Visualizing Internet Topology Dynamics with *Cyclops*

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***Abstract*— The Internet AS-level topology is a highly dynamic structure that evolves over time under diverse technical, economical and social forces. Up to now the few efforts on topology visualization have taken only static snapshots of the topology graph. In this poster, we present *Cyclops*, an interactive visualization tool that highlights the *changes* in the Internet AS-level topology. We use case studies to demonstrate how Cyclops helps reveal and understand AS topology changes. We also propose a new set of functionalities to be added to Cyclops, which can greatly benefit from the community input and feedback.**

I. Introduction and Overview

The Internet has been evolving rapidly over time like a living organism and so has its topology. Characterizing the dynamics and evolution trends of the Internet topology is an important research topic for several reasons. It is an essential input to understanding the performance and limitations of existing routing protocols and evaluating new designs; it is indispensable in projecting future needs and designing next generation Internet architecture; and it will advance our understanding of the interplay between applications, technology, the resulting topology, and the economic forces behind them. From the network operational viewpoint, understanding the dynamics of network topology helps autonomous systems make informed decisions about their inter-connectivity. For example, when a user network N evaluates an Internet Service Provider (ISP) P as its potential provider, it would be interesting to know how stable P's customer base is, and how well connected P is to other major ISPs. Similarly, an AS $A1$ interested in establishing a peering relationship with another AS $A2$ would like to know the history of $A2$'s connectivity with other ASes.

However the Internet AS level topology is huge in size, the AS connectivity changes constantly, and there is no centralized database to record the AS topology or its changes. All these factors make the above data extraction difficult. We propose to tackle these difficulties through visualization based on collected routing data. To that end we have prototyped an AS topology change visualization tool, named Cyclops, as described below.

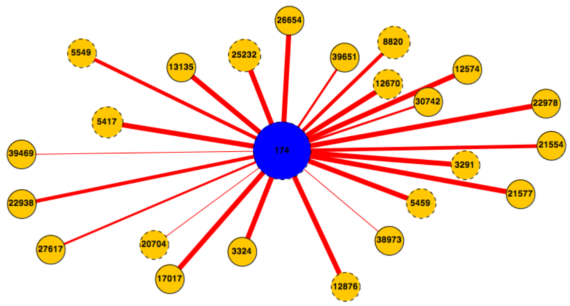
A. Cyclops Features

Cyclops aims to help users capture AS connectivity changes, and correlate these changes across both time and space. Although the large size of AS topology makes visualization difficult, Cyclops helps users focus on the *changes* of the interested topological area. One can start the visualization with an AS of interest, say AS A, and show A's losses and gains in its connectivity to other ASes over time. The following features are specifically designed to help the user understand the changes. (1) Stub and transit ASes are visually distinguished by using different contours; furthermore the user has the option to filter which type to visualize (2) Each node size is drawn proportional to its connectivity degree to allow one visually differentiating big ISPs from small ones. (3) Edge thickness is proportional to the *age* of the link, thus clearly separating edges that have existed for a long time from short lived ones. (4) By user choice, edge thickness can also be drawn proportional to the number of routes using that edge as observed from BGP log data. The above means provided in Cyclops help produce meaningful and readable visualizations even for large ASes. In the following we present two case studies taken from recent Internet topology changes to illustrate Cyclops' usefulness.

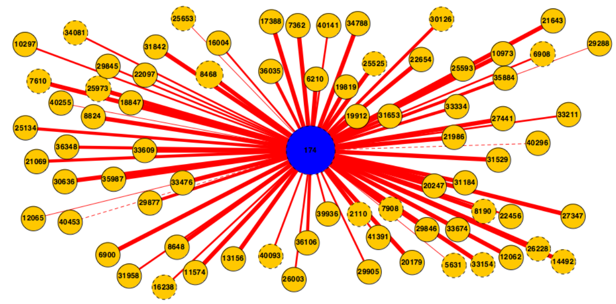
II. Case Studies

A. Cogent Depeerings

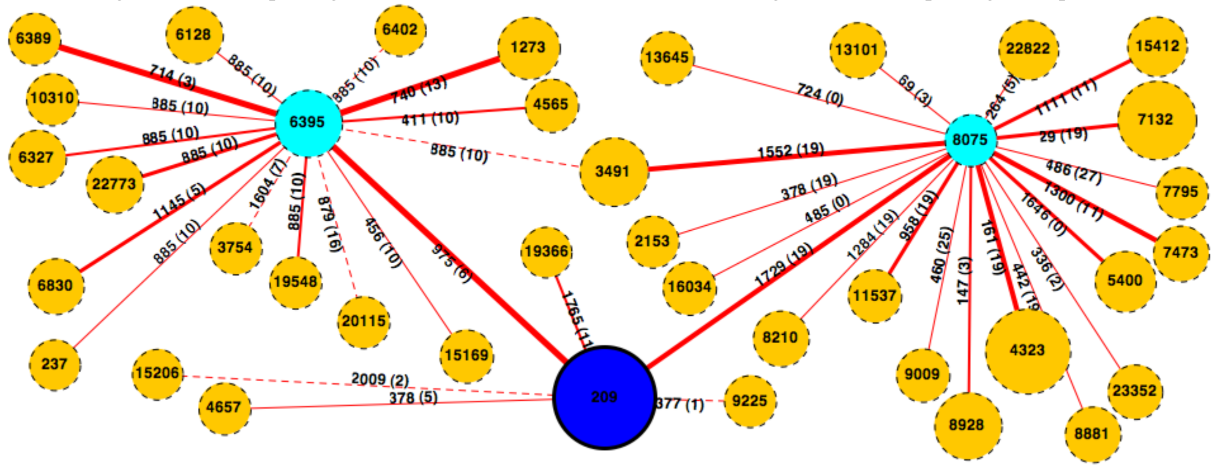
The first example visualizes the AS connectivity changes due to Cogent (AS174) de-peering, which is described in detail in [2]. During April 2007, it was reported that Cogent de-peered with several small European ISPs. Figures 1(a) shows the de-peering of Cogent during March 2007, and Figure 1(b) shows Cogent's de-peering during April 2007. The thickness of the edges represent the age of the links at the time they were removed. The graphs included all the removed links, including the ones with stub ASes. As a verification, all the ASes that were reported by [2] to have been de-peered were found in Figure 1(b). A quick visual inspection shows that the depeering activity started in March, and became intensified in April. In addition, most



(a) Cogent(AS174) depeerings in March 2007.



(b) Cogent(AS174) depeerings in April 2007.



(c) Correlating changes across space in Qwest(AS209) and its neighbors as of April 30^{th} 2007

Fig. 1. Examples of topology changes viewed with Cyclops.

of the involved links have had a considerably long life time.

B. Correlating Changes Across Space and Time

Cyclops enables a user to visually correlate topology changes that happen close in space and time. As a second example, Figure 1(c) shows the AS connectivity changes due to Qwest (AS209) which de-peered with AS6395 and AS8075 in April 2007. The thickness of the edges in this case is set to be proportional to the number of routes carried, and the labels indicate the age and the time since depeering in days. Cyclops allows one to expand the view to show the connectivity changes of AS209's neighbors. Starting from AS209, Figure 1(c) shows the de-peering of AS6395 and AS8075. We observe that the depeering between Qwest and AS6395 is part of the depeerings most likely initiated by AS6395 about 10 days before the observation time (values within ()'s). On the other hand, the depeering between Qwest and AS8075 is part of a set of depeerings most likely initiated by AS8075 about 19 days before the observation time, also affecting several other ASes, including AS2153, AS3491, AS8210, AS11537.

III. Ongoing and Future Work

Cyclops builds a topology database using data gathered from several sources, including BGP tables and updates from RouteViews, RIPE, route servers and looking glasses [3]. One of the research challenges in topology study is to distinguish *real* topology changes from the *observed* changes, termed as the *topology liveness problem*. [1] introduces a tuning knob of *liveness threshold* to increase confidence of topology changes based on the period of observation. We are adding the confidence intervals to improve the accuracy of topology change inference. Although this direction of visualizing topology changes holds great promise, we feel we have barely scratched the surface. We hope to benefit from feedback from the research community to realize its full potential.

References

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