Data-Driven Large Scale Network-Layer Internet Simulation

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Internet is a spontaneously growing complex system whose large scale structure is affected by many interacting units aimed at optimizing local communication efficiency without a central authority. Very large number of nodes; wide-spread geographical distribution; predominant role of wireless access; mobility; strong presence of internet enabled smart devices, and heterogeneity increases the complexity of the internet tremendously. This immense global entity has not been precisely characterized, even though the building blocks of the Internet as well as the protocols and individual components have been subject to intensive studies for more than two decades. In the absence of accurate maps, researchers rely on a general strategy that consists of acquiring local views of the network from several vantage points and merging these views. Such local views are obtained by measuring a certain number of paths to different destinations, through the use of probes or the analysis of routing tables. Size of the output data after running the simulations on these several vantage points can reach up to terabytes in each simulation. The merging of several of these views provides a sample of a map of the internet [1].

In the earlier studies [2] [3] [4], it is stated that internet illustrates a power law behavior. Furthermore, some studies [5] present that the internet infrastructure shows the rich-club phenomenon in the internet topology. On the other hand, there are significant difficulties to get a comprehensive picture of the internet topology via sampling of the underlying topology. Available network topology generators are designed to produce a power law distributed connectivity in the generated topologies. Even though, network generators try to capture the internets' large-scale topology, due to the predefined network models, heavy tailed degree distribution and clustering coefficient of the internet may not be represented well, so that they may lack various features of underlying topology due to the internet specific problems such as subnet resolution[6]. Our ability to design realistic network generators can be enhanced by understanding the underlying network of the internet. Thus, the data-driven generation of synthetic topologies can enable us to develop more accurate synthetic graphs that reflect the underlying internet topology.

In this study, we develop and utilize a data-driven multi-layer (i.e. Autonomous System and Router levels) large scale network-layer internet simulation. We try to identify the underlying mechanisms that shape the internets' topology by combining several databases (e.g., capturing the Autonomous System relationships, IP address assignments, and responsive IP census data). Based on several datasets collected from the Internet, we build multi-layered graphs. We then simulate the path discovery (i.e. traceroute) to understand how the underlying networks are sampled with the traceroute tool that is relied for Internet backbone sampling. This simulator can help us understand how biased internet sampling is and how the bias can be corrected. We then identify mechanisms that can be utilized to adjust for sampling bias introduced by the path sampling.

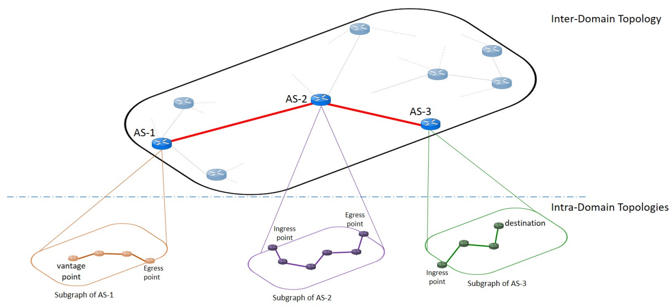

Fig. 1. Multi Layer Topology of the Internet.

In our simulator, we populate our lists and tables by using the data sets in order to generate original inter-domain and intra-domain topologies. In order to estimate the subgraph size and intra-domain topology, we first collect the subnet prefixes for each AS announced by CIDR report[7], CAIDA[8] and UCLA[9]. Then, we merge the ingress node counts for each AS, which are populated from CAIDA's *IPv4 Routed AS links* dataset. With the data collected, we run BRITE [10] internet topology generator and SONET [11] Subnet Oriented Internet Topology Generator in order to generate subgraphs of each AS. After completing the intra-domain topology generation for each AS, we consider the peering relationships and the AS neighborhood relationship from CAIDA and UCLA datasets in order to create the edges between ASes which end up in inter-domain topology. We utilize around 51,000 ASes, 750,000 Subnet Prefixes announced by these ASes, and around 230,000 ingress points.

In the next phase, we process Ant-Census Internet Survey dataset in order to get the list of IP addresses which actively responded to PING calls and grouped them into ASes based on the subnet prefix announcements collected in previous phase that these IP addresses may be used as destination IPs in our path discovery (i.e. traceroute) approach. In total, a bit less than 400 Million of IP addresses detected and grouped.

Vantage points are the most crucial components in the internet measurement studies [12]. Ending result of the network samples highly depend on location and vision of the vantage points. In our experiments, we use two subsets of link level nodes as vantage points(VP). In the first subset, we collect the active Planet Lab [13] node ip addresses and group them into ASes. Briefly, Planet Lab consists of around 200 active node all around the world which users can deploy their own codes and collect personalized measurement data. In the second subset, we randomly select 10, 100, 1000 and 10K nodes from random AS subgraphs as vantage points.

In the traceroute approach implementation, we follow two calculation methods. For the inter-domain topology, we have used path-vector route calculation and stored the calculated routes in each as (AS centric all paths). For the intra-domain topology, we implemented the dijkstra shortest path algorithm and stored the calculated paths (node-to-node, node-to-egress) for each AS.

At this point, we have a two layer topology, close to the real form of routing approach, vantage points and destinations. In order to achieve fast processing time we develop our system in a distributed system fashion in two phases. In the first phase, we develop a server process which utilizes the AS level Graph and waits for slave processes to request tasks. On the other hand, slave processes are designed to run in a multi server and multi core fashion where every slave requests a task from the server with the parameters required to generate an instance of the subgraph of that specific AS node. Depending on the topology generator chosen and based on the number of nodes, ingress and egress points information given, intra-domain subgraphs will be generated.

Probing is implemented in the distributed manner as well. In Figure 1 we show our multi-layered topology and the probing approach. For instance, we have a vantage point in the AS_1 and we need to traceroute a destination node which is in the AS_3. We first bring the pre-calculated inter-domain path stored in the source AS(such a way that *What is the shortest path from me to the* AS_3), which results as $AS_1 \to AS_2 \to AS_3$. This shortest path result is parsed and for the source AS: we take shortest path,which is the dijkstra output for the intra-domain topology of the AS_1, from vantage point to AS_1's egress node which is the peering point to the AS_2. After that we take shortest path,which is the dijkstra output for the intra-domain topology of the AS_2, from ingress node of AS_2 to one of it's egress nodes which connects AS_2 to the AS_3. Finally, we compute the shortest path from one of the ingress nodes of AS_3 connected with AS_2 to the target node and merge all paths.

Even though there are some challenges that have to be addressed, in order to guarantee the quality and relevance of the Internet data such as unresponsive router resolution, IP alias resolution, and subnet resolution[6]; conducting the topography analysis and studying large-scale characteristics of the Internet can be reached by taking advantage of the big data tools and approaches.

We aimed to generate a data-driven simulation environment which can be used to test different topologies, different sizes of traceroute pairs (i.e. variety of the number of vantage points versus variety of the number of target IPs).

Quality of the synthetic topology increases the efficiency of the analysis and gives more realistic insights about the dynamics of the underlying network. Moreover, better internet protocols and services can be developed by understanding the underlying characteristics of the Internet. With the help of our simulator, we strongly believe that it is possible to obtain synthetic representative internet map samples which can further be processed as big data samples.

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