Lightweight Anycast Enumeration and Geolocation

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***Abstract*—Several Internet services such as CDNs, DNS name servers, and sinkholes use IP-layer anycast to reduce user response times and increase robustness with respect to network failures and denial of service attacks. However, current geolocation tools fail with anycast IP addresses. In our recent work [1], we remedy to this by developing an anycast detection, enumeration, and geolocation technique based on a set of delay measurements from a handful of geographically distributed vantage points. The technique (i) detects if an IP is anycast, (ii) enumerates replicas by finding the maximum set of non-overlapping disks (i.e., areas centered around vantage points), and (iii) geolocates the replicas by solving a classification problem and assigning the server location to the most likely city. We propose to demo this technique. In particular, we visually show how to detect an anycast IP, enumerate its replicas, and geolocate them on a map. The demo allows to browse previously geolocated services, as well as to explore new targets on demand.**

I. Introduction

Many research and commercial tools [2] propose to associate an IP address with a geographic location. IP geolocation improves both research and business applications. More specifically, it helps researchers characterise Internet usage, service deployments, and network performance per geographic areas. It also facilitates the curation of Internet content (e.g., news feeds, advertisements, restaurant recommendations) depending on the user location for commercial purposes. Existing IP geolocation tools are either database-driven (e.g., MaxMind [3], WHOIS registry) or measurement-driven [2], and provide different geographic resolution ranging from city-level to precise latitude and longitude coordinates. While database-driven tools are unreliable and not always up-to-date [4], measurement-driven tools, which use multi-lateration to constrain an IP address to a *single* location, intrinsically fail with IP-layer anycast addresses – where *multiple* physically disjoint (and generally geographically dispersed) replicas share a single IP address.

IP-layer anycast [5] allows a group of replicas to offer the same service using a shared IP address from geographically distinct locations around the globe. Inter-domain routing directs the traffic destined to an anycast address to the topologically closest replica. Many Internet services use anycast to reduce response times and mitigate the effects of server failure and denial of service attacks. While historically anycast has been mostly used for DNS (e.g., root and TLDs servers, google public DNS infrastructure), IPv4 to IPv6 relays, and sinkholes, we observe that lately also CDN networks such as EdgeCast and CloudFlare increasingly rely on IP anycast to replicate their services around the world.

As previous work on anycast enumeration exploits DNS-specific requests to enumerate replicas, its domain of application is rather narrow [6]. In contrast, our very recent work [1] propose a lightweight, protocol-agnostic methodology that not only enumerate, but also geolocates IP anycast replicas irrespectively of the service they offer (i.e., DNS, CDN, sinkhole, 6-to-4 relays, etc.). We propose to demonstrate our methodology in an interactive fashion, to complement its presentation at INFOCOM'15 [1]. This is part of our ongoing effort to offer our methodology as a service to the research community, of which the demo represents an interactive and graphical user interface.

II. Methodology overview

Our methodology [1] takes as input an anycast IP address t and operating according to the following steps, outputs a set of geographical locations around the world. We walk through the different steps of our methodology using a real-world example comprising four vantage points in Europe toward the IP address serving the root server L in Fig. 1.

(a) Latency measurements. We issue several RTT measurements towards t from a set of distributed vantage points with known geographical position (e.g., RIPE, PlanetLab). We retain the minimum RTT value $\delta(p,t)$ per vantage point p and map it to a disk $\mathcal{D}_p$ with center p and radius $d^+(p,t) = c_f\delta(p,t)$, where c_f is the speed of light in optical fiber. The target t serving queries from p is surely located in $\mathcal{D}_p$. In Fig. 1(a), latency measurements from four vantage points are mapped to four red discs.

(b) Anycast detection. Next, for each pair of VPs p, q, we determine that they are contacting different replicas if we detect a speed-of-light violation:

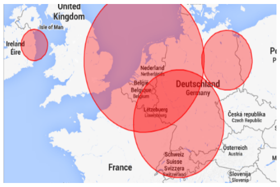
$$d^g(p,q) > d^+(p,t) + d^+(q,t)$$

where $d^g(p,q)$ is the geodesic distance between p, q. This condition translates into non-overlapping disks $\mathcal{D}_p$ and $\mathcal{D}_q$ as shown by the green discs in Fig. 1(b).

(c) Replica enumeration. We enumerate the replicas $|\mathcal{E}|$ of t by solving the *Maximum Independent Set (MIS)* problem. We use a greedy (5-approximation) algorithm which consists in sorting disks in increasing radius size and adding to $|\mathcal{E}|$ only non-overlapping disks:

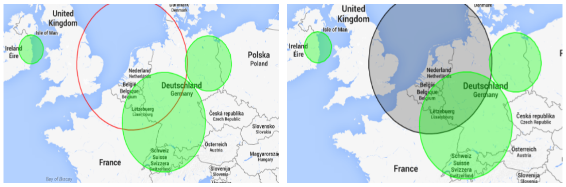
$$\forall \mathcal{D}_p, \mathcal{D}_q \in \mathcal{E}, \qquad \mathcal{D}_p \cap \mathcal{D}_q = \emptyset$$

Fig. 1(c) illustrates two steps of the greedy MIS solver. The set of green disks represent $|\mathcal{E}|$ in Fig.1(c).

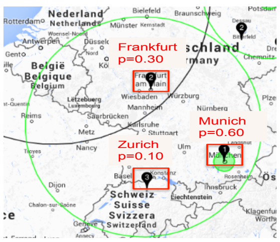


(a) Mapping latency measurements to disks centered around vantage points

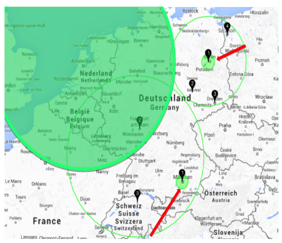
(b) Anycast is detected via non-overlapping disks (speed-of-light violation)



(c) Anycast replicas are enumerated by solving a Maximum Independent Set problem: each disc in the set of non-overlapping disks $\mathcal{E}$ contains a different replica (two steps of greedy solver shown)



(d) Anycast replicas are geolocated within disks via a classification problem, by jointly weighting latency measurement and city population information



(e) When disks are collapsed around geolocated replicas, disks may no longer overlap, and another enumeration/geolocation iteration takes place

Fig. 1. Anycast detection, enumeration and geolocation workflow

(d) Replica geolocation. We refine the geographic location of each replica in $|\mathcal{E}|$ from a disk $\mathcal{D}_p$ to one of the cities $\mathcal{C}$ located in $\mathcal{D}_p$. We bias our selection of $\mathcal{C}$ based on (i) city population and (ii) the distance from the city to the disc border. Fig. 1(d) exemplifies a classification policy that selects the city with the largest likelihood, computed with equal weights for the population vs the distance information.

(e) Iteration. We collapse each disk in $|\mathcal{E}|$ to the geolocated city as depicted in Fig. 1(e). Therefore, the grey-shaded disk in Fig. 1(c) no longer overlaps with the remaining disks and can be included in the next iteration of the workflow. We apply the same heuristic to all disks previously excluded until no more disks can be included. This iteration step increases the number of discovered replicas.

III. Demo overview

The demo is composed of a *back-end* measurement component and a *front-end* analysis and visualisation tool. The back-end component is a set of distributed vantage points in PlanetLab with known geographic coordinates in charge of preforming ICMP measurements towards a given anycast IP address. As part of our ongoing effort of performing an

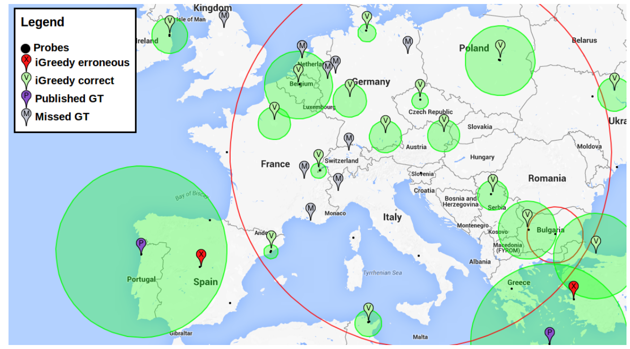


Fig. 2. Final result (root server L in Europe).

Internet scale anycast census, our tool runs in the background over a set of target IP prefixes, producing a set of browsable historic measurement results. The tool also allows the audience to interact by performing live on-demand measurements.

Live and historic measurement results are stored in a front-end repository. Upon user request, the front-end visualisation tool queries the repository, runs the methodology (with tuneable parameters) and outputs a map with the geographical locations that share the IP address. When latency measurements are available, our method takes few tens of milliseconds to analyse hundreds of vantage points measurement. Therefore, the demo also has a slow-motion mode to allow users to track each iteration of the methodology.

In case of services with publicly known list of replicas, results of our methodology can be compared with the ground truth (GT), to assess the quality of our method. As an illustration, Fig. 2 depicts all the replicas of root server L that our method is able to discover in Europe, providing the user with information about replicas that are listed in the official webpage of root server L, and are either successfully geolocated, wrongly geolocated, or missed by our methodology.

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