

# Exploring Reachability via Settlement-Free Peering

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## ABSTRACT

The importance of an autonomous system is typically derived by its economic relevance, in Internet terms measured by the number of customer ASes it provides with connectivity. Such simple business relationship does not hold anymore. In this paper, we analyze the importance of peer-to-peer links between BGP peers. We show that settlement-free peering may change the global rank of an AS by three orders of magnitude.

## Categories and Subject Descriptors

C.2.1 [Network Architecture and Design]: Computer-Communication Networks—*Network topology*

## Keywords

BGP peering, Internet measurement, AS importance

## 1. INTRODUCTION

On the most abstract level of routing, the Internet consists of autonomous systems (ASes). An AS represents a set of networks under the same administrative domain. Each AS receives IP reachability information from other ASes by BGP. Depending on the business relation between two BGP peers, different information is exchanged. Originally, provider-to-customer (*p2c*) peerings inform customer ASes about all IP prefixes known at the provider [1], but they require agreements with costs for the customer. In contrast to this, a peer-to-peer (*p2p*) relationship is settlement-free, but provides only reachability data for prefixes owned by the peering partner or its customers.

Typically, the relevance of an AS is defined by the amount of recursively reachable (downstream) customer peers. However, it is well-known that p2p-based peering is becoming more relevant with respect to the inter-domain connectivity [2,3] and that the common business models are incomplete. For example, paid peering uses announcement policies

similar to settlement-free peering but is based on billing contracts. This configuration is not visible from the outside and therefore subsumed under p2p relationships. From this perspective, we argue that the relevance of p2p-based connections may directly affect the importance of dedicated ASes.

In this paper, we analyze the impact of p2p links on the relevance of ASes. To measure the importance of an AS, we deploy a ranking scheme that compares the traditional view on ASes with existing p2p relationships. We study approaches that estimate the importance of ASes without relying on (hardly available) active measurements such as throughput but instead using passively acquired data, particularly BGP dumps and inferred business relationships between ASes. We explain our methodology in detail and discuss our results in § 2. § 3 concludes with an outlook.

## 2. METHODOLOGY AND RESULTS

**Methodology** To determine the relevance of an AS, CAIDA proposes the notion of the *customer cone size*. The customer cone of an AS  $A$  is the set of ASes defined as  $A$  and all ASes that can be reached from  $A$  by following only p2c links. ASes will then be ranked by the customer cone size  $CCS(A)$ , i.e., the number of ASes in the customer cone of  $A$ .

We extend the calculation of the AS rank to include the customer cone of all peering neighbors connected via p2p links. Let  $PCS(A)$  denote the size of the peer-related cone, then the peer-customer cone size of  $A$  is calculated as follows:

$$PCCS(A) = (1 - w) \cdot CCS(A) + w \cdot PCS(A) \quad (1)$$

where  $0 \leq w \leq 1$  is a weighting factor. This weighting factor allows us to gradually examine the impact of peering links on the local reachability.

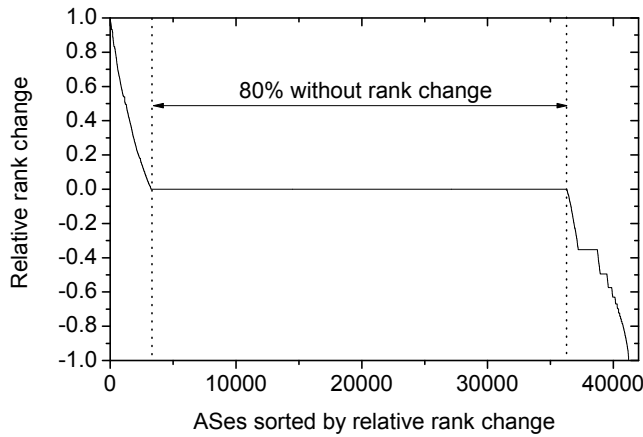
**Data Set** For our subsequent evaluation we use the AS relationship provided by CAIDA [4]. We admit that the data set—as all BGP measurements—is incomplete in terms of observed links, in particular p2p links are hard to collect. This affects dedicated ASes but the general observations of this study are still visible. We note as an advantage that the CAIDA data features a ground truth in relationship inferences of 94.7 % for p2p links [5]. To compute the customer cone size, we build a directed graph based only on p2c links for each AS. In addition, we calculate the peer-related cone size and finally the  $PCCS$  as described in Eq. (1) for varying weighting factors.

**Results** Figure 1 shows the relative change in ranks from  $w = 0$  to  $w = 1$  for each AS. A positive value indicates a transition from a less important to a more relevant AS, whereas a negative value suggests decreasing relevance

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**Figure 1: Relative rank change ( $w = 0 \rightarrow w = 1$ ) of all ASes. Positive values indicate improved rank, negative values indicate degraded rank, 0 indicates constant rank for pure p2p peering.**

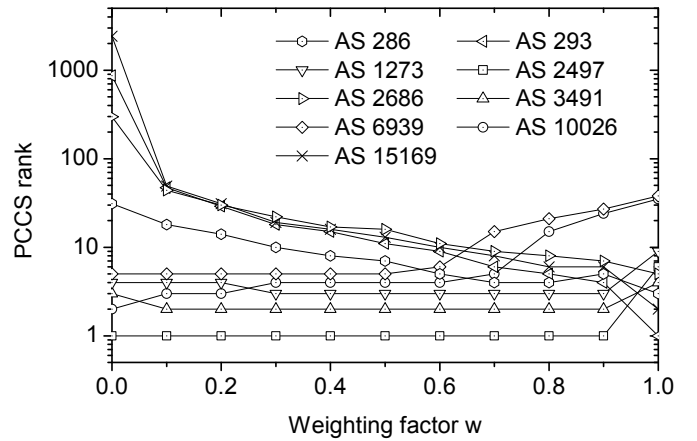
in pure p2p setups. It is noteworthy that about 80 % of all ASes do not change their rank. Those ASes have neither customers nor maintain p2p relations according to the AS relationship data. They are considered less important independent of the weighting.

To analyze this global view in more detail, we study the impact of our approach on tier 1 ASes. We define an AS as tier 1 AS if and only if it has no providers and it can reach over 95 % of all ASes. This definition yields a list of 19 ASes and contains ASes commonly considered to be tier 1 (e.g., AS 701). At  $w = 0$  the customer cones of tier 1 ASes exhibit different sizes. With an increased excluding of customers and including of p2p peers, the cone sizes converge towards a single value at  $w = 1$ . This is not surprising as tier 1 ASes per definition can reach all other ASes via p2p links.

As we are interested in the effects of settlement-free peering on ASes that currently require an upstream, we exclude tier 1 ASes from our further analysis. In our second analysis we reveal the changing importance of ASes depending on the weight of customer and p2p cones.

Figure 2 presents the AS rank based on the PCCS. For the sake of visibility, we limit the number of plotted ASes to those who are placed at rank 1 to 5 for  $w = 0$  and those who are under the top-5 for  $w = 1$ .

It is clearly visible that the rank of an AS significantly depends on the cone ratio. On average, initially highly ranked ASes lose relevance and weakly ranked networks gain importance. For example, AS 3491 (BTN-ASN) attains rank 2 when considering only p2c relationships but falls to rank 13 when only the peer-related cone size is used. Particularly striking is Google (AS 15169). It maintains peerings to only very few customers and therefore yields a very low rank with respect to its customer cone size. However, an increased weight of the p2p relations increases its position. This is due to the fact that AS 15169 directly peers with many tier 1 ASes. The striking rank change of Google demonstrates that despite having few customers and therefore being very low ranked with respect to the customer cone size, an AS may reach a significant portion of the Internet solely based on its p2p peerings.



**Figure 2: Absolute rank change of (non-tier 1) ASes ranked under top-5 with  $w = 0$  or  $w = 1$ .**

### 3. CONCLUSION AND OUTLOOK

The common business model within the Internet has changed. P2P-based Internet peering has grown in importance over the last years as it usually provides ISPs with selected reachability without upstream costs. In addition, the p2p concept has been extended to paid peering, which establishes a business contract between two peers but with the selected view of a p2p relationship. Following these observations, p2p peering will directly affect the importance of ASes in the global Internet ecosystem, even though the current extent is hard to predict.

In this paper, we proposed a metric that evaluates the importance of an AS with respect to reaching other networks without any upstream connectivity. The measurement reflects the uncertainty of importance of p2p relations. We applied our ranking on a real-world data set. We observed that considering the customer cone sizes of p2p peers can indeed significantly affect the ranking of ASes.

In future work, we will quantify errors introduced by incomplete data and compare our AS ranking with other established network metrics or combinations thereof. We will also evaluate the impact of our proposal on rankings of nation-specific AS topologies [6]. We will work on a (nation-centric) AS topology atlas to support network operators in identifying critical AS paths and options to mitigate failures.

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