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Inter-domain Multi-Hop Negotiation for the Internet

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Abstract—**Inter-domain connectivity in the Internet is currently established on policy-based shortest-path routing. Business relationships of the Internet entities are translated into routing decisions through policies. Although these policies are built on simple mechanisms provided by BGP, they give rise to very complex market structure. Extensive research efforts have been made to understand common practices of inter-domain policies. In early stages, hierarchical models were thought to be adequate to explain negotiation between the entities over improving routing and expressing routing preferences in general. Then, it has been realized that there are significant number of local policy exceptions and random decision making over hierarchical structure. In this work, we examine how effective these local policy exceptions are in providing better quality paths. Our analysis on traces captured from the Internet quantitatively shows that currently adopted local policies could not be as effective as multi-hop negotiations for the purpose of attaining better paths in terms of multiple path quality metrics.**

I. Introduction

Current Internet Architecture only allows limited expression of choice for Quality of Service at the inter-domain level. An Internet Service Provider (ISP) usually has limited capability to influence route selection process beyond its next hop. Although ISPs can proactively apply traffic engineering policies to improve quality of their connections to the rest of the Internet, these policies often fall short on providing desired end-to-end performance due to lack of signaling mechanisms which can achieve multi-hop end-to-end path negotiation on multiple quality metrics as recently proposed by many researchers [1], [2]. In this paper, we analyze how effective currently available improvement methods are in compared to flexibilities promised by future Internet architecture proposals.

Our analysis relates to the efforts of modeling inter-domain routing over the Internet, which has been a very challenging research question. We have made many simplifications to achieve this task. We specifically analyze policy effectiveness in overcoming spatial constraints which are faced by ISPs. We develop a simplistic k-step local improvement model where an ISP has a greater control within k-hop locality. With increasing range of its control, we analyze the increasing network performance in this local improvement policy model. Our preliminary analysis on real Internet traces shows that the existing localized methods are not as effective as the multi-hop, multi-metric negotiation frameworks.

II. Effectiveness of Current Routing Policies

Today, a common ISP forwards traffic to the closest exit point of its domain to minimize resource usage in its own network. Many open peering agreements confirm the significant implementation of this practice called "Hot-potato Routing" despite of its well-known handicaps in achieving overall end-to-end service quality [3]. As shown in Figure 1, ISP S, usually does not have a chance to influence ISP 1's decision on choosing exit points for traffic destined to ISP D. Even though it is possible to implement "Cold Potato Routing" or "Best Exit Strategy" practices to achieve better quality at next-hop level in paid settings, ISP S cannot express this choice beyond ISP 1 which is the immediate next-hop neighbor of ISP S.

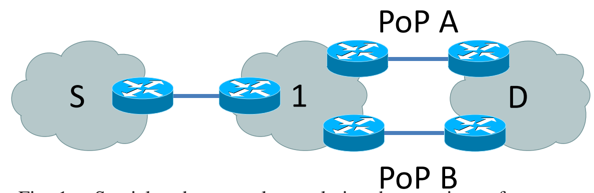

Fig. 1. Spatial and temporal granularity shortcomings of current policies.

Current SLAs promise soft-guarantees over latency and packet loss rates to the most Internet destinations in a coarse-grained manner. However, these guarantees can not be extended beyond the borders of next-hop provider ISP.

An ISP may establish paid peering agreements with alternative providers to detour local performance bottlenecks. Also, an ISP can improve quality in provided services for a geographic region via broadening its points of presence (PoP) locally. We define these localized methods as ***"k-step Local Improvement Policy"***, where an ISP extends its reachability horizon and improves the service quality by getting better connected to the rest of the Internet through more diverse set of connections via local peering and enhanced presence.

According to this model, an ISP, which adopts the k-step local improvement policy, is able to choose optimal paths within k-hop locality. Beyond k-hop neighborhood, traffic will be forwarded in according to hot potato routing. Our intention is to quantify overall benefits that can be ripened by these local policies against performance of multi-hop negotiation methods proposed by clean-slate architectures which offer end-to-end quality paths comparable to global optimum [4].

III. Performance Evaluation

We deploy a simple yet realistic (min AS Path, closest exit) policy for our analysis. As reported by Madhyastha et al., these two policies together are capable of predicting 65% of the current Internet routes correctly [5]. We use iPlane PoP-level Internet topology [5] which provides latency and packet loss rate measurements for the links connecting ISPs' points of presence (PoP). In their work [5], authors have shown that

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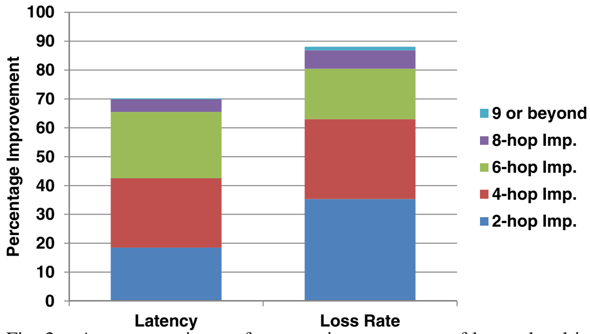

Fig. 2. Average routing performance improvements of k-step local improvement routing over hot-potato routing

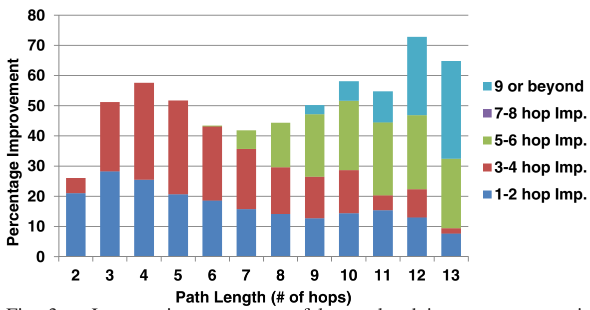

Fig. 3. Latency improvements of k-step local improvement routing over hot-potato routing for various path lengths in # of PoPs

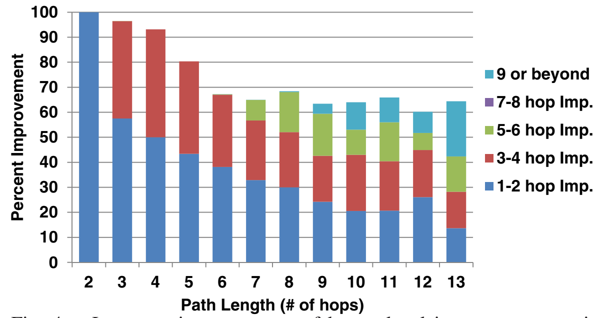

Fig. 4. Loss rate improvements of k-step local improvement routing over hot-potato routing for various path lengths in # of PoPs

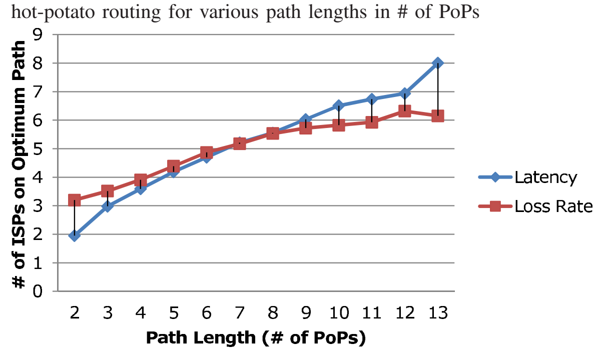

Fig. 5. Number of ISPs on the Global Optimum Path According to Latency and Loss Rate Improvement Policy

these measurements have been proven stable through many repetitions.

For our analysis, we randomly picked 101,000 PoP source and destination pairs. Then, we constructed end-to-end paths in according to 1) (min AS Path, closest exit) policy and 2) k-hop Local Improvement policy with varying k values. For the second case, we combined the best possible path segment within the k-hop locality with the path segment which is calculated in according to (min AS Path, closest exit) policy combination after k-hop border.

Improvements are reported as achieved gains in latency and packet loss in compared to (min AS Path, closest exit) policy. In Figure 2, we plot the improvements achieved by k-step local improvement policy for increasing k values. So, an ISP, who is able to choose best paths within 2-hop locality, can improve its end-to-end connectivity 18.21 percent in terms of latency and 35.31 percent in terms of packet loss on average. Overall, maximum improvement, i.e., 70.161 percent for latency and 88.175 percent for packet loss, can be achieved via 13-step local improvement.

In Figure 3 and 4, we plot k-step local improvement policy performance with increasing values of k for each class of end-to-end path length for latency and loss metric respectively. Local improvement policies, i.e., direct peering and PoP establishment, usually operate at 2-hop locality. These localized methods can achieve significant performance gains up to 50 percent, especially higher for short paths. However, they become ineffective for path lengths beyond 6 PoPs.

In Figure 5, we plot the number of ISPs which are required to cooperate so as to establish end-to-end optimum path. On average, approximately 5 ISPs need to be involved in such path negotiations to achieve highest performance. These results show us the necessity of automated SLA mechanisms in achieving desired multi-metric, multi-hop negotiation.

IV. Summary

In this work, we analyzed the effectiveness of current local peering policies for improving end-to-end path service quality. Our evaluations on iPlane PoP-level Internet topology with realistic policy setup show that these local policies are only effective within ISPs' immediate neighborhood. However, they are not as effective as multi-hop negotiation frameworks proposed by many researchers for exploring better quality alternative paths beyond immediate neighborhood. In the light of these findings, we believe that multi-hop, multi-metric policy methods should be developed in order to effectively utilize diversity and high level service capacities of the Internet.

V. Acknowledgment

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