ECE 478/578

Fundamentals of Computer Networks

Instructor:

Loukas Lazos

TA:

Chenyi Wang

Project #2:

Studying The Internet Topology

Colin Core

Jose Salinas Meza

11/23/2025

1. Introduction

1.1 Project Description

In this project, we will analyze the Internet's topology using real-world datasets from CAIDA. This study focuses on Autonomous Systems (ASes), their classifications, connectivity, and the distribution of IP address space.

2. AS Classification

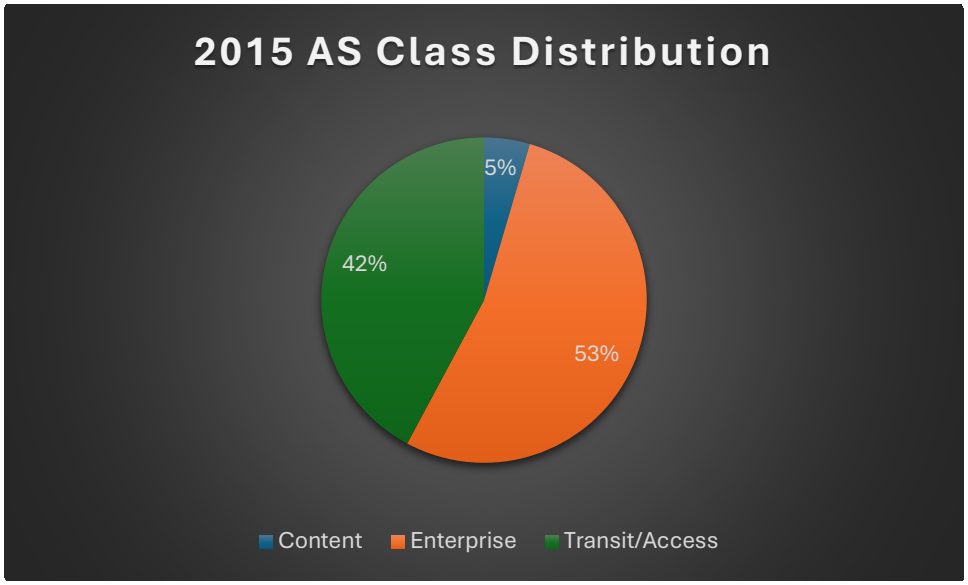

Figure 1. Distribution of Autonomous Systems (ASes) by type in 2015.

Figure 1 shows that in 2015, Enterprise Autonomous Systems (ASes) represented most of the Internet topology at 53%, followed by Transit/Access ASes at 42%, while Content ASes accounted for only a small fraction, roughly 5%.

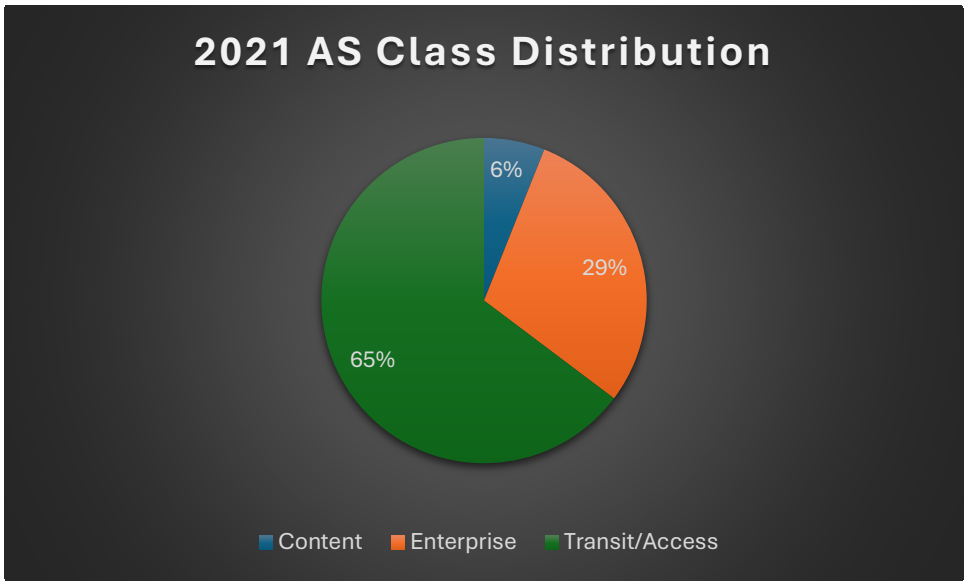

Figure 2. Distribution of Autonomous Systems (ASes) by type in 2021.

Figure 2 shows that in 2021, Transit/Access Autonomous Systems (ASes) dominated the Internet topology, representing 65% of all ASes, while Enterprise ASes accounted for 29%, and Content ASes made up a smaller fraction of 6%.

Additionally, Figures 1 and 2 illustrate how the distribution of AS classes within the Internet topology has changed over time. Content ASes consistently make up only a small portion of the topology, accounting for approximately 5% in 2015 and 6% in 2021. Enterprise and Transit/Access ASes compete for dominance: in 2015, Enterprise ASes represented 53% of the topology while Transit/Access ASes made up 42%. By 2021, this shifted, with Transit/Access ASes dominating at 65% and Enterprise ASes decreasing to 29%. This highlights a trend toward a more provider-centric Internet over recent years.

3. Topology Inference Through AS Links

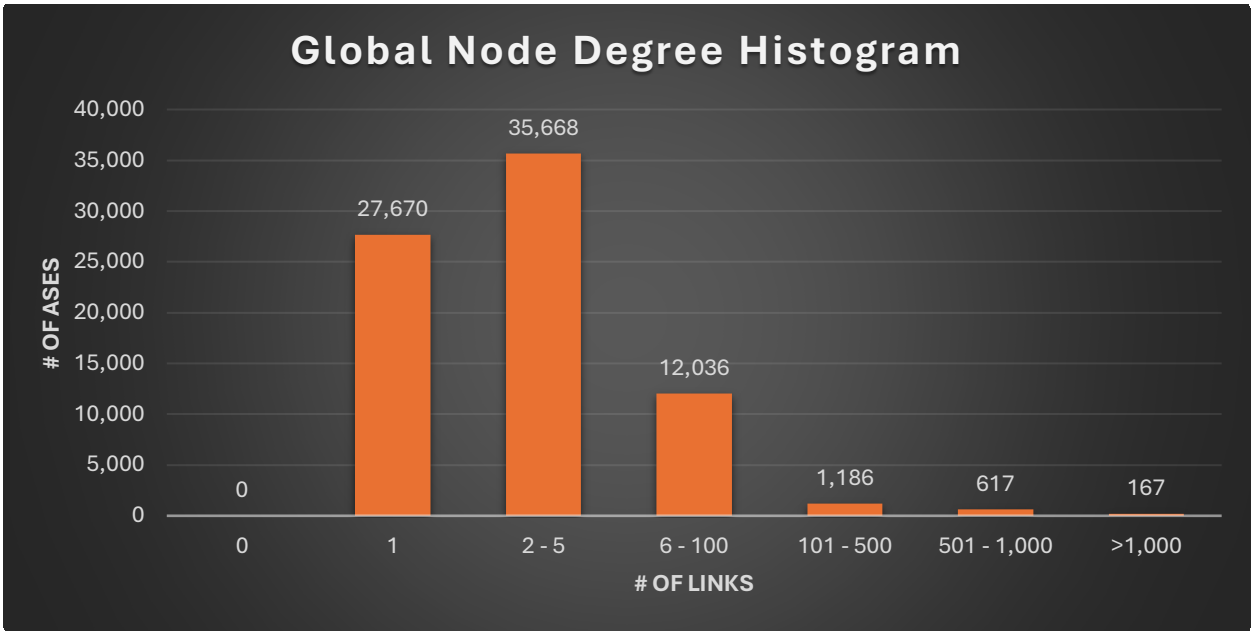

Figure 3. Histogram of the global node degree distribution of Autonomous Systems (ASes).

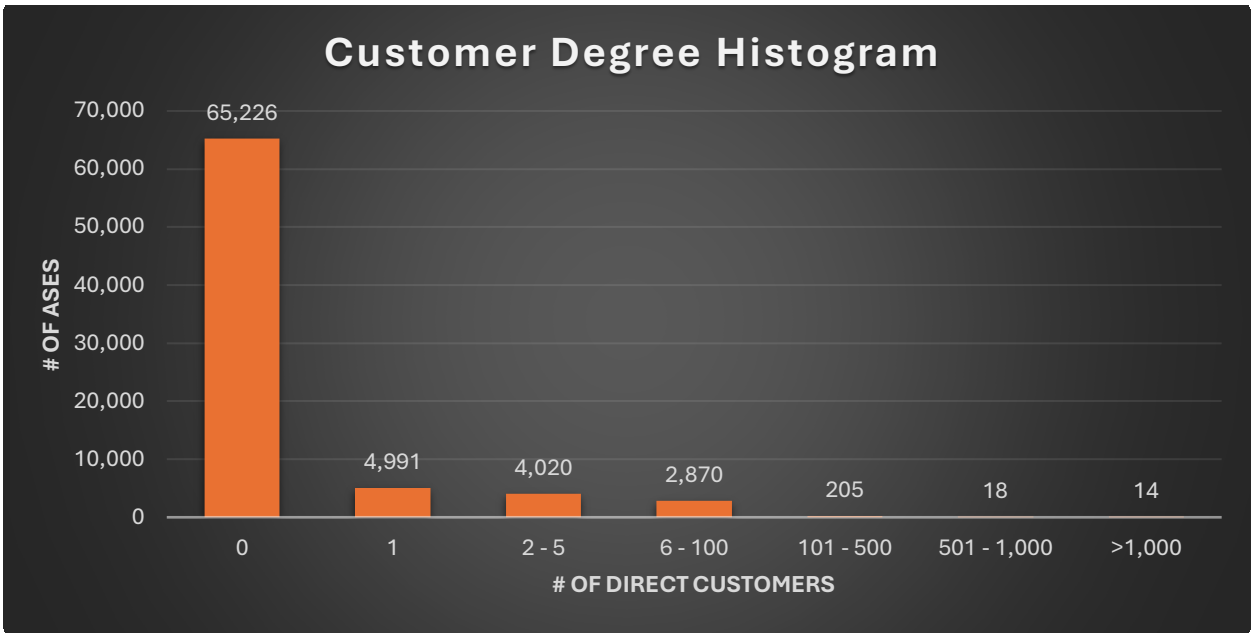

Figure 4. Histogram of the customer degree distribution of Autonomous Systems (ASes).

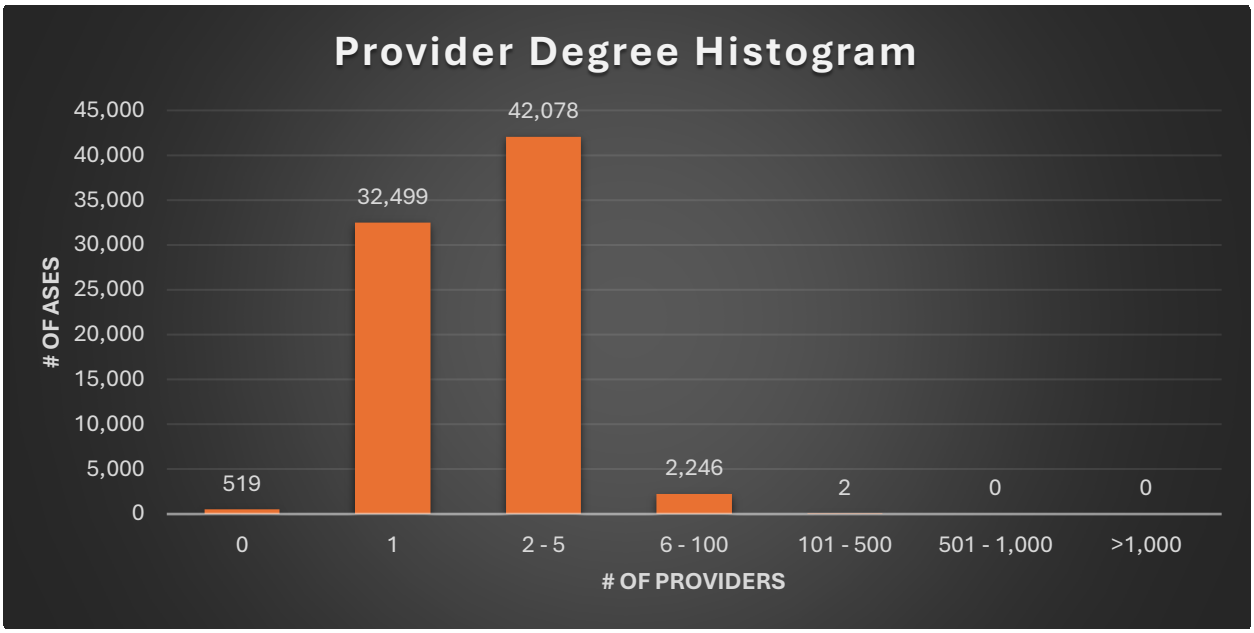

Figure 5. Histogram of the provider degree distribution of Autonomous Systems (ASes).

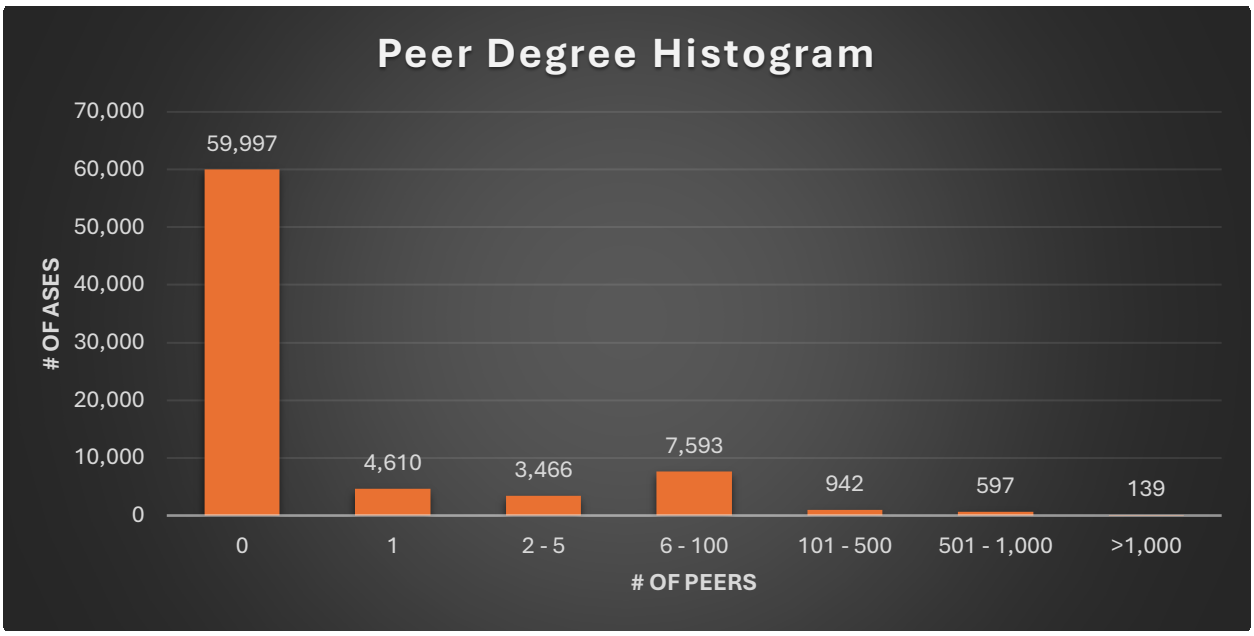

Figure 6. Histogram of the peer degree distribution of Autonomous Systems (ASes).

The distribution of Autonomous Systems (ASes) reveals a highly hierarchical and uneven Internet topology, as illustrated in Figures 3-6.

1. *Global Degree*: According to Figure 3, most ASes have a low number of total connections, with the majority (1–5 links) accounting for nearly 63% of ASes. Only a small fraction of ASes have extremely high degrees (>1,000), representing major backbone providers that connect to a large portion of the Internet.

2. *Customer Degree*: Figure 4 shows that a large majority of ASes (~65,226) have no direct customers, meaning they are stubs that do not provide transit. Only a few ASes have many customers, which highlights a small set of large provider ASes that serve many downstream networks.
3. *Provider Degree*: Figure 5 highlights that most ASes rely on 1–5 upstream providers, proving that the Internet connectivity is mostly hierarchical. Very few ASes have many providers, which shows that the redundancy in upstream connectivity is limited for most networks.
4. *Peer Degree*: Figure 6 shows that most ASes (~59,997) have no peers, indicating minimal peering for most networks. Only a minority of ASes engage in multiple peering relationships, and very few have hundreds or thousands of peers.

The Internet is dominated by a small number of highly connected ASes (transit and content providers) with many links, customers, and peers, while the majority of ASes are low-degree stubs with few connections. This creates a highly skewed, hierarchical topology with a core of highly connected ASes supporting many peripheral networks.

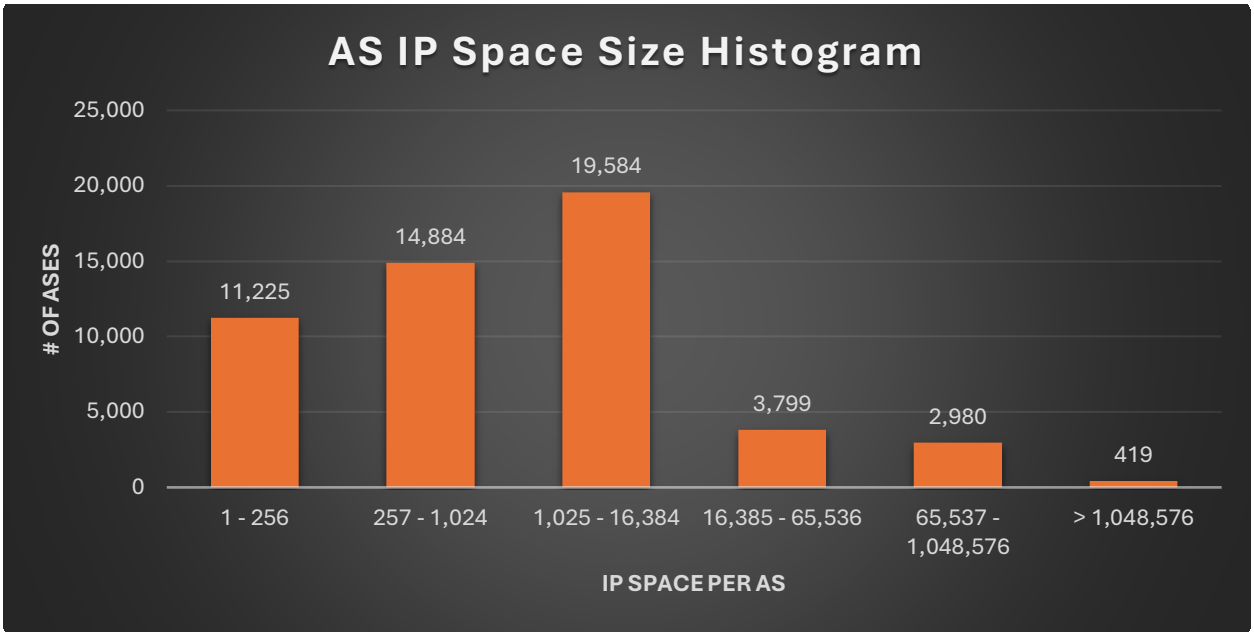

Figure 7. Histogram of the IP address space assigned to each Autonomous System (AS).

The bins for the IP space histogram (Figure 7) were chosen to reflect the exponential nature of IP address allocations, which are typically assigned in powers-of-two increments (e.g., /24, /20, /16). Using this allows us to better capture the wide variation in the IP space while preserving meaningful distinctions between small, medium, and very large ASes. These bins correspond roughly to the common allocation sizes: very small blocks (e.g.,

/24), small blocks (multiple /24s), medium blocks (/20 to /18), large blocks (/16), very large blocks (/12 to /8), and enormous allocations held by Tier 1 ISPs or major content providers.

Figure 7 shows that most ASes hold relatively small IP address spaces, with the majority assigned blocks ranging from 1 to 16,384 addresses. Only a small number of ASes control very large address spaces (>1,048,576), which are typically Tier 1 ISPs or large content networks. Furthermore, it shows that while most ASes are small or medium-sized networks, the bulk of IP resources is concentrated among a few highly connected providers, further showing the hierarchical structure of the Internet.

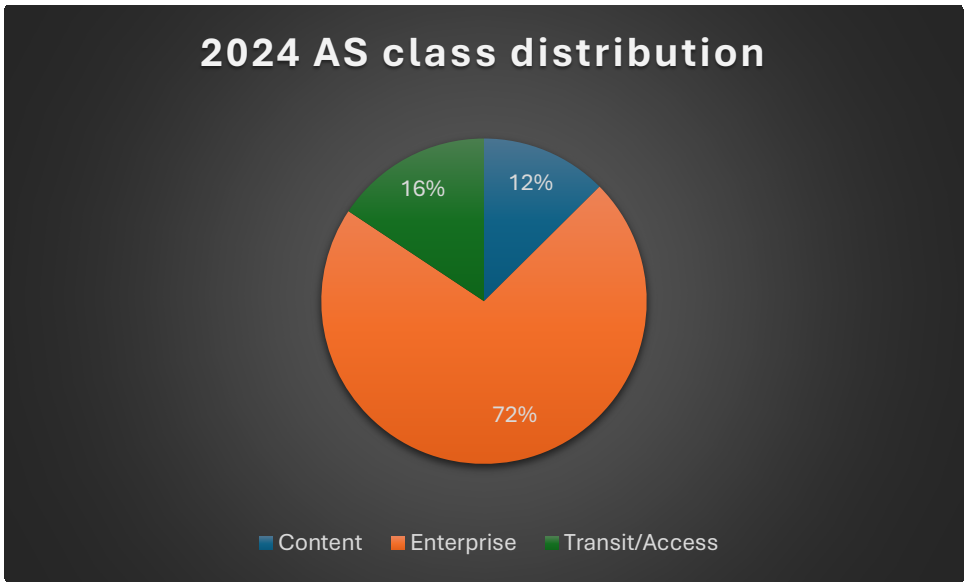

Figure 8. Distribution of Autonomous Systems (ASes) by type in 2024.

Figure 8 presents a link-based classification of ASes: those without customers or peers are labeled Enterprise, those with peers but no customers are labeled Content, and those with at least one customer are labeled Transit/Access. When contrasted with Figure 2, both distributions exhibit a dominant enterprise category. However, the 2024 results show a reduced proportion of transit/access ASes relative to the earlier classification.

4. Inference of Tier-1 ASes

4.1 Table #1 Tier-1 Inference Results

Rank	AS	Organization	Degree
1	6939	HURRICANE	9443
2	24482	SGGS-AS-AP	8723
3	49544	i3Dnet	6986
4	199524	GCORE	6118
5	39120	CONVERGENZE-AS	5777
6	35280	F5	5185
7	271253	LINK BRASIL	5063
8	37721	Virtual-Technologies-Solutions-SA	4705
9	137409	GSLNETWORKS-AS-AP	4163
10	6057	ANTEL	3909

Table 9. Tier-1 Inference Results.

4.2 Description

This graph shows the Top 10 ASes that are connected. For this graph, a Total of 77,344 AS nodes were examined. The top 50 ASes were scanned to find the clique of 10 AS nodes that are connected. A total of 12 candidates were analyzed to find the clique of 10 where all of them have a connection with each other.

5. Customer Cones and AS Rank

5.1 Table #2 Top 15 ASes by Customer Cone Size

AS Rank	AS #	AS Name	AS Degree	Customer Cone					
				Number Of			Percentage Of		
				ASes	IP Prefix	IPs	ASes	IP Prefix	IPs
1	3356	LEVEL3	6657	70219	976854	3543523823	91.23	90.79	82.95
2	1299	TWELVE99	2471	66994	941242	3100134298	87.04	87.48	72.57
3	174	COGENT-174	6781	66296	930691	3036363418	86.13	86.50	71.07
4	3257	GTT-BACKBONE	1846	59415	858598	2684982198	77.19	79.80	62.85
5	3491	CONSOLE-CONNECT-ASN	754	58281	856398	2772490749	75.72	79.59	64.90
6	2914	NTT-DATA-2914	1545	55624	812939	2682982434	72.27	75.55	62.80
7	6939	HURRICANE	9443	55231	819683	2634776700	71.76	76.18	61.67
8	6453	AS6453	629	54891	827693	2622414095	71.32	76.93	61.39
9	5511	Opentransit	368	53764	769462	2627339013	69.85	71.51	61.50
10	6762	SEABONE-NET	678	52555	776797	2547408726	68.28	72.20	59.63
11	6461	ZAYO-6461	2702	51273	739646	2459835422	66.62	68.74	57.58
12	3320	DTAG	697	48956	706475	2416386866	63.60	65.66	56.56
13	12956	TELXIUS	256	48283	720792	2370246447	62.73	66.99	55.48
14	1239	SPRINTLINK	4612	46949	679565	2210477987	61.00	63.16	51.74
15	4826	VOCUS-BACKBONE-AS	1348	46889	690961	2309738062	60.92	64.22	54.07

Table 10. Top 15 ASes by Customer Cone Size.

5.2 Description

For this table, the customer cone was calculated for each AS. Customer cone: the number of ASes an AS can reach via only p2c (provider-to-customer) links. In this table, the top 15 ASes with the largest customer cones are shown, along with additional details for each AS.