POSTER

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Poster: Evaluating CAIDA's Inferred AS Relationships Through ASPAs

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Abstract

Autonomous System (AS) relationships are the commercial agreements that define how ASes interact to route Internet traffic. For over a decade, researchers have relied on CAIDA's inferred AS relationships, which, however, lack validation against publicly available ground-truth data. This work presents the first systematic validation of CAIDA's AS relationships dataset using Autonomous System Provider Authorization (ASPA) objects—cryptographically signed records of the authorized providers of an AS. Analyzing 124 ASPA-compliant ASes, we find that CAIDA's inference aligns with ASPA data for only 22 ASes, often underestimating the number of providers and, in some cases, misclassifying them as customers.

CCS Concepts

• **Networks** → **Public Internet**; • **General and reference** → **Evaluation**.

Keywords

ASPA, Autonomous System Relationship, RPKI, BGP

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1 Introduction

The Border Gateway Protocol (BGP) enables Autonomous Systems (ASes) to share reachability information (i.e., AS-level routes to IP prefixes). For instance, a given AS (e.g., AS_1) will decide whether to propagate a route received from AS_2 to AS_3 based on the type of commercial agreements established with the two. Such agreements, commonly referred to as *AS relationships*, are generally categorized as either customer-to-provider or peer-to-peer. For over a decade, CAIDA has been inferring AS relationships from publicly available BGP data [3], which, however, provides an incomplete view of the global routing ecosystem with no ground-truth validation data [8].

A promising source of data is Autonomous System Provider Authorization (ASPA) [1], a novel mechanism for improving routing security that is currently under standardization at the IETF. ASPAs are cryptographically signed objects listing the authorized providers of an AS. Each AS is responsible for generating its ASPA, which is then distributed to other ASes through the Resource Public Key Infrastructure (RPKI) [9]. It overcomes (some of) the limitations of Route Origin Authorization (ROA) [10] in securing and verifying BGP routes. Specifically, it provides a mechanism to detect most BGP route leaks by allowing ASes to verify that routes do not violate the valley-free rules [5]. Simulations have already shown the effectiveness of ASPA in preventing route leaks, even in partial deployment scenarios [4].

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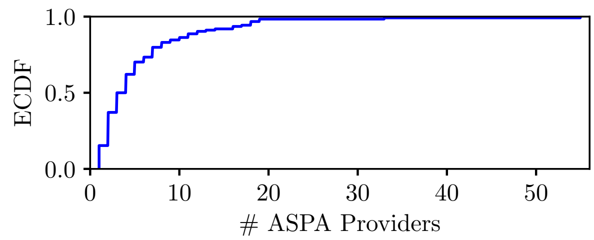

Figure 1: Distribution of the number of providers listed by the 124 ASPA-compliant ASes.

In this work, we evaluate the accuracy of CAIDA's inferred AS relationships using ASPA objects as a ground-truth source for customer-provider relationships. We restrict this analysis to the 124 ASes that, at the time of writing, have published their ASPA in the RPKI, and refer to them as ASPA Customers. For each ASPA Customer, we compare the ASes listed as providers within the respective ASPA object (i.e., ASPA Providers) with the ASes that CAIDA infers as providers (i.e., CAIDA Providers). We find that CAIDA's inference aligns with ASPA data for only 22 out of 124 ASes, with many missing providers not inferred at all.

We observed a significant increase in ASPA adoption since July 2025: the number of ASPA Customers grew to 124, after averaging at ≈ 85 during the first six months of the year. We believe ASPA represents a strong opportunity to enhance CAIDA's inference algorithm and for the community to gain a deeper understanding of the global routing ecosystem.

2 Dataset

Our analysis compares CAIDA Providers from the latest available AS relationships dataset (September 2025) [2] with ASPA Providers. To align with CAIDA's methodology of using the first five days of a month for AS relationships inference [6], we retrieved all ASPA objects from the RIPE NCC's RPKI archive [7] for September 1–5,

Figure 2: Distribution of the ASPA Customers based on the accuracy of CAIDA-inferred Providers.

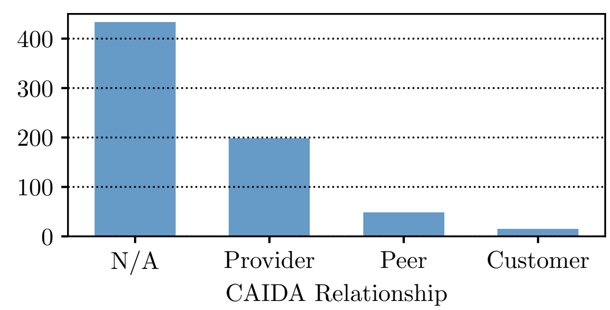

Figure 3: Distribution of ASPA Providers by CAIDA Relationships.

extracting on each day all ASPA Customers and the respective ASPA Providers. We defined the provider set of an AS over the specified period as the union of all ASPA Providers observed during that time frame. Overall, we identified 124 ASPA Customers. Figure 1 shows the distribution of the number of providers listed in their ASPAs. While the interquartile ranges between 2 and 7 ASPA Providers each, two ASes are responsible for the tail of the distribution: AS215828 (33) and AS52025 (55).

3 Analysis

Figure 2 shows the distribution of the 124 ASPA Customers (cell values) by the number of ASPA Providers that CAIDA's inference missed (x-axis, false negatives) versus the number of CAIDA Providers that are not ASPA Providers (y-axis, false positives). Notably, for only 22 out of 124 ASes, the sets of CAIDA Providers and ASPA Providers perfectly match. Ideally, all ASes should belong to the $(0, 0)$ cell. The heatmap highlights a tendency of CAIDA to underestimate the providers of ASes (x-axis > 0) and, rarely, mislabel peers or customers as providers (y-axis > 0). The last column of the heatmap aggregates the 21 ASPA Customers for which CAIDA misses 7 or more ASPA Providers. For most (12), the number of false negatives is in the 7–9 range, for 5 it is between 10 and 14. The remaining four ASes (AS396064, AS200160, AS21528, and AS52025) list 18, 19, 33, and 55 providers in their ASPA, with CAIDA missing 18, 19, 29, and 41 of them, respectively. While this heatmap focuses on false positives (y) and false negatives (x) and does not explicitly highlight it, there are 42 ASPA Customers with zero true positives, meaning CAIDA fails to infer any of their ASPA Providers.

To better understand false negatives, Figure 3 breaks down the relationships that CAIDA infers between ASPA Customers and the respective ASPA Providers. Only 198 (28.5 %) of the customer-provider relationships are accurately inferred. A total of 63 ASPA Providers are mistakenly labeled as peers (48) or customers (15). The high number of 'N/A' values (433) suggests that the incomplete view of the global routing ecosystem provided by publicly available BGP data is insufficient to accurately infer all customer-provider relationships.

The large number of relationships not inferred by CAIDA indicates that prior studies relying solely on CAIDA's dataset may have underestimated the extent of customer–provider relationships.

4 Next Steps

Overall, our analysis highlights substantial gaps between CAIDA's inferred customer-to-provider relationships and those explicitly declared in ASPA, underscoring the importance of integrating RPKI-based ground truth to enhance the accuracy of Internet topology mapping.

In future work, we plan to monitor the ASPA adoption rate along with the risks associated with erroneous, incomplete, or oversized ASPA objects, and investigate the discrepancies between ASPA Providers and CAIDA Providers, specifically examining how inaccuracies in CAIDA's inferred relationships may correlate with non-ASPA-compliant BGP announcements.

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