Understanding the impact of Internet exchange points on Internet topology and routing performance

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ABSTRACT

The growth of Internet eXchange Points (IXPs) as an important component in the Internet Autonomous System (AS) level topology has led to the need for a detailed evaluation of their effect on Internet topology evolution and inter-domain packet routing. In this work, we carry out initial measurements to analyze the effect of the additional peering links and observe path quality in terms of round-trip time and loss rates of routes going through an IXP between pairs of Internet hosts. We observe significant effects of IXP-links on Internet growth and topology evolution while the routing performance points to numerous cases of Triangle Inequality Violations (TIVs) due to the IXP switches.

1. INTRODUCTION

Internet eXchange Points (IXPs) are now an essential component of the Internet's Autonomous System (AS) level substrate [1]. The rapid growth of various networks aiming to connect with each other and exchange data (figure 1) in a reliable, efficient and cost-effective manner has led to a plethora of research aimed at designing a stronger underlying Internet infrastructure. IXPs have recently been identified as an integral element of this infrastructure and present opportunities for Internet Service Providers (ISPs) to extract considerable economic and technical benefits.

With IXPs playing a major role in the development of the Internet topology, understanding the effects of IXP peering links on the overall Internet topology has become an important research problem.

The effect of IXPs on packet routing is also understandably huge. With a total of 342 exchange point locations worldwide, significant volumes of Internet traffic are now being subject to exchange point effects. A peering relationship between ASes should ideally lead to an improved routing performance. Numerous IXP-peering links will have an overall effect on routing over the Internet and identifying these effects will thus be a significant step in determining the impact of IXPs in the overall evolution of the Internet.

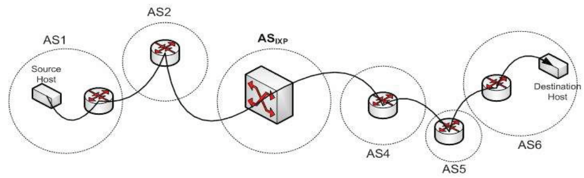

Figure 1: Simplified figure of a path through an IXP from a source to a destination host. AS2 and AS4 are participating ASes at the IXP along the path

In this work, we study the impact of IXPs first on Internet topology evolution and follow it up with measurements studying their effect on inter-domain routing performance across the Internet.

2. TOPOLOGY EVOLUTION

AS-level topology maps are constructed from three existing datasets - traceroute based topologies from CAIDA's Ark infrastructure, BGP graphs from RouteViews and the IXP-specific peering links from the IXP Mapping project [1]. Daily snapshots of the Internet topology for a period of 31 days in May 2010 is taken from the first two sources are then combined to form *one* graph each for the entire month. We combine IXP peering links from [1] with both the previous regular Internet topology graphs to create a graph representing the entire Internet. We thus have three different final graphs: $CAIDA$ from traceroute based studies which represent the control plane of the Internet; $RVIEWS$ from BGP data denoting the Internet's data plane and the entire Internet's $IXPALL$ graph combining the previ-

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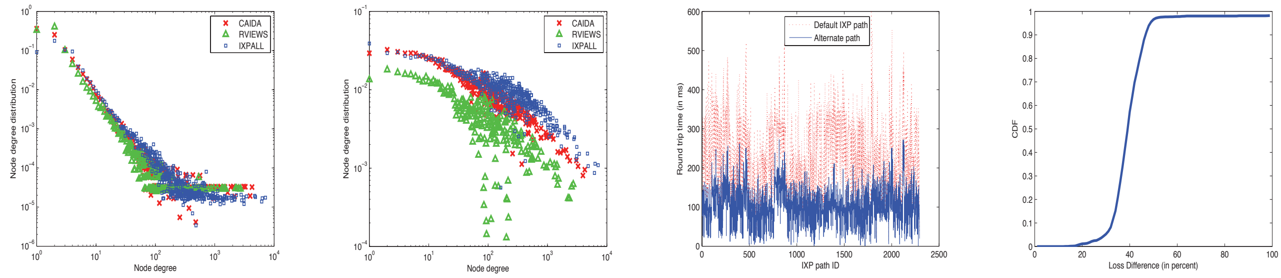

(a) Node degree distribution (b) Joint degree distribution (c) Recorded RTTs of IXP and best alternate non-IXP path (d) CDF of Loss Differences

Figure 2: Topology: (a) Power law behavior remains constant and (b) Greater neighbor connections; Routing: (c) Non-IXP alternate paths have much lower RTTs overall and (d) Losses are in terms of packet loss percentages with majority within 30 to 50 percent range

ous graphs with the IXP-specific peering links from *IXPMAP*. We compare these graphs based on important metrics:

1. **Node degree distribution**: Figure 2(a) presents this result with increasing node degree and the familiar distinct power law characteristics are maintained in all datasets. The *IXPALL* graph still follows a power law but with a different exponent defining it. Thus all the new IXP-peering links do *not* change the basic topology evolution characteristic of the Internet.

2. **Joint degree distribution**: This metric gives us an idea of the general neighborhood of a randomly chosen node with average degree. From figure 2(b) the effect of the IXP peering is evident for medium to high degree nodes. Numerous peerings between ASes at different exchange points result in tangential links between similar ASes exhibiting higher degrees resulting in the *IXPALL* graph showing consistently high values throughout the middle and latter sections.

3. ROUTING PERFORMANCE

Peering agreements between ASes while primarily leading to financial benefits should also help improve routing performance for traffic originating at either AS. With upper tier transit providers eliminated, more efficient data transfer through the IXP switch should theoretically be observed. This improved path performance is an implicit goal of IXP infrastructure and we aim to answer if these IXPs are actually working in the quest to improve inter-domain Internet routing performance. We use detour-style routing to select alternate paths between a source-destination host pair and compare its performance with routes traversing an IXP.

We select a set of 138 globally diverse PlanetLab vantage points (end-hosts) and conduct traceroute and ping-probing measurements continuously for a period of 21 days across May-June 2010. A total of 13,795 unique and stable paths were obtained and 2865 of those paths incorporated an IXP hop along the path. Ping probes are sent from every host to all others at two hour intervals with blocks of 500 packets with individual packet intervals measured at half a second. The initial results obtained are:

1. **Round trip times (RTT)**: RTTs for both the default IXP path and the best alternate path not traversing an IXP is presented in figure 2(c). We observe that in most cases there is an alternate path with a significantly lower RTT than the default IXP path. This result reinforces established concepts in overlay routing where the presence of better alternate paths has been shown.

2. **Loss rates**: Figure 2(d) exhibits the difference in loss rates observed between IXP and the best alternate non-IXP path and we observe there are almost no IXP-paths with lower loss amounts than the best alternate path. This shows that losses due to IXPs are always greater than alternate paths.

4. DISCUSSION

Measuring the complete impact of the growth of IXPs on the Internet requires more extensive measurements and study as is evident in the results seen so far. While comparing the IXP and non-IXP paths are inherently difficult, we need to quantify and analyze the reasons behind the observed effects of IXPs both on the topology evolution model of the Internet and on inter-domain routing performance. An in-depth study on this important component of the Internet infrastructure will shed light on its working and overall effectiveness.

5. REFERENCES

[1] B. Augustin, B. Krishnamurthy, and W. Willinger. IXPs: mapped? In *IMC '09: Proceedings of the 9th ACM SIGCOMM conference on Internet measurement conference*, pages 336–349, New York, NY, USA, 2009. ACM.