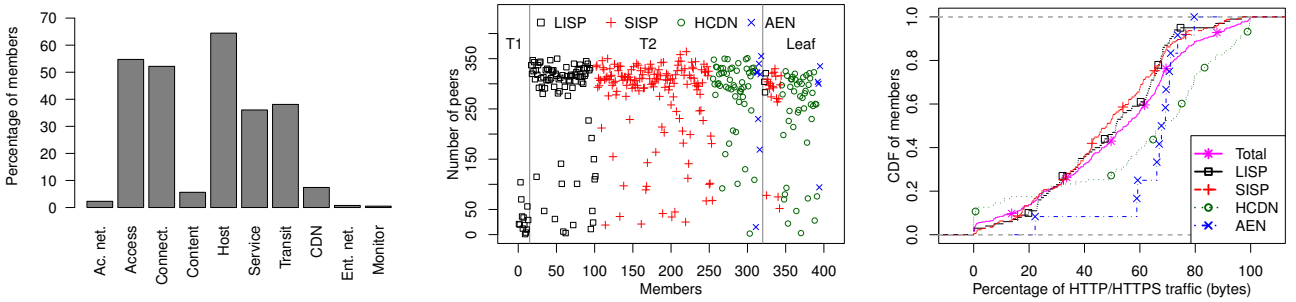

(a) AS classification by business types. (b) Scatter-plot of num. of peers per member. (c) Fractions of web-traffic across members.

Figure 4: Diversity in members: business type, number of peerings, and application mix exemplified by web-traffic.

AEN. Based on this classification, we find that in the LISP group, the member ASes with a small number of peerings are the tier-1 ISPs and those ISPs with a selective peering policy. In the HCDN group, the networks with a few peerings include some of the large players, but also small hosting providers (e.g., for banks or online games). The picture is less clear for the SISP group. In general, the observed large number of member ASes that have a large number of peers at this IXP is testimony for the ease with which member ASes can peer at this (and other) IXP. In fact, the findings of a recent survey [50] provide compelling reasons – some 99 % of the surveyed peerings were a result of "handshake" agreements (with symmetric terms) rather than formal contracts, and an apparent prevalence of multi-lateral peering agreements; that is, the exchange of customer routes within groups of more than two parties.

4.3 Traffic

The contributions to the IXP's overall traffic by the individual member ASes is highly skewed, with the top 30 % of member ASes contributing close to 90 % of the overall IXP traffic. Examining in more detail the traffic volume that each member AS contributes to the IXP's overall traffic, we first investigate what role the traffic exchange ratio plays in establishing P-P links. To this end, we consider the traffic asymmetry across all peerings between any two member ASes and show in Figure 5(a) the empirical cumulative probability distribution of this asymmetry. For improved readability we only show the part of the curve for ratios up to 100:1 (75 % of all peerings). The figure reveals a high variability in terms of exchanged traffic between the two member ASes of a peering. Indeed, only 27 % of the links have a traffic ratio of up to 3:1 (see support lines), where a 3:1 ratio is often stated as a typical requirement in common formal peering agreements [35]. Moreover, for 8 % of the peerings the ratio exceeds 100:1, and for another 17 % we observe traffic in only one direction. Figure 5(a) also depicts the empirical cumulative probability distribution for the P-P links at this IXP involving only tier-1 ISPs and shows that these peerings are less asymmetric, with more than 33 % of them having a ratio below 3:1.

Figure 5(b) shows the traffic asymmetry of the member ASes (i.e., the ratio of outgoing bytes vs. incoming bytes of a given member AS). The traffic of 52 % of the member ASes is more or less symmetric and within the range of 1:3 to 3:1. However, a significant number of member ASes fall in the 3:20 to 20:3 range[5]. In agreement with expectations, HCDNs have more outgoing than incoming traffic, while the opposite is true for LISPs and SISPs. However, there are various exceptions to this rule, and we find HCDNs with significantly more incoming than outgoing traffic and LISPs and SISPs where the opposite holds true. Note that despite the significant diversity in the ratio of incoming and outgoing traffic, more than half of the member ASes that send most of the traffic also receive most of the traffic. Indeed, there is a 50 % overlap among the top 50 member ASes according to bytes sent and the top 50 member ASes according to bytes received.

We can also examine how similar or dissimilar the overall application mix (see Section 2) is across all the IXP member ASes. For example, when computing for each member AS the fraction of HTTP/HTTPS traffic relative to the total number of bytes sent and received, we find in Figure 4(c) that this application mix differs significantly across the member ASes and follows almost a uniform distribution, indicating that without additional information, it would be difficult to predict which percentage of a member AS's traffic is HTTP. However, as soon as we include for example information about the member AS's business type, we observe that as expected, hosting providers and CDNs tend to send a larger fraction of HTTP traffic. However, rather unexpectedly, we also see more than 10 % of the hosting providers and CDNs with only marginal fractions of HTTP traffic. Closer inspection shows that these member ASes are primarily service providers that do not provide web content.

4.4 Prefixes

We next consider the prefix exchange ratio. For this purpose, we say that a prefix is *served* by a member AS if the member AS receives traffic for that prefix. Vice verse, we say that a prefix is *used* by a member AS if output traffic of its access router is destined toward that prefix. Figure 5(c) depicts a scatter-plot of the ratio of the number of prefixes used vs. the number of prefixes served by each member AS and provides clear evidence that the vast majority of the member ASes of our IXP use more than 10-times the number of prefixes they serve. Specifically, we see that hosting providers and CDNs have a tendency to serve a smaller number of prefixes but to use some two orders of magnitude more prefixes. Focusing on the ISPs, we can identify two groups. The first, larger group, serves a diverse but limited set of prefixes, from a few tens to a few thousands. The second, smaller group, serves and uses a large number of prefixes, some tens of thousands. Members that serve such large numbers of prefixes are likely acting as transit networks for other member ASes. However, we again observe exceptions to these general observations in almost all categories.

4.5 Geographical aspects

Conventional wisdom about IXPs states that ASes join regional

[5]To illustrate, if we had a member AS that would only deliver content using 1,500 byte-sized packets, the ratio could be as bad as 1:58, assuming on average one ACK of 52 bytes for every two data packets of 1,500 bytes and no overhead for the TCP connection establishment.