate in the abuse.
- Financial lower bound.
  - Ad-abuse component of TDSS/TDL4.

Our Results

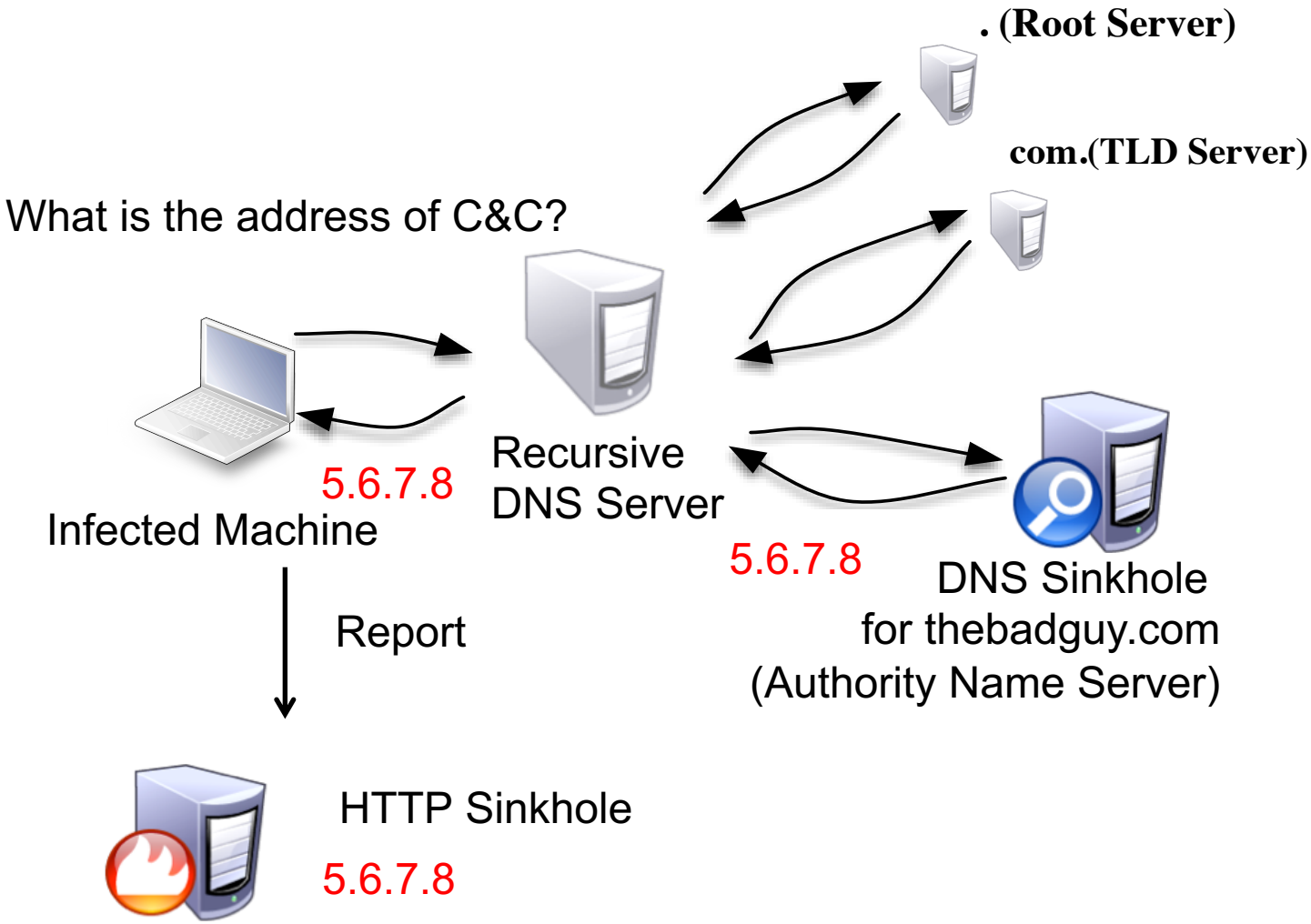


- Millions of dollar/day when most active
- 228 IP addresses and 863 resolved domain names
- $24.22 million gain for botmasters

TDSS/TDL4


. (Root Server)
com.(TLD Server)
What is the address of C&C?
The Ad Ecosystem
1.2.3.4
Recursive
DNS Server
Infected Machine
1.2.3.4
thebadguy.com
(Authority Name Server)
Commands,
e.g., ads to view,
ads to click though
Report
C&C Server
1.2.3.4

Ad-abuse Analysis System (A^2S)



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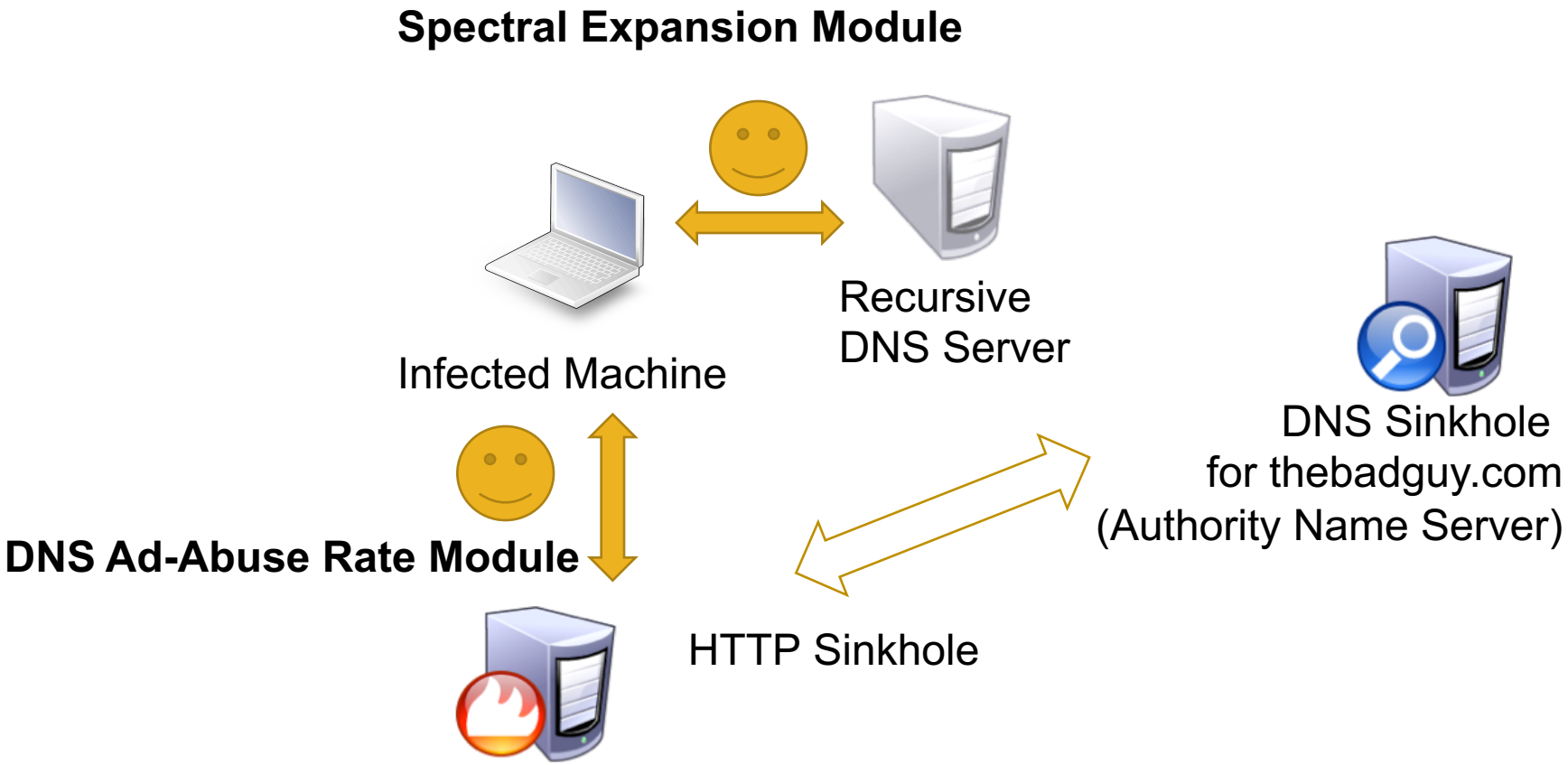
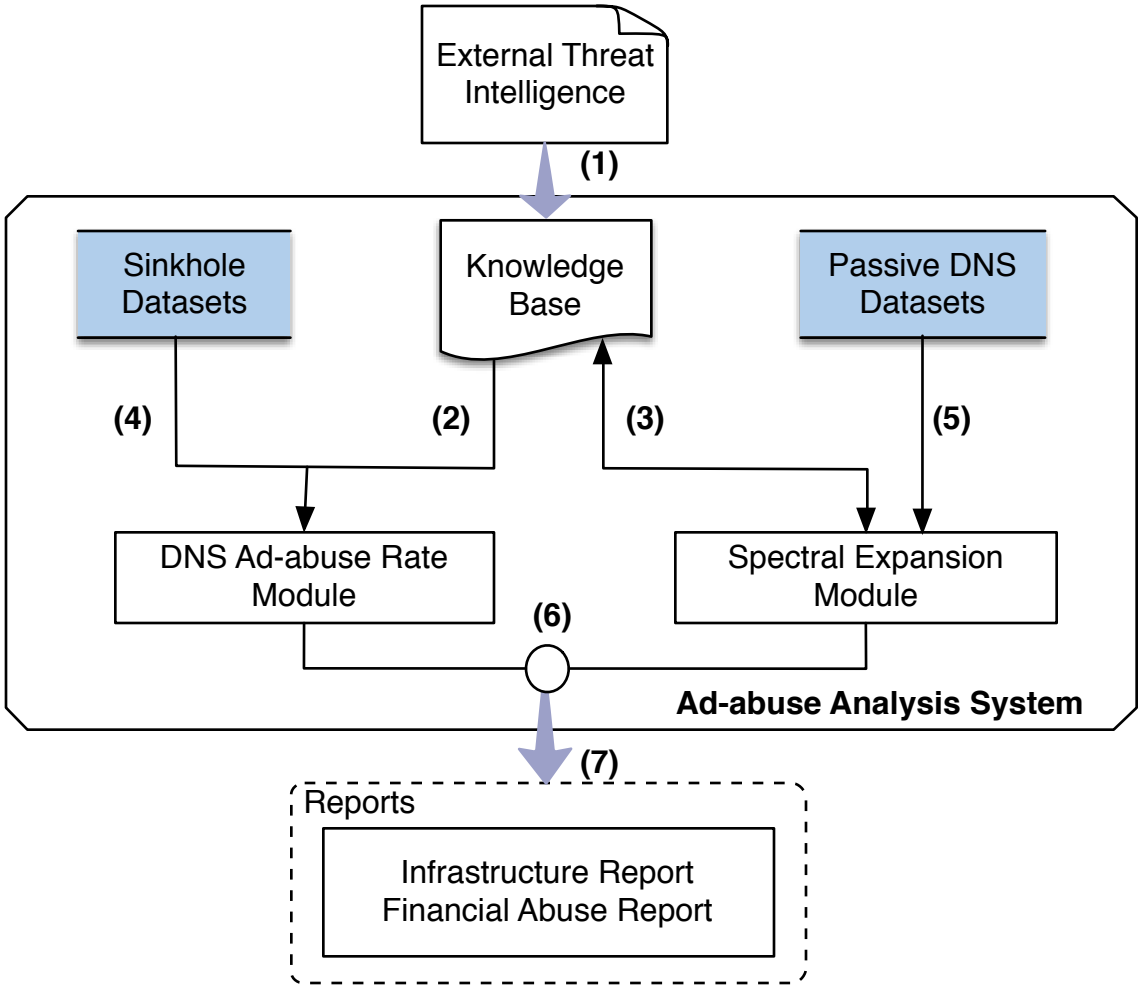
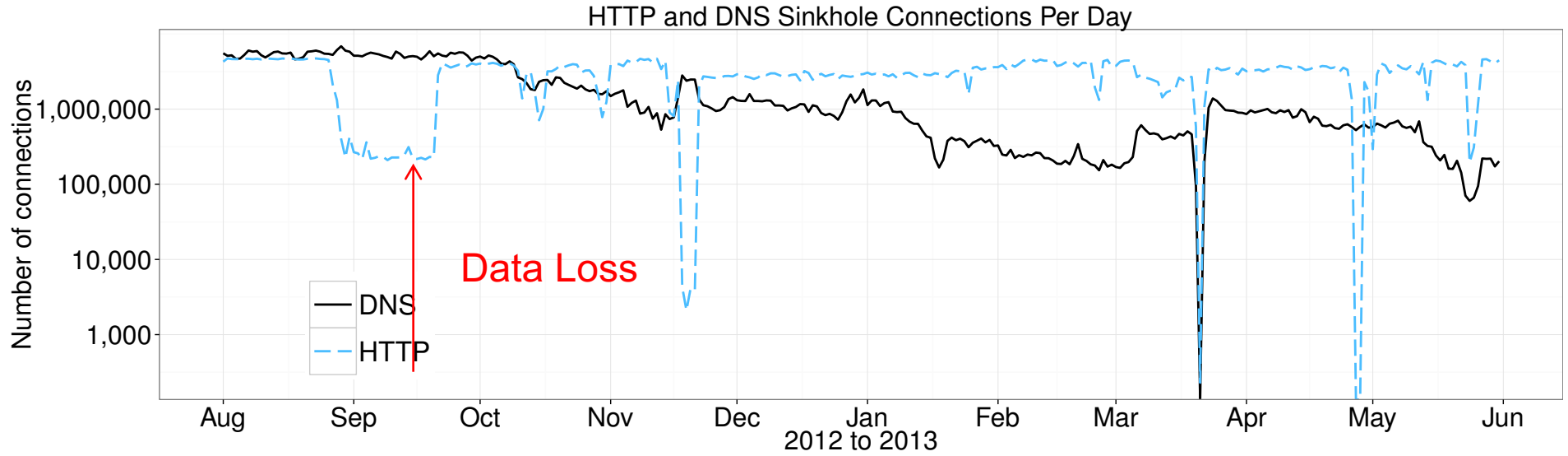


Ad-abuse Analysis System (A^2S)

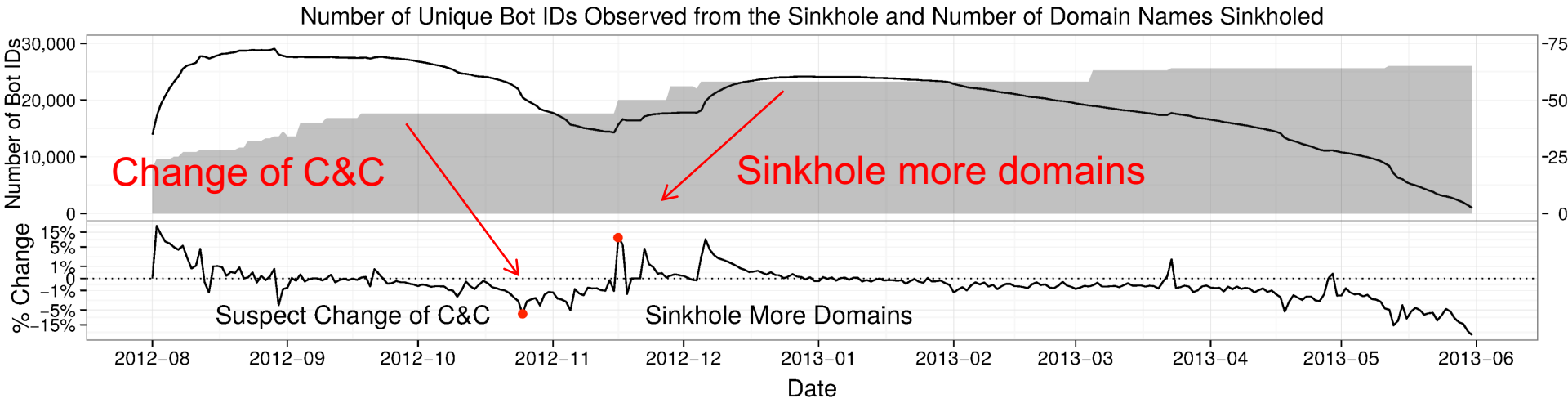


Datasets

	Date Range	Size	Records (millions)
DNS Sinkhole	8/1/2012 - 5/31/2013	6.9G	565
HTTP Sinkhole	8/1/2012 - 5/31/2013	248.6G	919
NXDOMAIN	6/27/2010 - 9/15/2014	133.5G	13,557
pDNS-DB	1/1/2011 - 11/6/2014	17.9T	10,209

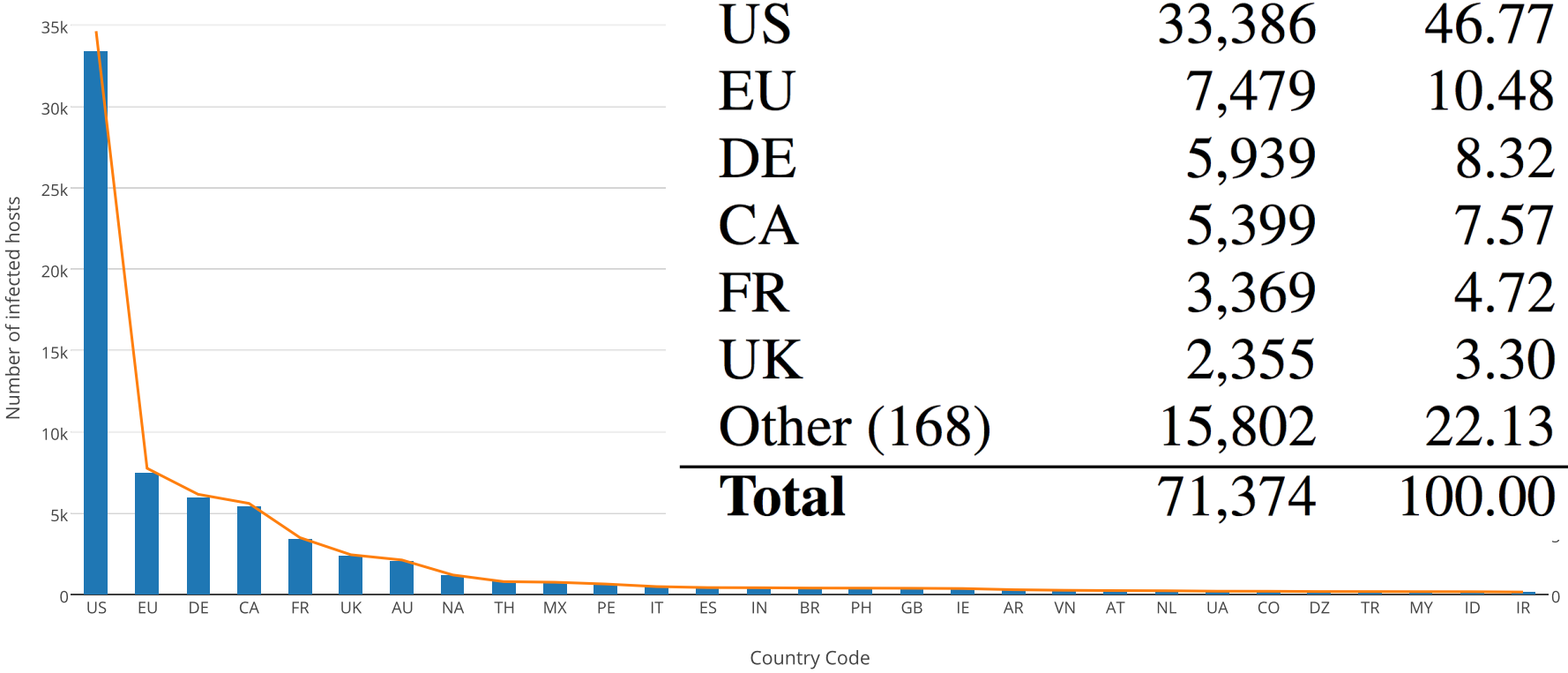


Sinkhole Datasets



- C&C domains change a lot.
- We need to track change.

Countries Affected



Country	Infections	%
US	33,386	46.77
EU	7,479	10.48
DE	5,939	8.32
CA	5,399	7.57
FR	3,369	4.72
UK	2,355	3.30
Other (168)	15,802	22.13
Total	71,374	100.00

Observation: The measurement in ISP includes less than 15% of the botnet population.

DNS Ad-abuse Rate Module

- ζ = (# of HTTP C&C) / (# of DNS resolutions)
- # of DNS requests to # of ad-abuse C&C connections
- “short-term” sinkhole observations to “long-term” passive DNS observations.

Spectral Expansion Module

- Unknown C&C domains can be
  - queried by known infected hosts
  - share infrastructure with known C&C domains.

- Iterative algorithm
  - Tripartite Graph: infected hosts - domains they queried - resolved data (A, CNAME).
  - Spectral clustering
    - Singular Value Decomposition + XMeans
  - Update Ad-abuse domains by cluster analysis

- Sanitize resulting domains
  - Financial Analysis: known email addresses or TDSS name servers.

Algorithm 1 Spectral Expansion Algorithm

Infected Hosts

1: $H \leftarrow \{h | \exists q \in D_A : h \text{ queried } q \text{ on day } d_i\}$
2: $D \leftarrow \{q | \exists h \in H : h \text{ queried } q \text{ on } d_i\}$
3: $Rdata \leftarrow \{ip | \exists q \in D : q \text{ resolved to } ip \text{ historically}\} \cup \{cname | \exists q \in D : q \text{ resolved to } cname \text{ historically}\}$
4: Apply thresholds α and β to the sets of $Rdata$ and H, respectively, to remove noisy IPs and hosts.
5: $M \leftarrow$ relationship between D and ($Rdata$, H). Normalize by IPs, CNAMEs and Hosts.
6: $S \leftarrow M \times M^T$
7: $U \Sigma V^* \leftarrow SVD(S)$
8: $clusters \leftarrow XMeans(U)$
9: $D_A \leftarrow$ Analyze $clusters$.
10: $i = i + \delta$, Go to line 1.

Algorithm 1 Spectral Expansion Algorithm

Require: δ

Domains Queried by Known Infected Hosts

2: $D \leftarrow \{q | \exists h \in H : h \text{ queried } q \text{ on } d_i\}$

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Require: δ

1: $H \leftarrow \{h | \exists q \in D_A : h$ queried q on day $d_i\}$

Resolved IP addresses and Canonical Names

3: $Rdata \leftarrow \{ip | \exists q \in D : q$ resolved to ip historically$\} \cup$ $\{cname | \exists q \in D : q$ resolved to $cname$ historically$\}$

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Remove (more than) parking IPs, sinkholes, and large gateways.

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Matrix normalization

5: $M \leftarrow$ relationship between D and $(Rdata, H)$. Normalize by IPs, CNAMEs and Hosts.
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4: Apply thresholds α and β to the sets of $Rdata$ and H, respectively, to remove noisy IPs and hosts.
5: $M \leftarrow$ relationship between D and $(Rdata, H)$. Normalize

Association matrix -> similarity matrix

6: $S \leftarrow M \times M^T$
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Singular Value Decomposition

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6: $S \leftarrow M \times M^T$

Cluster the left Eigen vectors

8: $clusters \leftarrow XMeans(U)$
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6: $S \leftarrow M \times M^T$
7: $U\Sigma V^* \leftarrow SVD(S)$

Cluster analysis and label propagation

9: $D_A \leftarrow$ Analyze $clusters$.
10: $i = i + \delta$, Go to line 1.

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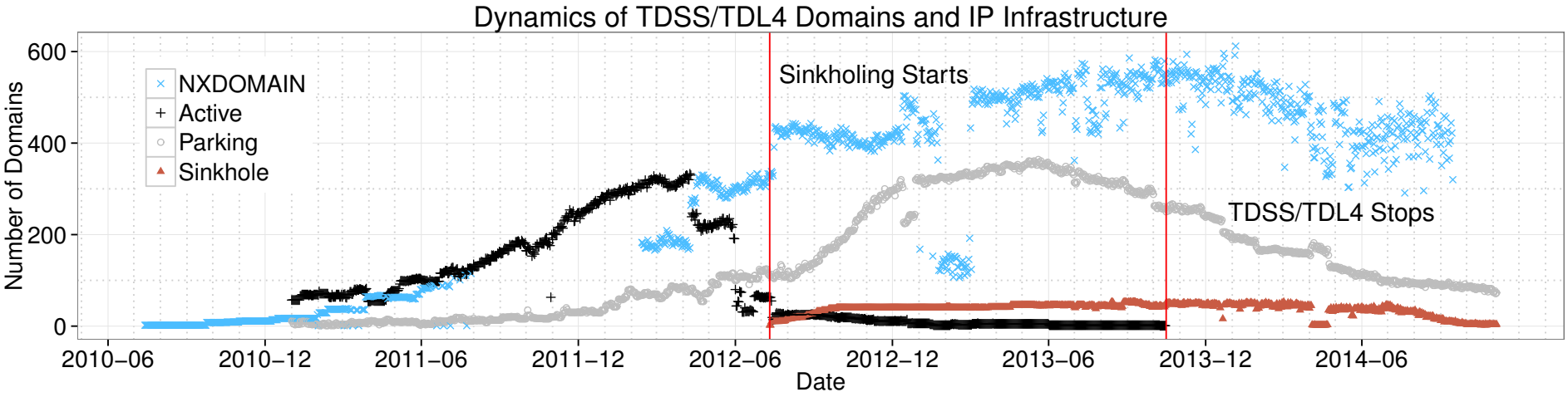
Next iteration

10: $i = i + \delta$, Go to line 1.

Infrastructure Report



- 3 False Positives out of 1,134
- http://tinyurl.com/dimva16-tdss-domains

Observation: The number of active domain names daily increased from 2010, and reached the maximum (333) on 4/9/2012.

Observation: None of the domains resolved to any active IP after 10/15/2013.

Financial Model

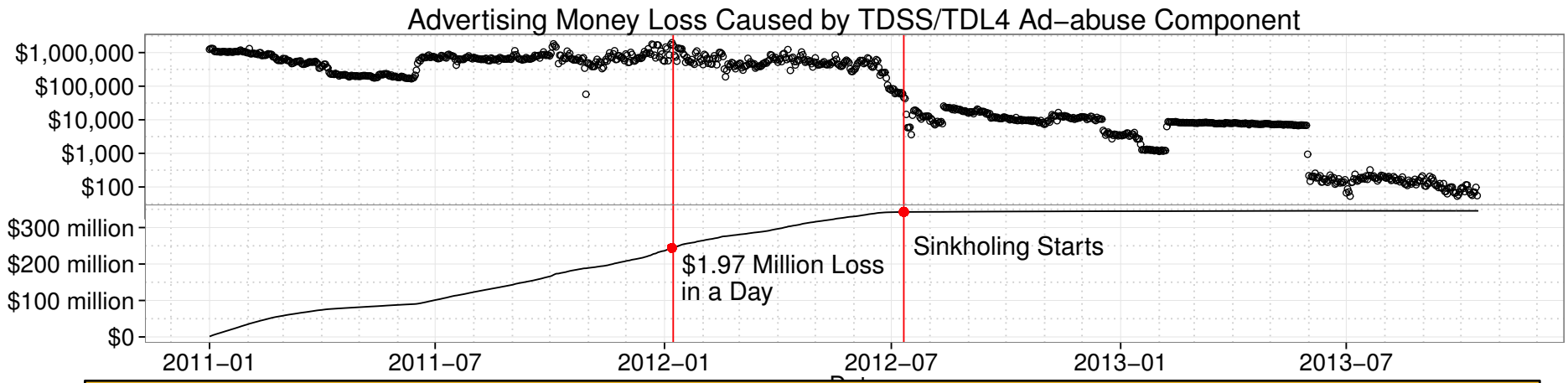
$$M_{impression} = \sum_i \zeta * R_i * (p_{im} * \frac{\mu_{im}}{1000} * CPM)$$

Number of DNS Requests

Impression Fraud Component

- ζ: DNS Ad-abuse Rate
- p_{im}: impression percentage
- μ_{im}: number of impressions per C&C HTTP connection
- CPM: Cost Per Millie (Cost per thousand impressions)

Financial Report



Note: $14 million were found in DNSChanger operators' bank accounts.

Stakeholders		Money (millions)
Advertisers' Capital		346.00
DSP	45%	155.70
Ad Exchange (inbound)	8%	27.68
Ad Exchange (outbound)	8%	27.68
Ad Networks	32%	110.72
Ad Server/Publisher (Affiliates)	7%	24.22

Questions?