ODNS Clustering

Unveiling Client-Side Dependency in Open DNS Infrastructure

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Background & Motivation

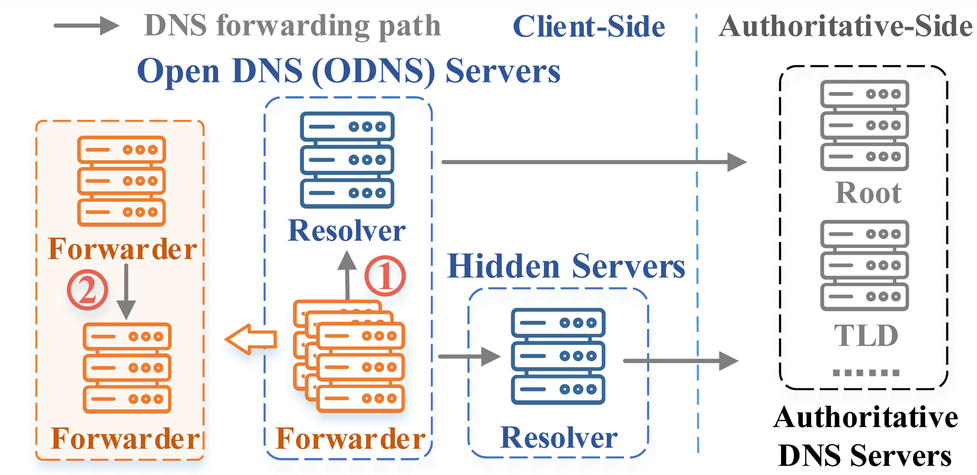
Many DNS servers do not resolve DNS queries by themselves

- **DNS forwarding behavior causes complex dependency**
  - ① Dependency between forwarder and forwarder
  - ② Dependency between forwarder and resolver
- **Dependency causes potential risks**

  Single-point failure, Amplify malicious behaviors, Entrances for Attacks

How to characterize the dependencies among ODNS

ODNS servers with dependence naturally form **clustered structure**



- **DNS infrastructure and client-side structure.**

Methodology: ODNS Clustering

Concept: What is ODNS Cluster

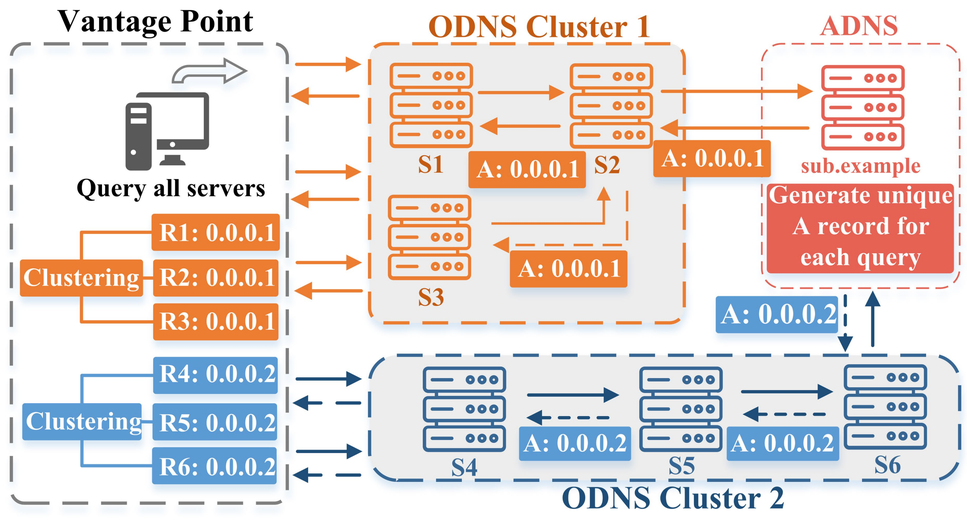
- Collection of **upstream servers and forwarders** with dependencies.
- **Example:** S1-S6 are divided into two ODNS clusters. Servers **S1-S3** in **Cluster 1** and **S4-S6** in **Cluster 2**.

Methodology: Divide DNS servers into multiple clusters

- Servers are clustered by **A record** (**S1-S3 get 0.0.0.1, S4-S6 get 0.0.0.2**)

ADNS — Controlled ADNS for specific domain. Generate unique **A record** for each query (e.g. **0.0.0.1**, **0.0.0.2**)

Vantage Point — Send A queries for specific domain to **each ODNS servers**, and collect the responses.

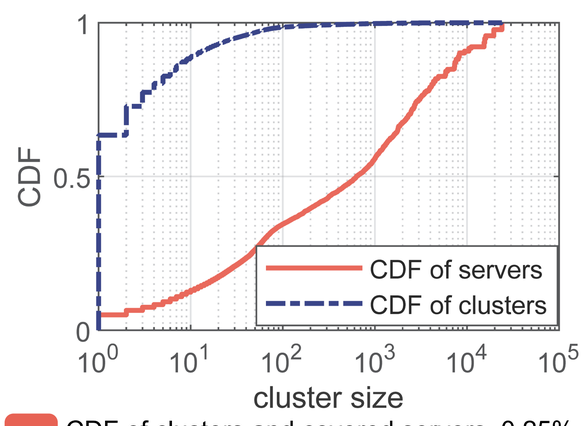


- **ODNS dependency measurement and ODNS clustering.**

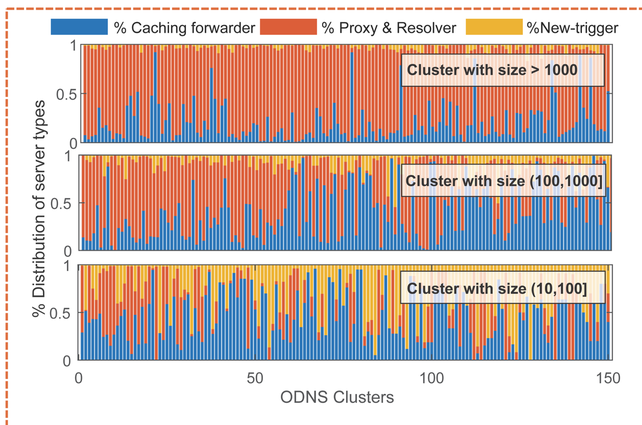
Measurement & Analysis: Million-scale ODNS servers in the wild form only 81,636 clusters

Key Observations

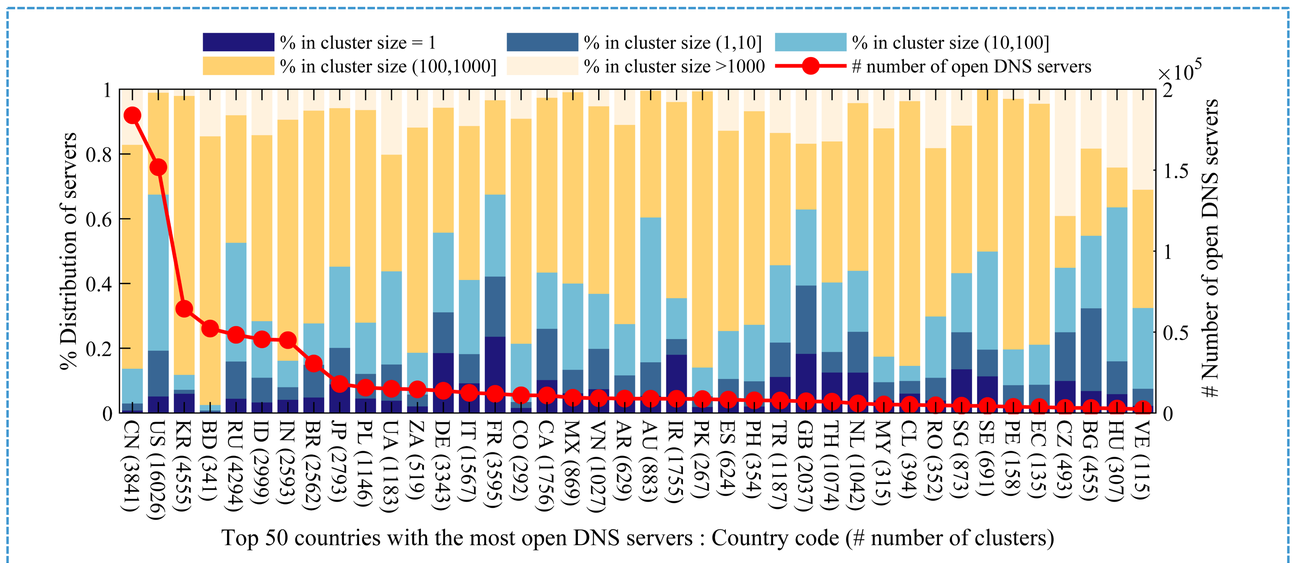
1. **Cluster Size Bias** 95% open resolvers exhibit dependencies on others for name resolution. The distribution of cluster size is heavily biased.
2. **ODNS Server Types** About 61.7% of forwarders are non-caching proxies, which may be leveraged by attackers to attack the upstream resolvers.
3. **Geolocation Bias** Cluster size distribution varies significantly across countries, implying differences in DNS infrastructure.
4. **Network Centralized** Clusters that are led by major public DNS servers cover 47% open DNS servers.
5. **Problematic Clusters** 9% of the ODNS servers direct web requests to the wrong destinations.



1 CDF of clusters and covered servers. 0.25% top clusters cover 44.1% open DNS servers.



2 Cluster composition analysis results. 61.7% forwarders are non-caching proxies.



3 The top 50 countries with the most open DNS servers. Some countries (e.g., CN) are dominated by large clusters (i.e., ≥ 100), while others (e.g., DE and FR) have more servers in small clusters.

Response Type	Subcategory	# of clusters
Success	Parked Domain	218
	Filtered/Blocked	60
	Error Page	72
	Others	29
Redirection	Malicious	65
	Normal	101
No Response	—	3648
Error	—	2864

5 Response type statistics for unexpected A record in problematic clusters. 65 clusters (affecting 1581 ODNS servers) led users to potentially malicious pages.

Provider	# of clusters	% covered rate
Google	268	27.99%
Cloudflare	228	9.76%
OpenDNS	46	5.33%
Yandex.DNS	118	4.24%
Others	—	4.63%

4 Clusters for top public DNS. Popular public resolvers lead a large portion of open DNS servers. The use of Anycast results in multiple clusters for one public DNS provider.