Kindred Domains: Detecting and Clustering Botnet Domains Using DNS Traffic

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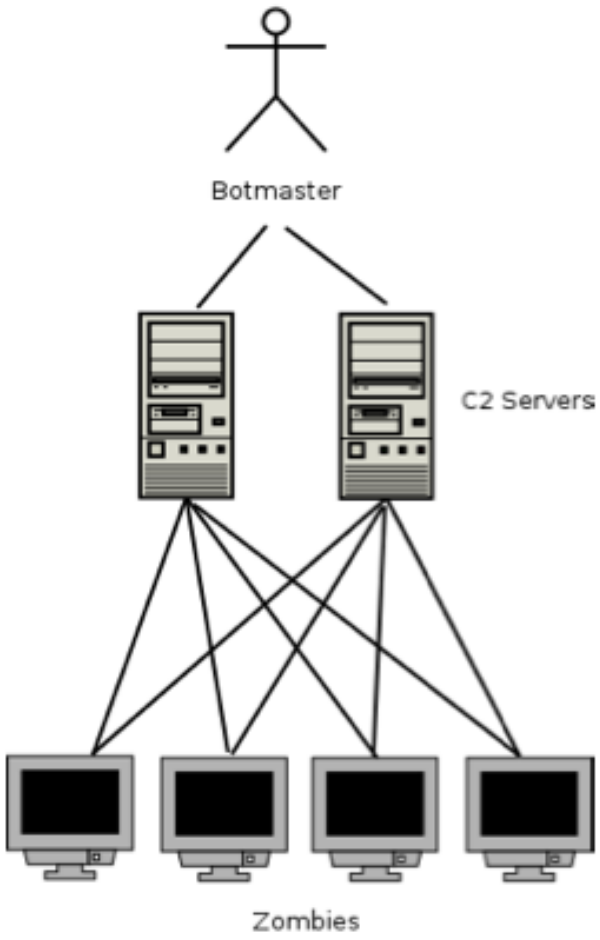
An Overview of Command & Control Botnets



- Malware commonly uses Domain Fast-Fluxing or Domain Generation Algorithms (DGA)
- Typically seeded by system clock
- Domains span many TLDs
- DNS traffic lookup patterns will emerge as all infected hosts resolve the same set of domains
  - Most result in NXDomain

Conficker: The Quintessential DGA

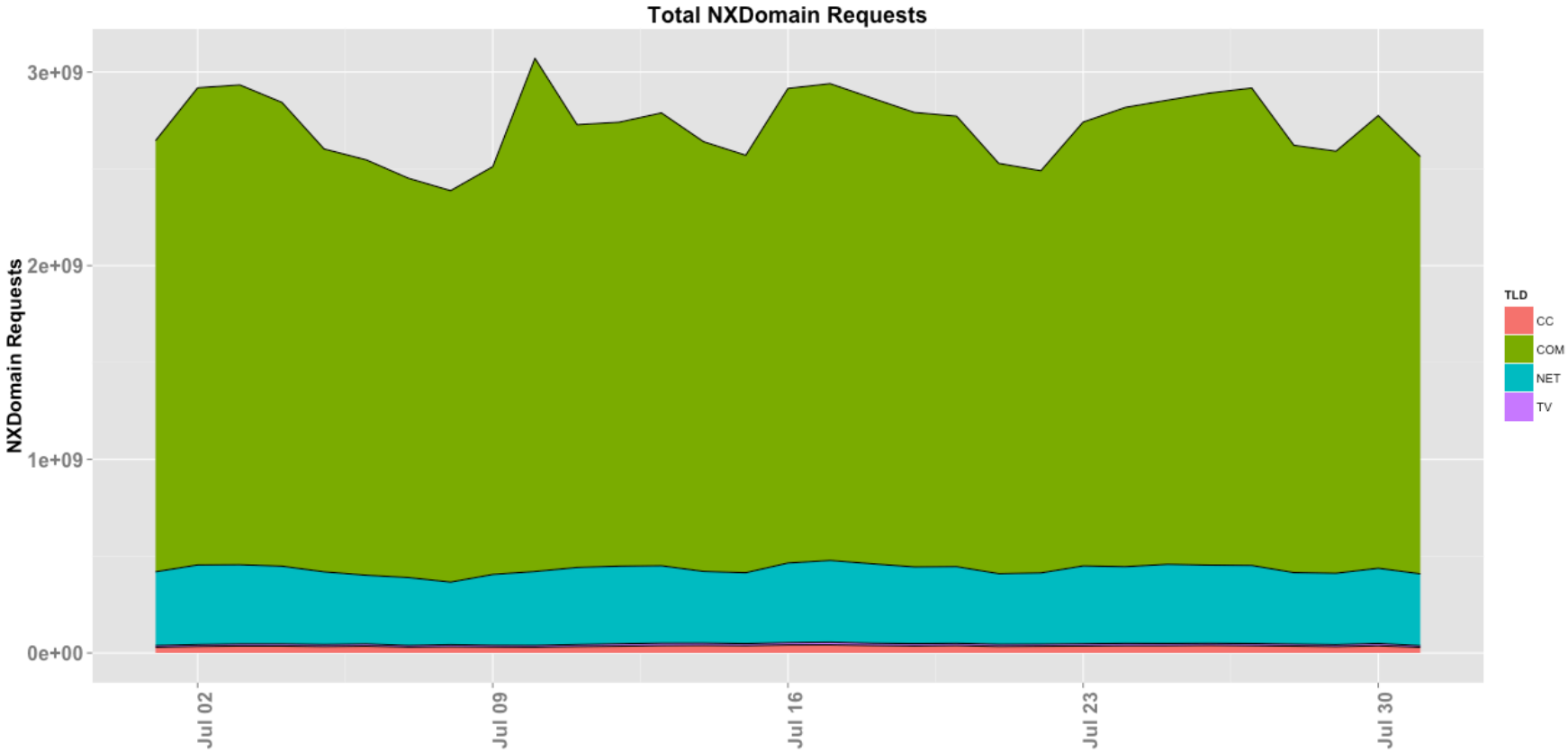
- A malware family that popularized the concept of DGA
- Thousands of infected machines still exist
- Many variants – each generates different set of domains

Variant	Domains / Day	TLDs
A	250	biz, info, org, net, and com
B	250	biz, info, org, net, com, ws, cc, cn
C	50k	110 ccTLDs not including tv or cc

- DGA Algorithm was reverse engineered
  - Provides set of domains generated for each variant for a given day
  - Useful “ground truth” for detection

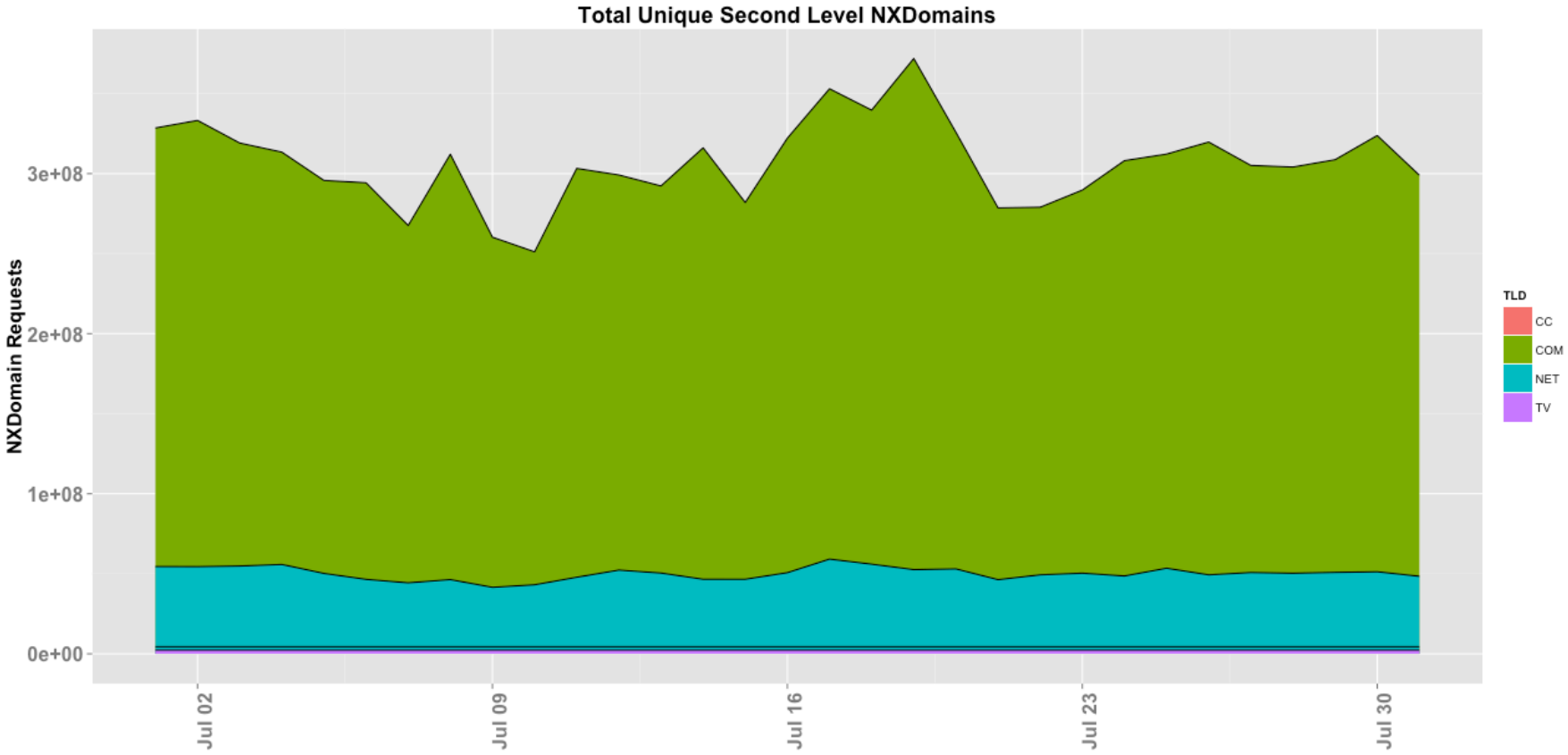
How does Conficker traffic differ from typical NXD traffic?

NXDomain Traffic Data



- Daily volume of NXD traffic for CC/TV/NET/COM
- NXD traffic is associated with domains not registered, mistyped, etc

NXDomain Traffic Data

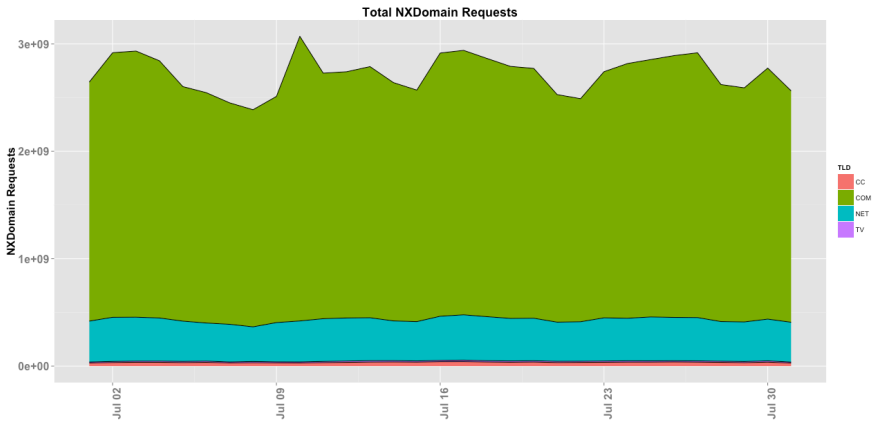


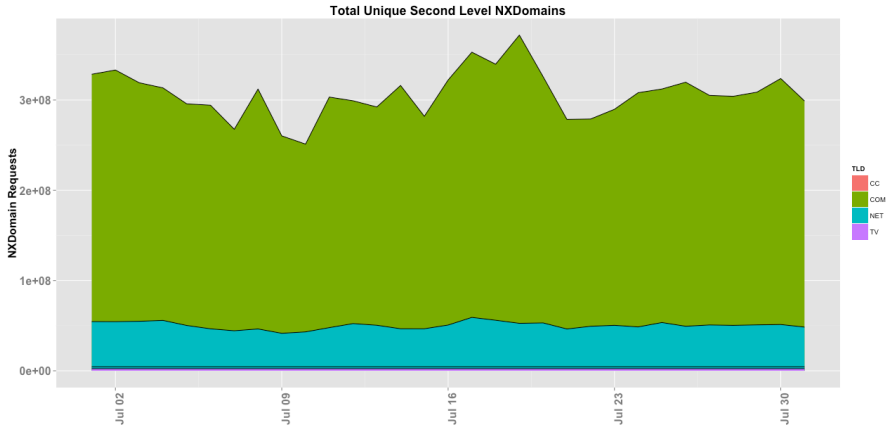
- Daily number of unique Second Level Domains (SLDs)
- The traffic is NXD (not registered domains, mistyped, etc)

NXDomain Traffic Data

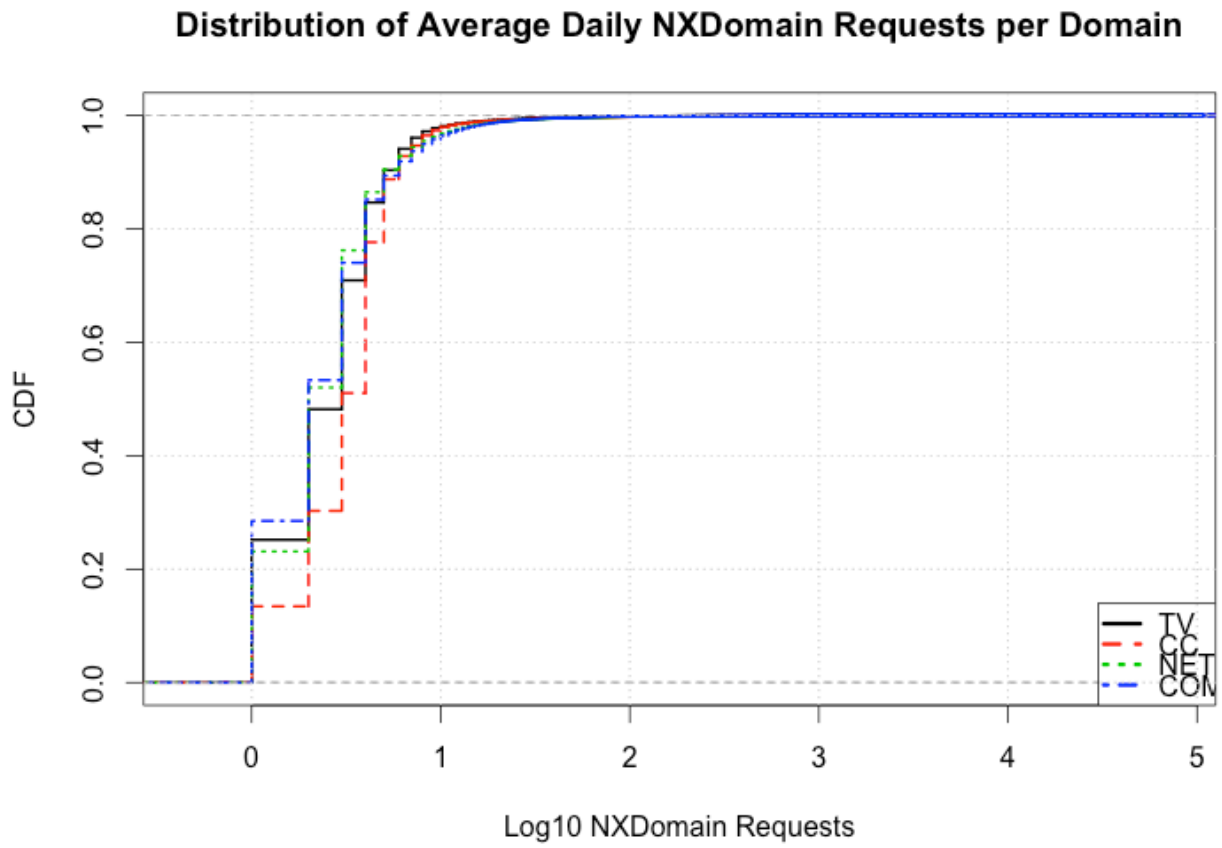
- COM typically sees ~2.5 billion NXD requests per day and spans over 350 million unique SLDs
- NET receives 500 million NXD requests over 60M SLDs (SLDs that are not registered, or mistyped)
- ccTLDs receive significantly less traffic, and less NXD

What's the distribution of requests per SLD?



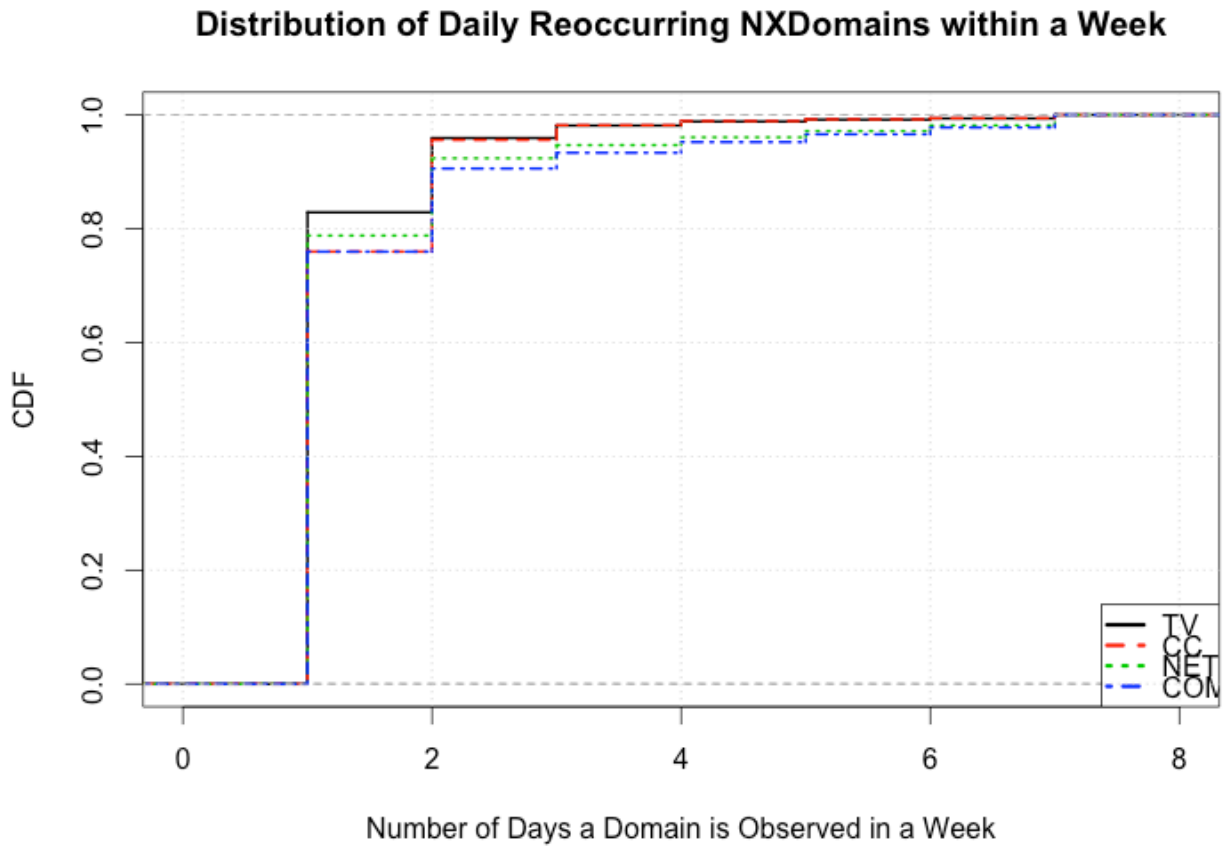


NXDomain Traffic Data



- CDF of average number of NXD requests per SLD

NXDomain Traffic Data

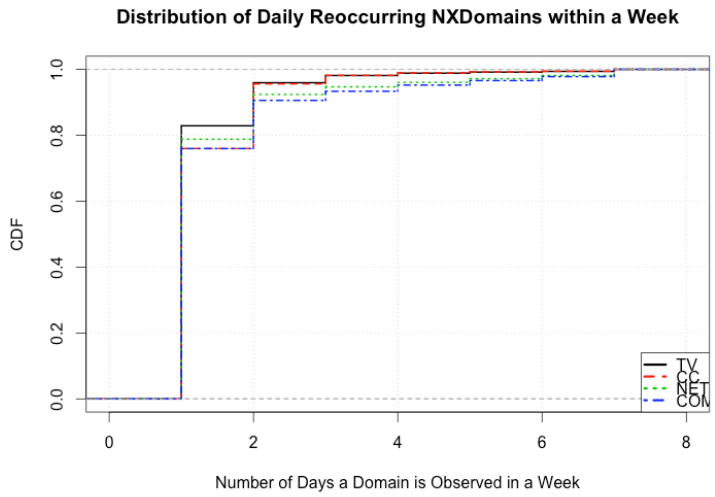


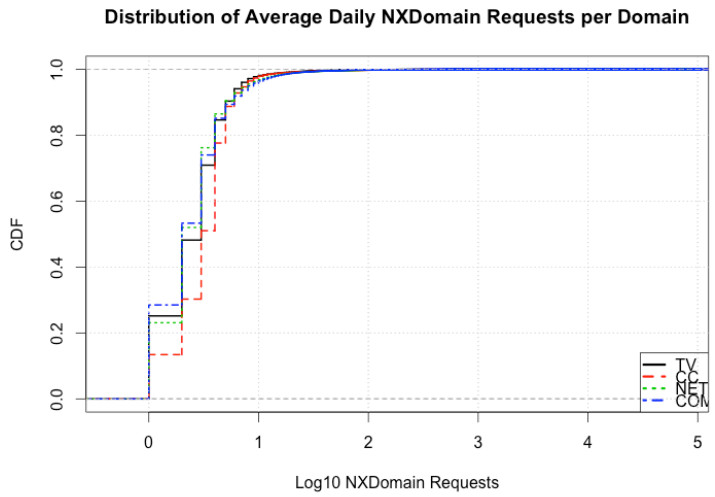
- CDF of number of days an SLD appears in a week

NXDomain Traffic Data

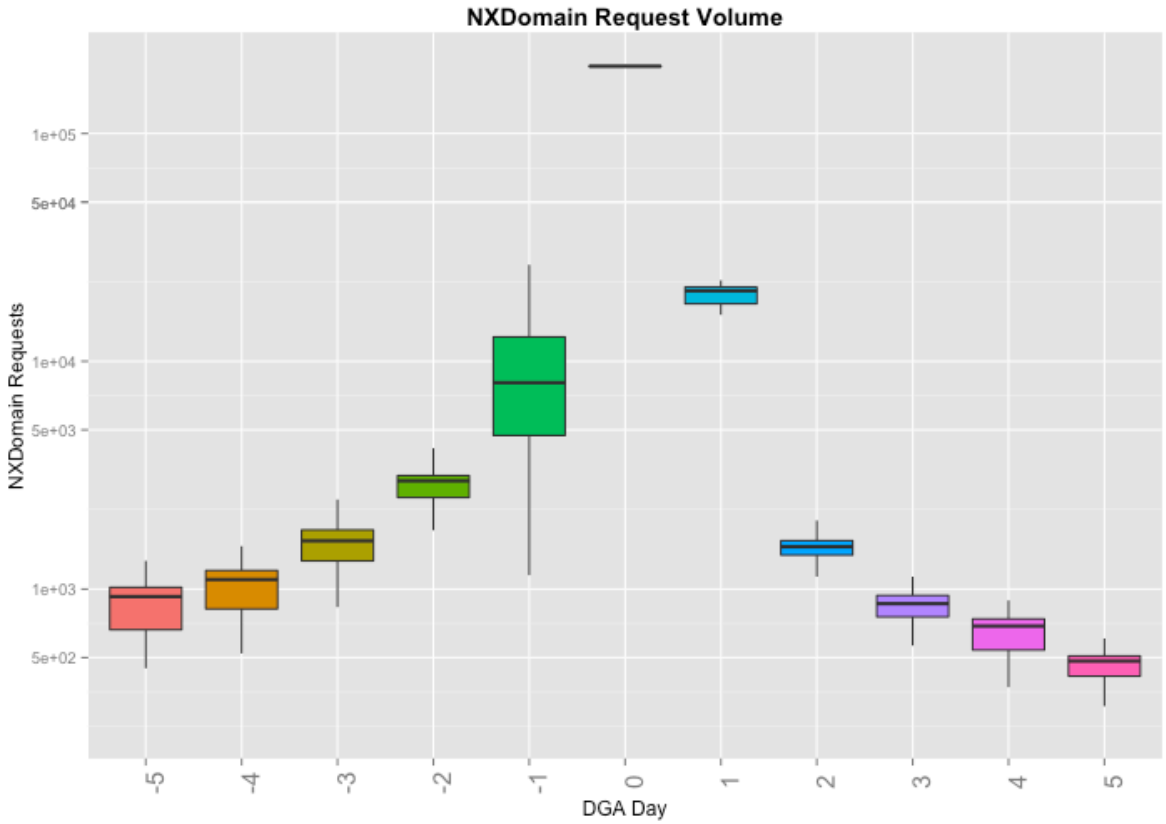
- Average SLD receives minimal amount of NXD traffic
  - 95% of SLD's NXD receive less than 10 requests within 24 hours
- High "churn" rate within the SLD set during a week

How does Conficker's NXD traffic compare?



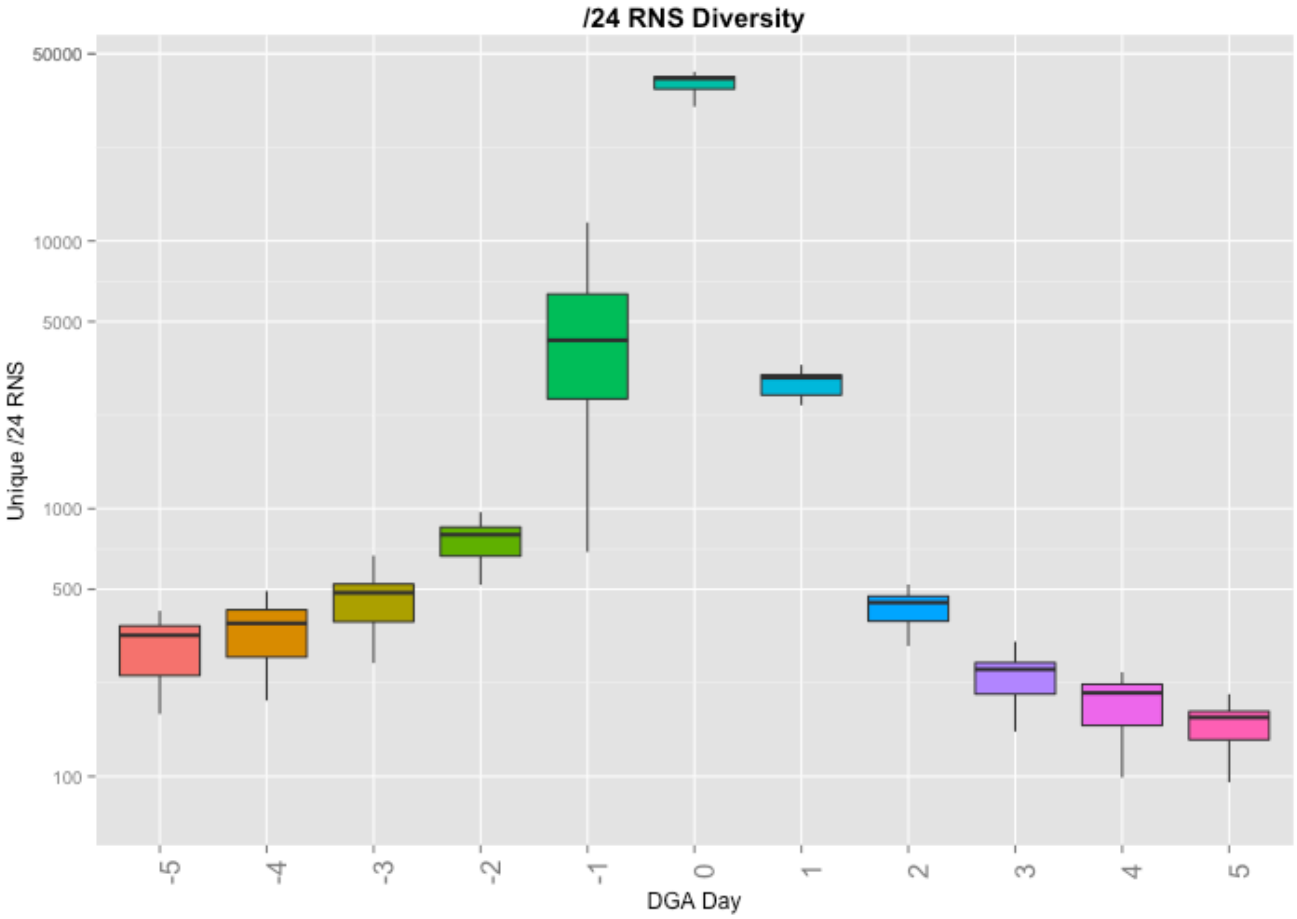


Conficker's NXDomain Traffic Data



- NXD traffic volume for DGA domains prior, during and after their expected generation date

Conficker's NXDomain Traffic Data

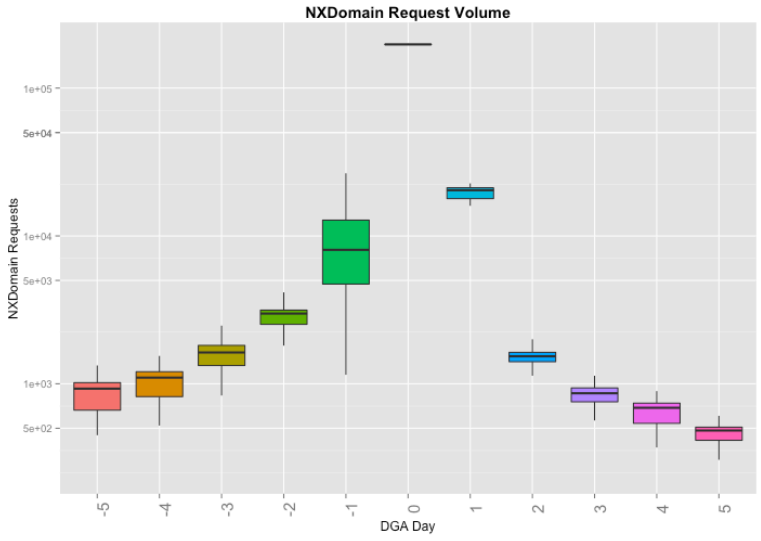


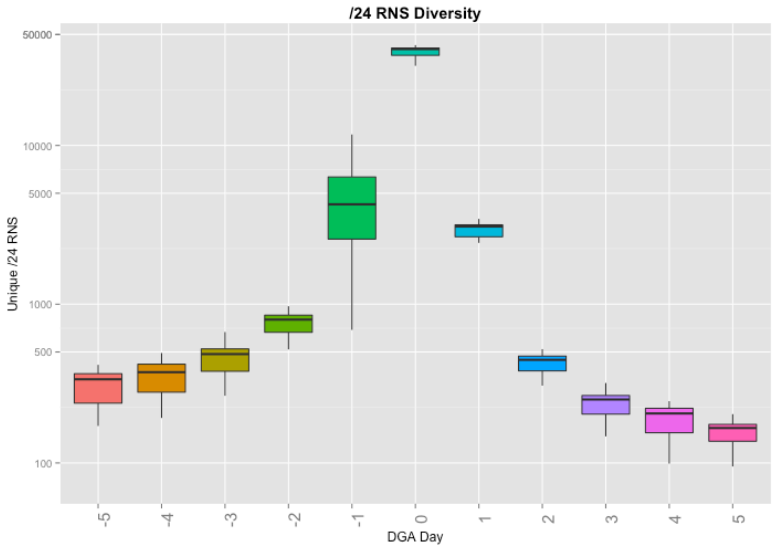
- NXD traffic diversity (/24 of the RNS) for DGA domains prior, during and after their expected generation date

Conficker's NXDomain Traffic Data

- Despite specific generation date, DGA domains receive traffic pre and post its specific generation date
  - Possible global clock skew; also possible misconfiguration
- Large amount of traffic from diverse set of RNS for SLDs
  - Statistical abnormal compare to whole NXD population

How can we detect and associate malware domains?





Detection and Clustering

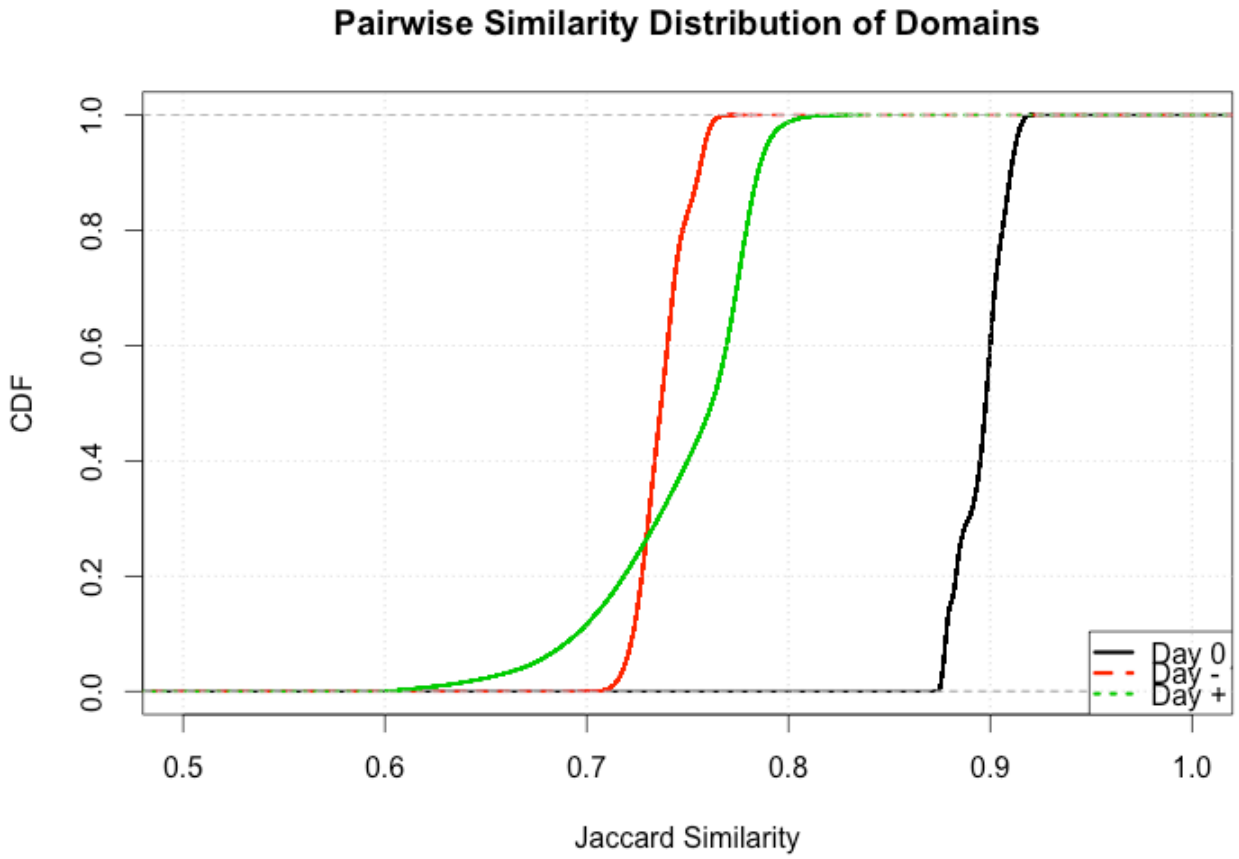
Computing Traffic Similarity

- We try to address the following questions:
  - How similar are traffic streams to each other?
  - Can the similarity be used to group different traffic streams?

- The similarity function is a real-valued function that quantifies the *similarity* between two entities
- Jaccard Index is a statistic for comparing the similarity and diversity of sample sets (one among many)

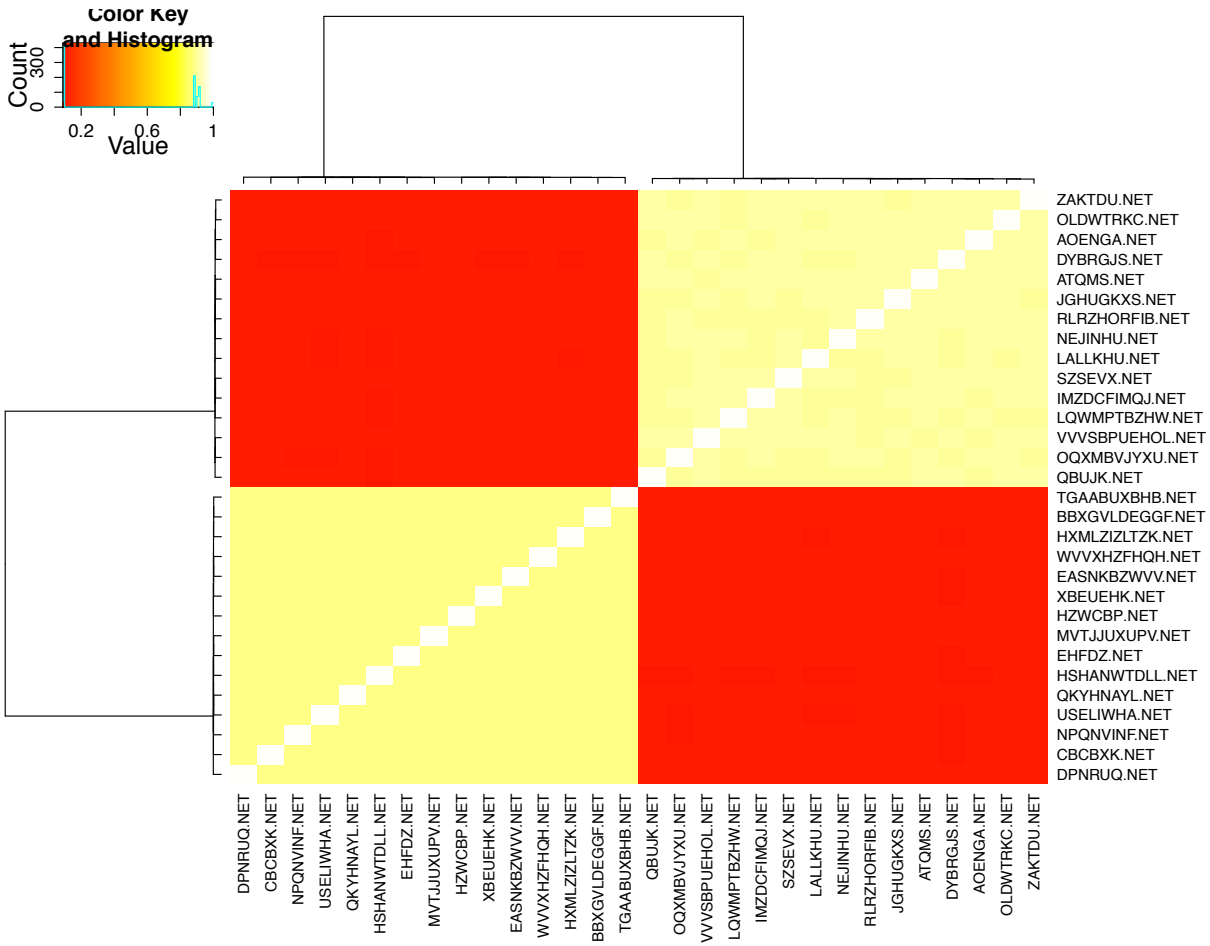
$$J(A,B) = \frac{|A \cap B|}{|A \cup B|}. \qquad 0 \leq J(A,B) \leq 1.$$

Conficker's Traffic Similarity



- CDF of pairwise domain similarities for a set of DGA domains based on on their /24 RNS set for a given day

Conficker's Traffic Similarity

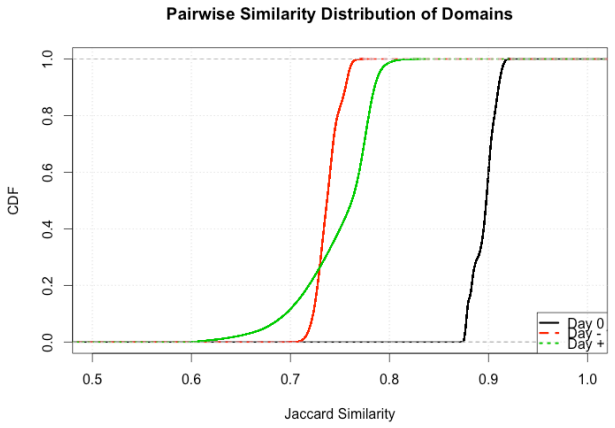


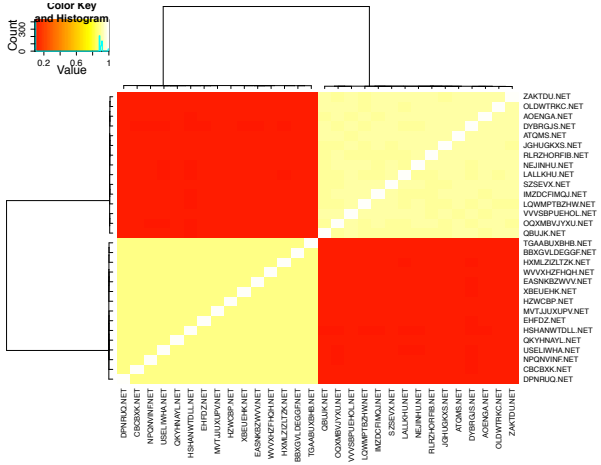
- Subset of domains from Conficker A & B clustered based on similarity using single-linkage algorithm

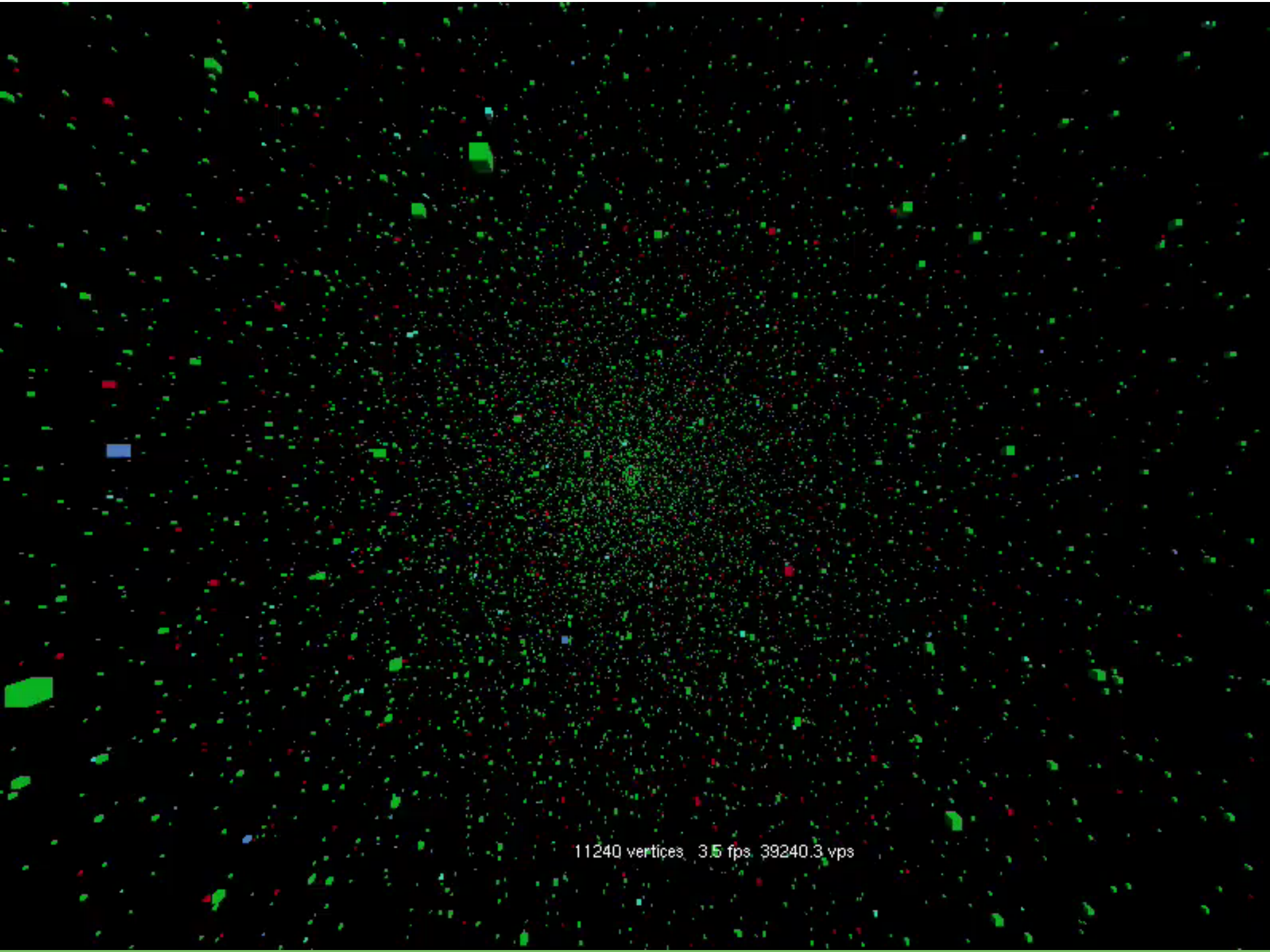
Conficker's NXDomain Traffic Data

- Domains on a specific DGA date have very high similarity measures, most measuring higher than 0.9
- Techniques such as hierarchical clustering could potentially group domains from a specific DGA into distinct clusters based on DNS traffic similarity

How do various similarity thresholds affect the cluster?

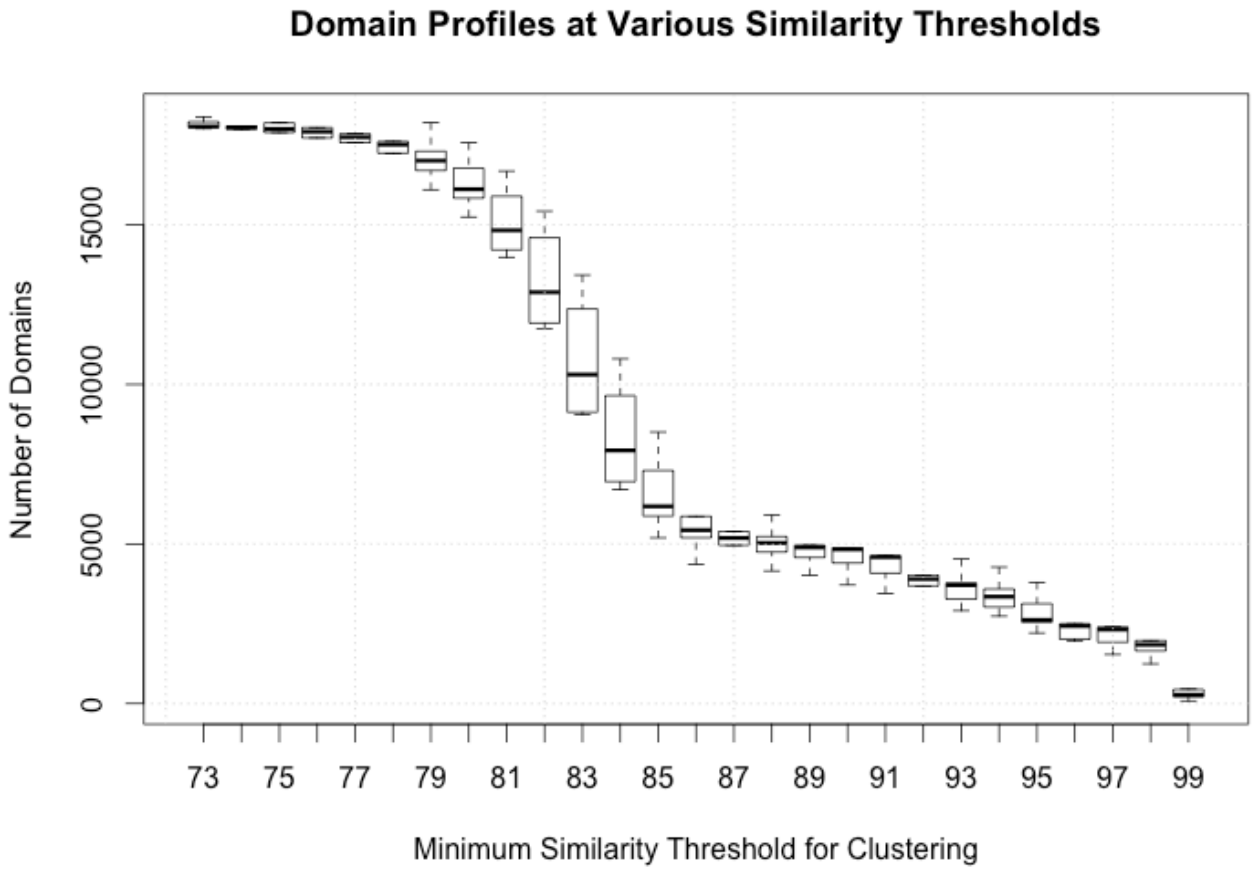





11240 vertices 3.5 fps 39240.3 vps

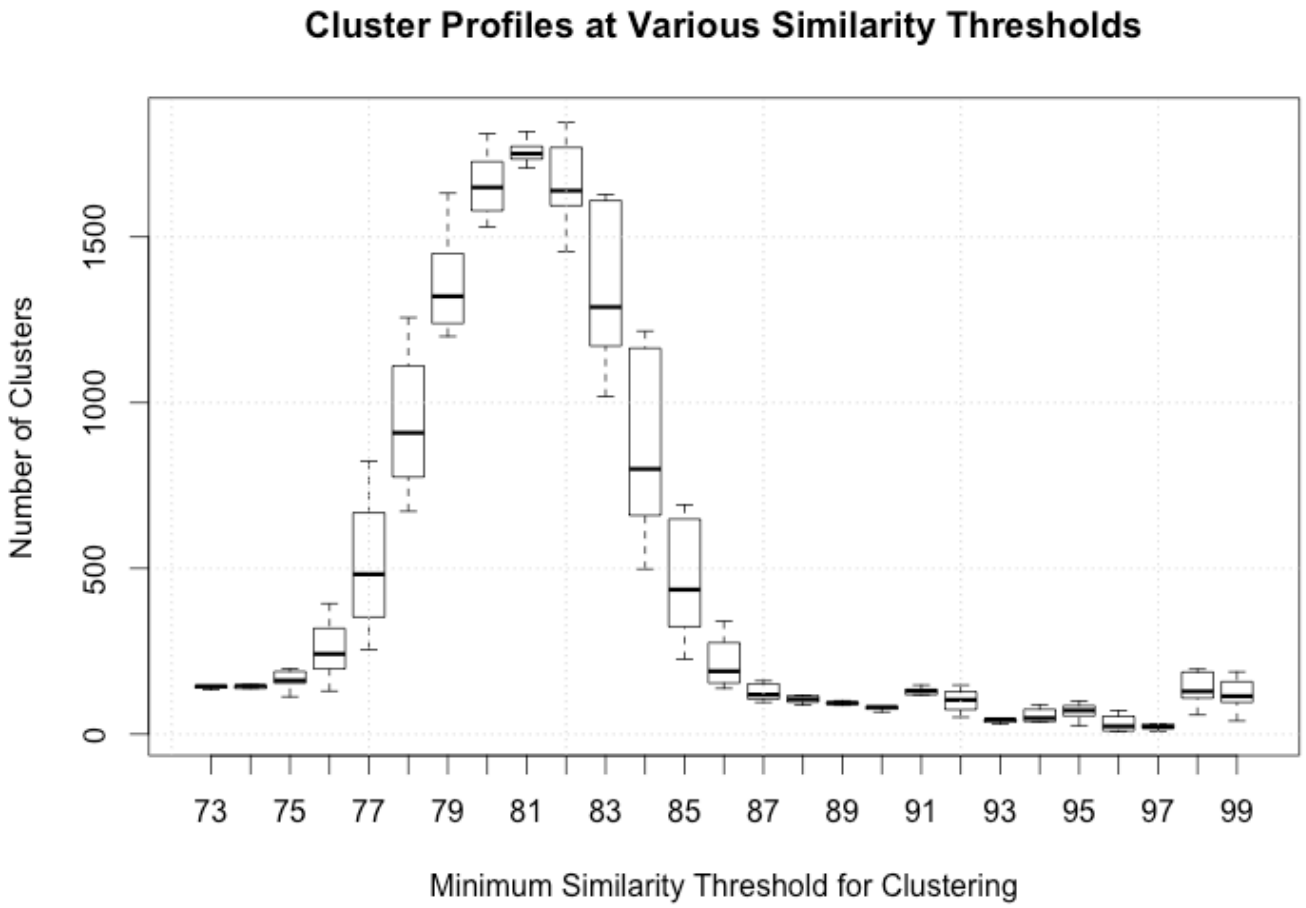
Clustering – Similarity Thresholds

Clustering – Similarity Thresholds



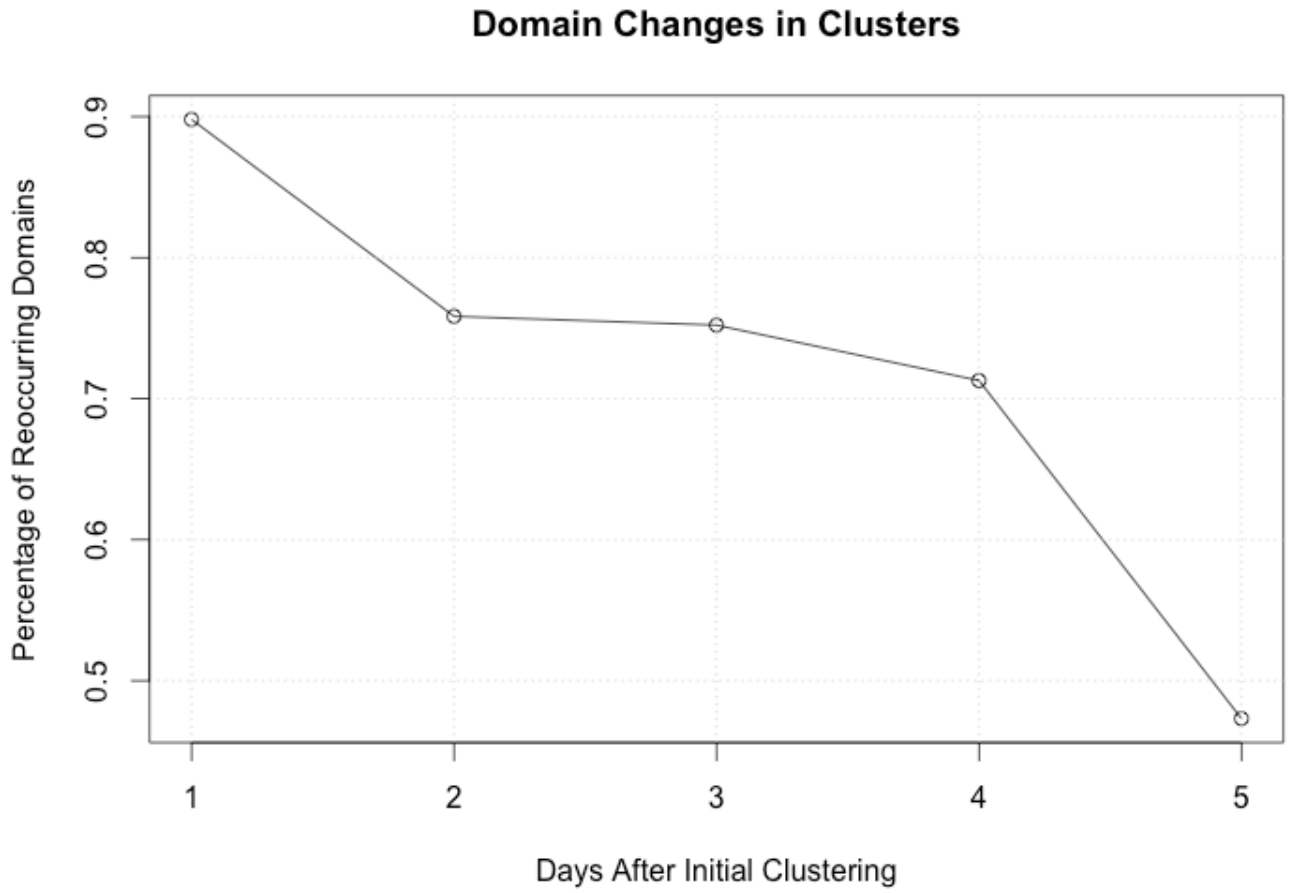
- The number of SLDs contained in a cluster at various similarity threshold levels

Clustering – Similarity Thresholds



- The number of distinct clusters formed at various similarity threshold levels

Clustering – Similarity Thresholds



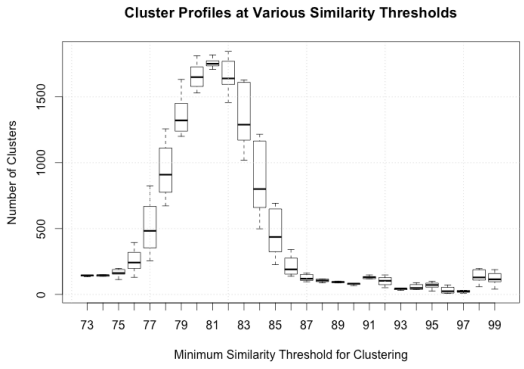
- Temporal evolution of clusters based on SLDs present

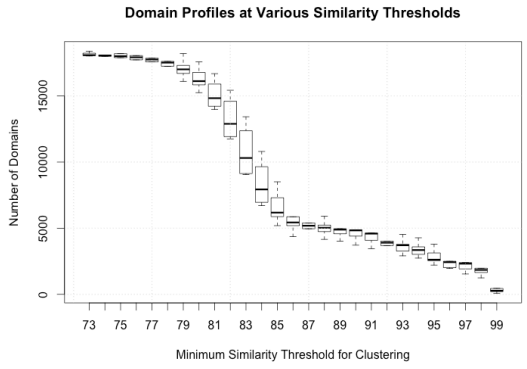
Global Malware Detection

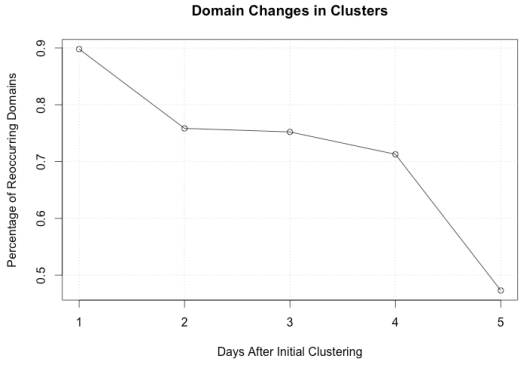
Global Malware Detection

- Similarity thresholds influence the number of clusters and the number of domains within each cluster

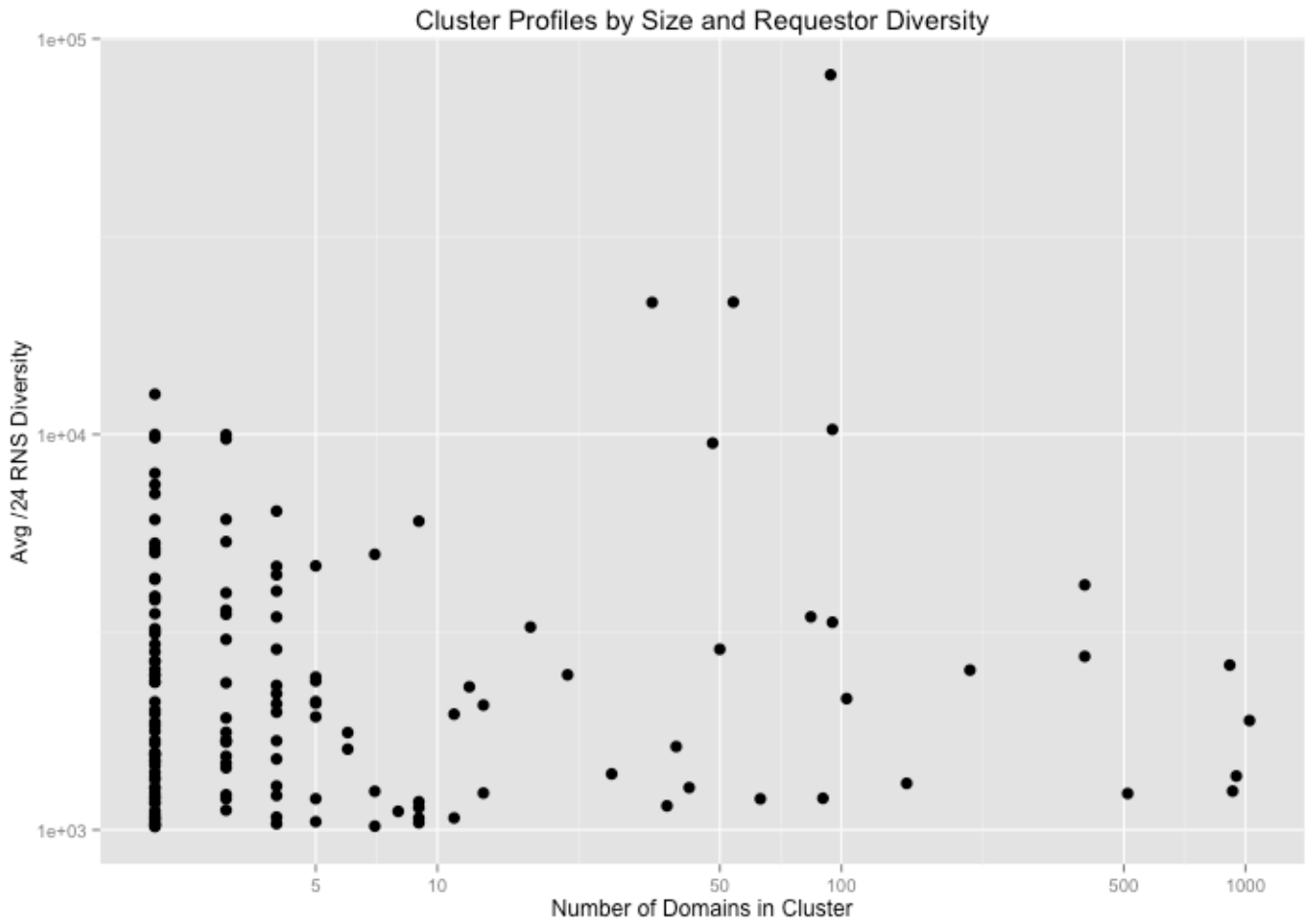
What resulting clusters appear when such a technique is applied to all NXD traffic?







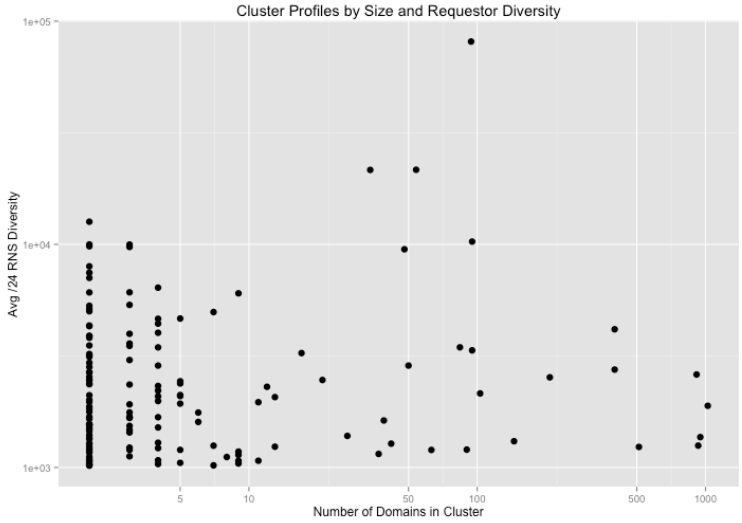
Global Malware Detection



- Clusters identified with a similarity threshold set to > 0.9
- Each point is a cluster – measures # domains and # RNS

Global Malware Detection

- Many detected clusters of malware/variants use a small amount of domains observable in our dataset
- A few clusters generated several hundred domains
  - May influence evasiveness and resilience of a botnet
- Several clusters have thousands of distinct /24s
  - Infection rate or prevalence of a malware



Concluding Remarks and Future Work

- We look at using the authoritative NXD traffic for identifying DGA's used as the C&C channel of malware
  - We use the largest dataset from com/net resolution
  - Domain names used for C&C are identifiable by their request pattern
  - Different generations of the Conficker malware family are identified
  - Clustering of traffic yields interesting structures identifying evasion
- Future works: We will look into extending the work
  - To other malware families using DNS for C&C
  - Highlight operation impact and evolution of evasion techniques
  - Explore spread of infections via remote sensing at the DNS level

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