RIPE NCC

Internet Country Report: The Nordic Region

December 2022

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Introduction

The Internet is a global network of networks, yet every country's relationship to it is different. In our latest country report, we provide an outlook on the current state of the Internet in the Nordic Region, including Iceland, Denmark, Norway, Sweden, Finland, Greenland, Åland and the Faroe Islands. We offer an analysis of this region's market landscape and state of development, examine Internet routing within the region, take a close look at its access to the global Domain Name System, and investigate connections between the major networks in each country as well as their connections to the global Internet. This analysis is based on what we can observe from the RIPE NCC's measurement tools as well as a few external data sources.

By focusing the spotlight on this part of the RIPE NCC service region, we can present a comprehensive analysis of its unique Internet ecosystem in order to inform discussion, provide technical insight, and facilitate the exchange of information and best practices. This is the tenth such country report that the RIPE NCC has produced as part of an ongoing effort to support Internet development throughout our service region by making our data and insights available to decision makers, local technical communities and policymakers.

Highlights

- The region displays a relatively healthy level of market competition, although broadband and mobile prices are some of the highest in the world
- The region's five countries hold an exceptionally large amount of IPv4 relative to their populations
- Despite holding large amounts of IPv6, many of the countries/regions show very low IPv6 capability rates, and all require further IPv6 deployment to accommodate long-term growth
- There is a high level of interconnectivity between the networks in each country
- In general, there is good diversity in international connections into and out of each country/region
- Routing is reasonably well optimised in the region, although local Internet exchange points don't appear to be heavily used and a few paths extend across unnecessarily long distances

The Market and Opportunity for Growth in the Nordic Region

The Market Landscape

The five countries and three autonomous regions included in this report vary greatly in terms of their populations, geographical remoteness, and membership within the EU. Nonetheless, these countries and regions also have a lot in common when it comes to their Internet landscapes. The region as a whole is highly interconnected and has been shaped by a shared early adoption of the Internet. Major national infrastructure has been mainly built by private companies, although this is often supported by government aid, particularly in reaching more remote areas – a challenge that is common throughout the region. Despite large geographical distances and rural populations, the region is extremely well connected and has achieved some of the highest levels of Internet penetration in the world, ranging from 88% of the population using the Internet in Sweden up to 100% in Iceland.[1] The region also benefits from some of the fastest speeds: Norway ranks first in the world for mobile speeds, and Denmark ranks sixth for mobile and eighth for fixed broadband.[2]

The Nordic Region is also largely serviced by many of the same Internet service providers (ISPs), the majority of which are local companies. In Denmark, the incumbent TDC and Telenor are major providers in both fixed broadband and mobile services, with several smaller resellers also providing access. In Norway, Telenor, Altibox and Telia are major broadband providers while Telenor and Telia also dominate the mobile market. Telenor and Telia also dominate the fixed broadband and mobile markets in Sweden, where Tele2 and TDC are also big players. Telia also plays a large role in Finland in the fixed broadband and mobile markets, along with Elisa and DNA, while Síminn is a big player in Iceland's fixed and mobile markets, alongside Vodafone (which is operated by Syn) and Nova. There is generally good competition throughout the Nordic Region, with several big providers and incumbents having built much of the national infrastructure, and a significant number of smaller providers offering services built on that infrastructure. A number of submarine cables connect the different countries and regions to one another as well as to the UK, Ireland, mainland Europe and (for Iceland and Greenland) to North America.[3] Investment continues to extend the network, with an example being the Havsil cable between Denmark and Norway that was completed earlier in 2022.[4]

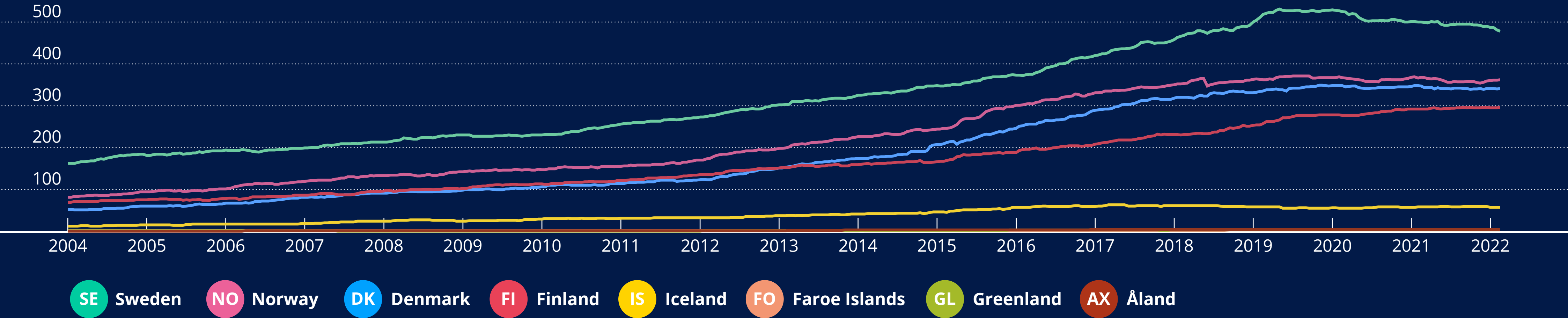
In the EU's 2022 Digital Society and Economy Index (DESI) — which takes into account factors including connectivity, digital skills, digital public services and more — Finland, Denmark and Sweden respectively rank first, second and fourth overall. Sweden ranks ninth place in connectivity but is below the EU average in 1 Gbps take-up and 5G coverage.[5] Denmark ranks first in connectivity but is slightly below the EU average in 1Gbps take-up. Denmark also has the most comprehensive 5G coverage in the EU, with 99% of spectrum assigned and 98% of households covered, and all major mobile operators offering 5G in both retail and commercial markets.[6] Finland ranks eighth in connectivity, with 61% overall fixed broadband use, falling below the EU average of 78%. It also falls behind the EU average in terms of fast broadband and very high capacity network (VHCN) coverage, particularly in rural areas, but scores above average in mobile broadband use and 5G coverage.[7]

Denmark has a national broadband strategy in place, with the 2020 goal of 100Mbps download speeds for all households and businesses having largely been reached (96%) in 2021, and a new goal of 98% of homes and businesses reaching 1Gbps download speeds by 2025. The strategy is built on a technology-neutral approach that will allow for a market-based roll-out, supported by state-funded grants for rural areas. The grants are awarded from a National Broadband pool established in 2016 and encompassing EUR 13.5 million in 2022. Sweden similarly has a national broadband strategy in place via the Swedish Broadband Forum, with a goal of 98% of the population reaching 1Gbps download speeds by 2025. The remaining 2% coverage is expected to be difficult due to the cost involved in connecting remote populations, and the Swedish Post and Telecom Authority made EUR 160 million available in 2021 and approximately EUR 130 in 2022 to support the country's broadband roll-out. Finland also struggles with VHCN coverage in remote areas and secured EUR 16 million in 2021 from the European Agricultural Fund for Rural Development for building fibre networks.

Note that we were not able to include full figures for the autonomous regions of Greenland, the Faroe Islands and Åland in every case throughout this report, as we aimed to cover the largest areas and populations possible given limited space; however, we have made the figures for these regions available online wherever possible.

1 https://www.itu.int/en/ITU-D/Statistics/Dashboards/Pages/Digital-Development.aspx
2 https://www.speedtest.net/global-index
3 https://www.submarinecablemap.com/
4 https://www.submarinenetworks.com/en/systems/intra-europe/havsil
5 https://ec.europa.eu/newsroom/dae/redirection/document/88713
6 https://ec.europa.eu/newsroom/dae/redirection/document/88699
7 https://ec.europa.eu/newsroom/dae/redirection/document/88700

Figure 1:
Number of Local Internet Registries over time



Number of Providers and Other Organisations Running Their Own Networks

As the Regional Internet Registry for Europe, the Middle East and parts of Central Asia, the RIPE NCC can track the development of the local Internet over time by looking at the growth in the number of RIPE NCC members and Local Internet Registries (LIRs). In general, a higher number of LIRs often signals a more diversified market, with a larger number of service providers operating their own networks; however, this is not always the case.

For a long time, the majority of RIPE NCC members were large Internet service and access providers. More recently, however, we've seen a significant increase in other types of organisations requiring IP addresses to run their own networks, including hosting providers, government agencies, universities, businesses, etc. As a result, an increase in the number of LIRs doesn't necessarily translate into an increase in the number of Internet access providers. However, it has allowed more organisations to exert more control over their Internet address resources and the ways in which they route their traffic.

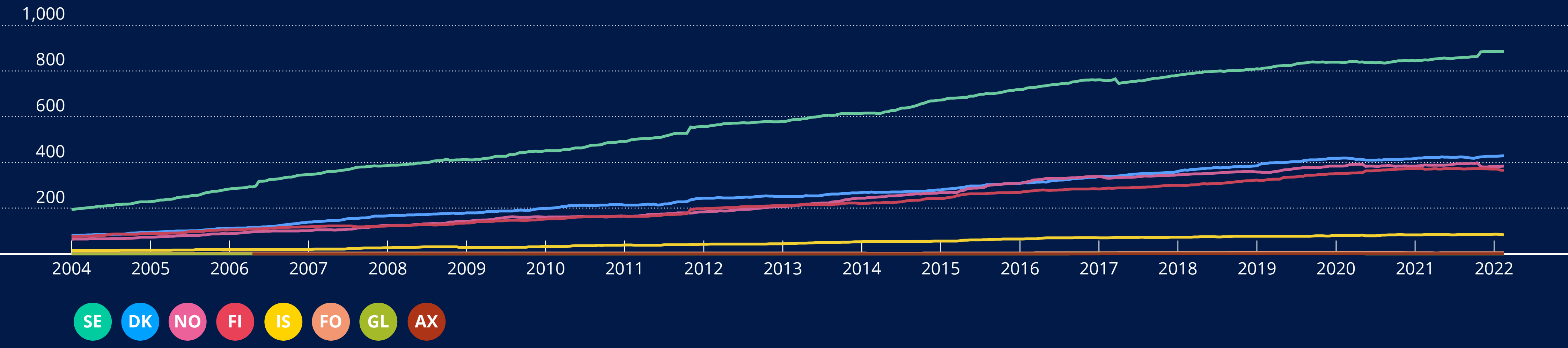
In addition, it's possible for the same organisation to hold several LIR accounts. This practice became a significant trend after 2012, when the amount of IPv4 address space being allocated was restricted as the remaining IPv4 address pool became smaller and smaller (as explained in more detail in the IPv4 section below).

RIPE NCC Members and Local Internet Registries

RIPE NCC members include Internet service providers, content hosting providers, government agencies, academic institutions and other organisations that run their own networks in the RIPE NCC service region of Europe, the Middle East and Central Asia. The RIPE NCC distributes Internet address space to these members, who may further assign IP addresses to their own end users. It is possible for members to open more than one account, called a Local Internet Registry (LIR).

Sweden, Norway, Denmark and Finland all saw significant growth in LIRs between 2012 and 2020. Since that time, the number has been decreasing in Sweden, which is likely the result of members closing additional LIR accounts, while

Figure 2:
Number of networks over time



Norway, Denmark and Finland have more or less plateaued. Iceland experienced modest growth until 2019, while the Faroe Islands, Greenland and Åland have only ever had a very small number of LIRs. Overall, this kind of growth pattern is typical to what we've seen in other countries in Europe and is indicative of a mature Internet landscape that developed early on.

Network Growth and Diversity

In general, a larger number of LIRs corresponds to a larger number of independently operated networks called Autonomous Systems, each of which is represented by an Autonomous System Number, or ASN. (An Autonomous System is a group of IP networks that are run according to a single, clearly defined routing policy. There are currently about 70,000 active ASNs on the Internet today.)

The number of networks in a given country is one indication of market maturity. The greater the diversification, the more opportunity exists for interconnection among networks, which increases resiliency. The RIPE NCC is responsible for the allocation of ASNs in its service region. This provides us unique insight into the distribution and deployment of these networks across the Internet.

In figure 2, we see a healthy amount of growth in the number of networks over time. Relative to their populations, we see the highest number of networks per capita in Iceland, Åland and the Faroe Islands, while Denmark, Finland, Norway and Sweden are all relatively on par with one another. There is only one ASN in Greenland, operated by Tusass (a postal and telecommunications company, formerly TELE Greenland), that is used by the other LIRs in the region.

IPv4 in the Nordic Region

Until 2012, RIPE NCC members could receive larger amounts of IPv4 address space based on demonstrated need. When the RIPE NCC reached the last /8 of IPv4 address space in 2012, the RIPE community instituted a policy allowing new LIRs to receive a small allocation of IPv4 (1,024 addresses) in order to help them make the transition to IPv6, the next-generation protocol that includes enough IP addresses for the foreseeable future. In November 2019, the RIPE NCC made the last of these allocations. A system now exists whereby organisations that have never received IPv4 from the RIPE NCC can receive an even smaller allocation (256 addresses), if available, from a pool of recovered address space (occasionally member accounts are closed and address space is returned to the RIPE NCC).

Figure 3:
IPv4 holdings over time

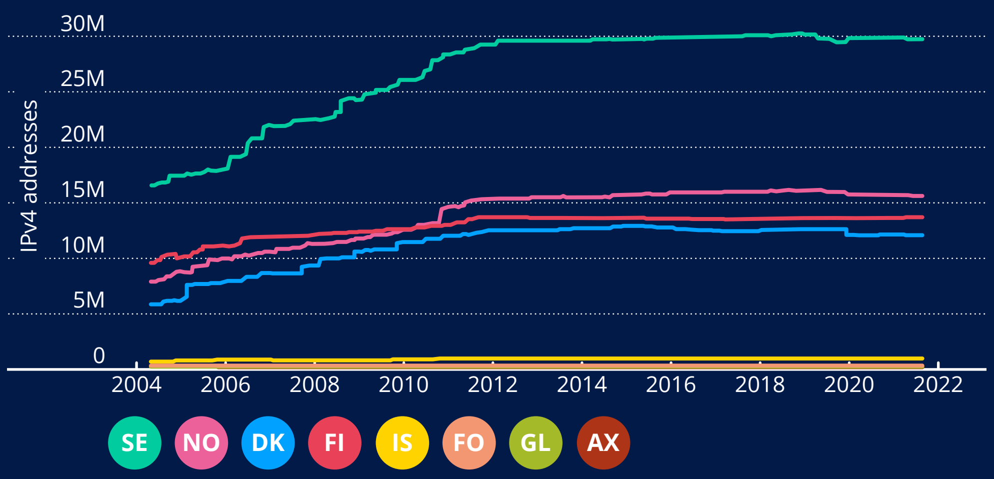
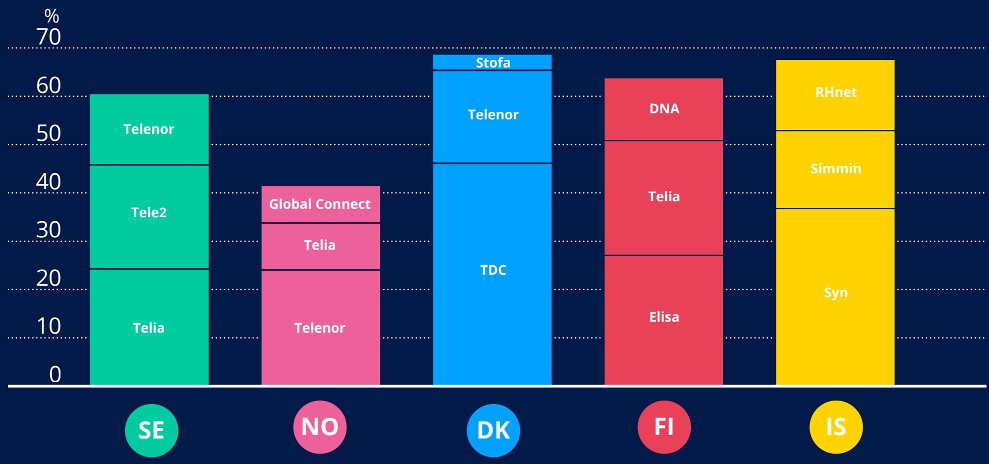


Figure 4:
Top 3 IPv4 holders



In figure 3, we can clearly see a period of significant growth in Sweden, Norway, Finland and Denmark until the policy change in 2012, when growth suddenly plateaus, while Iceland shows less growth. The region's early adoption of the Internet is clearly evident in the amount of IPv4 held by these countries, where we see a range of 2.1 IPv4 addresses per person in Denmark to 2.9 in Norway and Sweden. These are by far the largest per capita IPv4 figures we've seen in any of the countries covered by the RIPE NCC Internet Country Reports. Often, there are far fewer IPv4 addresses than people in any given country and users are forced to share addresses; however, there is far less pressure on the bigger Nordic providers to use address-sharing technologies. The situation is different for the three autonomous regions, however, where we see 0.6 IPv4 addresses per person in Greenland, 0.9 in the Faroe Islands, and 1.6 in Åland.

We see a moderate amount of consolidation in terms of the amount of IPv4 address space held by different companies in each of the five countries in the Nordic Region. This is most pronounced in Denmark, where the incumbent, TDC, holds more than 46% of the country's total IPv4 space. In general, the major providers hold the most space, which is to be expected. There is much more consolidation in the three autonomous regions, where Føroya Tele (an ISP) holds 70% of the IPv4 address space in the Faroe Islands, Tusass (formerly TELE Greenland) holds 82% of the space in Greenland, and Ålcom holds 85% of the space in Åland.[8]

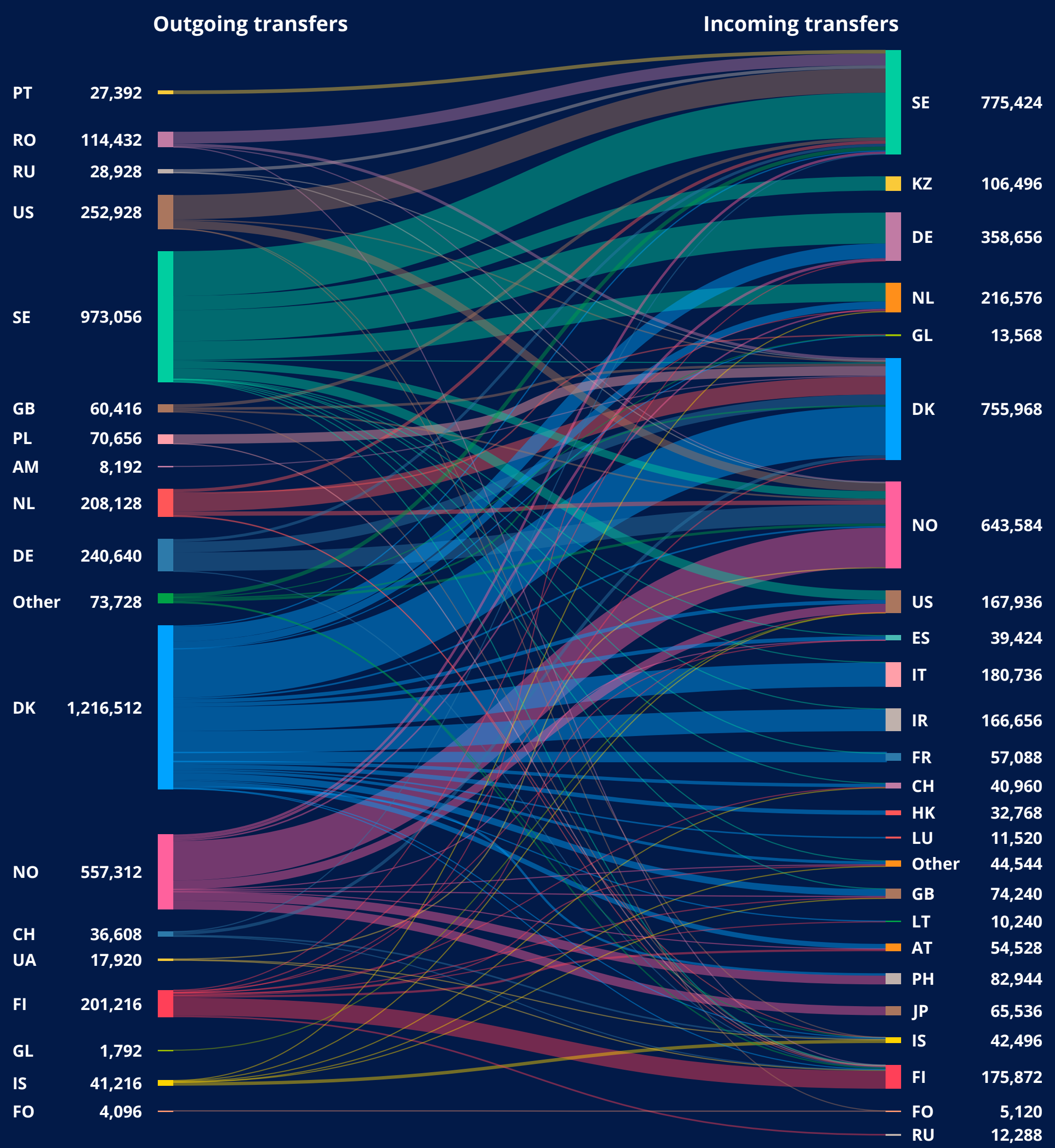
IPv4 Secondary Market

To fill the demand for more IPv4 address space, a secondary market has arisen in recent years, with IPv4 being bought and sold between different organisations. The RIPE NCC plays no role in these financial transactions, ensuring only that the RIPE Database – the record of which address space has been registered to which RIPE NCC members – remains as accurate as possible.

As demand for IPv4 continues despite the dwindling pool of available space, many providers and other organisations have turned to the secondary market. Figure 5 shows the IPv4 transfers that have taken place within, into and out of each country in the region since the market became active. (Note that these figures do not include resources that were transferred as the result of mergers or acquisitions.)

8 *Full data for the three autonomous regions can be found online: https://labs.ripe.net/author/suzanne_taylor_muzzin/ripe-ncc-internet-country-report-the-nordic-region/*

Figure 5:
IPv4 transfers within, into and out of the Nordic Region between October 2012 and September 2022



In figure 5, we see how active Denmark has been in the secondary IPv4 market compared to the other countries, especially considering the fact that it holds less than half the amount of IPv4 space than Sweden, for example. The National Agency for IT and Learning (Styrelsen for It og Læring) accounts for 60% of the transfers that originated in the country. Between 2016 and 2018, it sold its excess IPv4 addresses via a series of auctions, both to Danish and foreign organisations.[9] Iceland, Greenland and the Faroe Islands saw a minimal number of transfers, while there have been no transfers at all in Åland. Interestingly, the 1,792 IPv4 addresses transferred from Greenland to an organisation registered in the US had been acquired from a Danish resource holder two years earlier. We see a large number of domestic transfers taking place, whereby addresses are transferred between two different entities within the same country. This is particularly true for Norway, where 53% of the transfers originating in the country were domestic transfers. It's interesting to note that the very first transfer in the RIPE NCC service region took place in Norway, when a /18 was transferred from Telenor Norge to Canal Digital Kabel TV on 17 October 2012.

The organisations that were the biggest net importers of IPv4 address space via the secondary market in the Nordic Region, and the number of addresses they imported, include:

- Altibox (NO): 196,608
- Fibia (DK): 164,864
- Bahnhof (SE): 65,792
- SUNET/NORDUnet (SE): 65,536
- SEAS-NVE (DK): 65,536

Altibox, Fibia and Bahnhof are all ISPs. NORDUnet hosts several of the Nordic national research networks (NRENs), including SUNET in Sweden. SEAS-NVE is an energy and fibre company that also offers Internet services in Denmark.

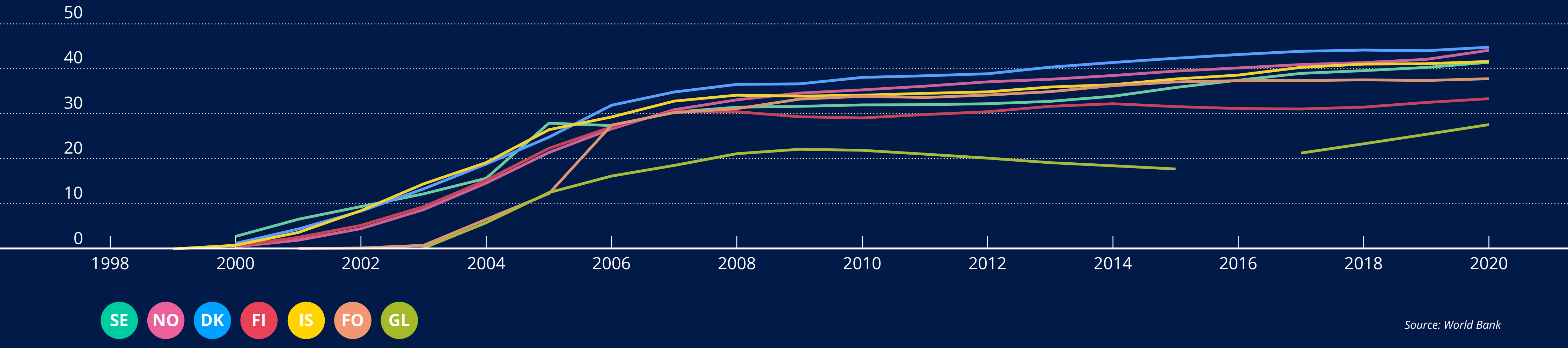
The organisations that were the biggest exporters of IPv4 address space via the secondary market in the Nordic Region, and the number of addresses they exported, include:

- Styrelsen for It og Læring (DK): 736,000
- Orange Business Services (SE): 196,608
- NextGenTel (NO): 196,608
- Tele2 (SE): 106,496
- Sagitta (DK): 65,536

Note that Orange Business Services operates in multiple countries and has transferred various blocks of IPv4 addresses; the figure listed only includes IPv4 addresses that were registered with country code SE. NextGenTel, Tele2 and Sagitta are all ISPs.

9 https://web.archive.org/web/20160304013144/https://ipv4.stil.dk/

Figure 6:
Fixed broadband subscriptions per 100 people over time



Source: World Bank

Internet Penetration and Potential for Future Growth

As previously mentioned, the countries and autonomous regions in the Nordic Region all have very large amounts of IPv4 for their populations. This is likely an effect of early Internet development in the region. Together, these factors have almost certainly contributed to the region's success in attaining some of the highest levels of Internet penetration in the world.

As we see in figure 6, the fixed broadband subscriptions are generally above the EU average of 36 per 100 people and well above the world average of 15. (Note that fixed broadband connections are generally shared among several people in the same household, and the numbers we see in figure 6 will therefore never approach 100.) It's interesting to note that Greenland's figure actually dipped for several years beginning in 2009, which isn't something we normally see. Finland also experienced a less pronounced dip for several years beginning in 2014. Broadband costs tend to be quite high, particularly for Greenland, which ranks 203rd in the world when it comes to the average cost of a broadband package, as well as Norway (185th), the Faroe Islands (176th) and Iceland (168th).[10] The fact that average salaries are also relatively high in this region could help explain the apparent lack of negative impact of high broadband prices on uptake.

10 https://www.cable.co.uk/broadband/pricing/worldwide-comparison/

Figure 7:
Mobile subscriptions per 100 people over time

Source: World Bank

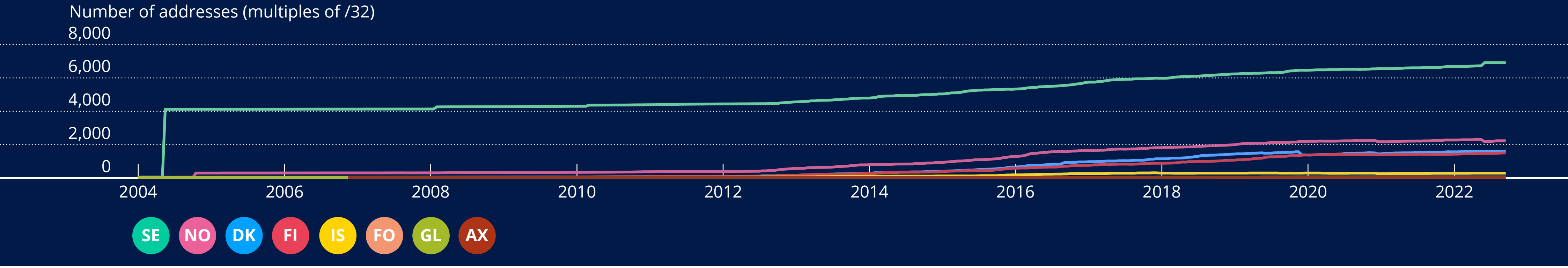
In terms of mobile subscriptions per 100 people, we also see quite high figures in the region, particularly in Finland, which reached a peak in 2012 at 172 subscriptions per 100 people – a very high figure for Europe, although we've seen even higher figures in the Middle East. The cost of mobile data doesn't appear to strongly affect the subscription rate; apart from Denmark, which ranks as the 25th least expensive country in the world when it comes to the cost of 1GB of mobile data, the Nordic Region is generally quite expensive, ranging from 75th place in the world (Iceland) to 203rd (Åland).[11] The mobile subscription rates we see in the Nordic Region generally fall between the world average of 105 and the EU average of 122 subscriptions per 100 people. We also see several countries or regions reaching a peak and then declining slightly here. This is much more common in mobile subscriptions and is something we've seen throughout Europe, which is likely a result of a mature market that has already reached saturation.

Because the five countries in the Nordic Region have exceptionally large numbers of IPv4 address space to serve their populations, and their high Internet penetration rates mean that most of these populations are already connected, they are seemingly much less stressed when it comes to IPv4 scarcity in the wake of the IPv4 run-out than many other parts of the world. In many places, broadband and mobile providers are struggling to serve their growing numbers of customers. Technical workarounds that allow multiple users to share a single IP address, such as carrier-grade network address translation (CGN), are especially in widespread use in mobile broadband connectivity; however, there are well-documented drawbacks to address-sharing technologies.

Even in the Nordic Region, and especially in the three autonomous regions where per capita rates are much lower, the IPv4 run-out and the growing cost of IPv4 on the secondary market means that newly established providers are going to find it difficult to obtain the resources they need to enter the market and maintain healthy competition. IPv6 is also required to support emerging technologies such as 5G, the Internet of Things, smart cities and more. For all these reasons, deploying IPv6 remains the only sustainable strategy for accommodating future growth.

11 https://www.cable.co.uk/mobiles/worldwide-data-pricing/

Figure 8:
IPv6 holdings over time



IPv6 in the Nordic Region

Usually, the amount of IPv6 in a country roughly corresponds to (though does not equal) its IPv4, which is generally what we see for the five countries in figure 8, although Iceland and Sweden both have a slightly higher ratio of IPv6 to IPv4 compared to the others. (Note that because of the huge numbers involved in IPv6, we use the equivalent of a /32 of IPv6 in our calculations.) The huge jump we see for Sweden in 2004 is the result of a /20 allocation that was made to Telia International Carrier. The exceptions are the Faroe Islands and Åland, which have some of the most IPv6 per capita in the region despite having less IPv4 per capita compared to the countries. This could be indicative of an Internet landscape that developed a little more slowly in these areas compared to the five countries, as IPv4 was more widely available earlier on and the focus more recently has been shifting to IPv6.

Sweden, Norway, Denmark and Finland all continue to increase their IPv6 holdings at a significant pace, although growth has slowed in recent years. It's not surprising to see significant uptake beginning around 2012, when the IPv4 policy change came into effect, and LIRs began receiving an IPv6 allocation along with their final IPv4 allocation as standard practice.

In terms of the top IPv6 holders, there is very little consolidation in Denmark, Norway, Finland and Iceland, where the countries' IPv6 is split among a large number of organisations that each hold a small amount. There is a moderate amount of consolidation in the Faroe Islands and Åland. In the Faroe Islands, three organisations hold 32% each of the IPv6 space: Føroya Tele, Kringvarp Føroya (the national public broadcaster) and P/F Elektron (an ISP). In Åland, two organisations hold 42% each: Ålands Penningautomatförening (a gambling operator owned by the regional government) and Carus (a software company). There's a high level of consolidation in Sweden and Greenland. In Sweden, the multinational Telia Company holds 60% of the country's IPv6 space (a result of the large /20 allocation it received in 2004), with the remainder being divided up among a large number of other organisations that each hold very little. The RIPE Database shows that Telia made 622 further assignments and sub-allocations from the /20, some of which went to other branches of Telia Company in Sweden, Denmark and Finland. In Greenland, Nanoq Media (which provides television and radio as well as broadband Internet) holds 80% of the region's IPv6 space, with the remainder divided between Comby (an IT company) and Tusass (formerly TELE Greenland).

Unlike IPv4, IPv6 addresses are widely available (although large allocations are based on demonstrated need), so hoarding tends not to play a role in the amount of space that organisations hold in the same way that it does when it comes to IPv4. However, it's worth noting that just because organisations hold large amounts of IPv6 address space does not mean they have actually deployed IPv6 and that the addresses are in use. Some networks might hold a large amount of address space without using it (possibly having presented plans for future growth when requesting large allocations), while others might be able to serve their entire customer base with a relatively small allocation.

Indeed, this is what we see happening in the Nordic Region, where approximately 64% of the region's IPv6 address space is actually being routed. However, the picture is less positive if we take into account the fact that Telia's /20 allocation accounts for about 33% of the total IPv6 space in the Nordic

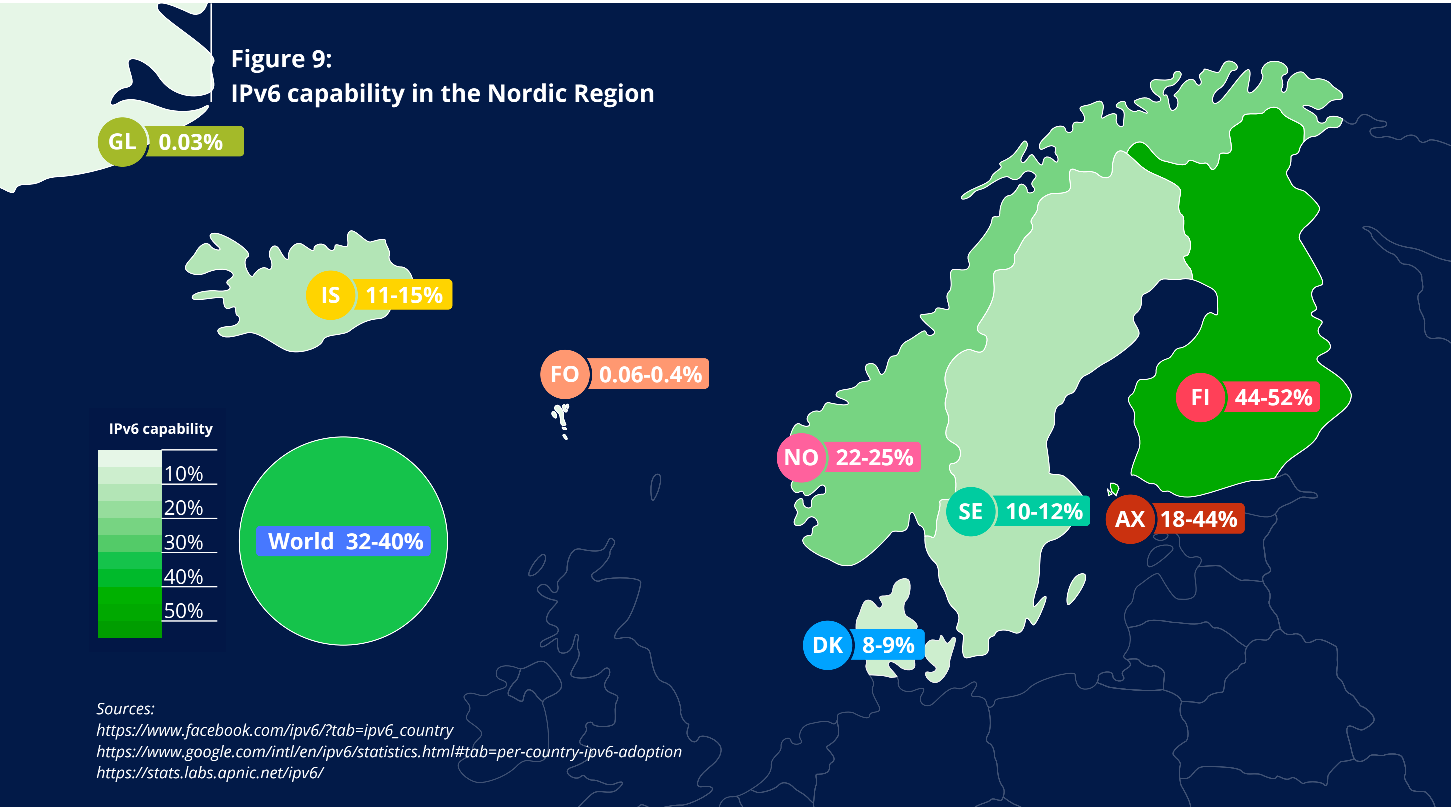


Figure 9: IPv6 capability in the Nordic Region

Sources:
https://www.facebook.com/ipv6/?tab=ipv6_country
https://www.google.com/intl/en/ipv6/statistics.html#tab=per-country-ipv6-adoption
https://stats.labs.apnic.net/ipv6/

Region and so contributes greatly to that overall figure. If we look just at the remainder of the region's IPv6 space (not including that /20 allocation), only about 46% of that space is being routed. Even then, the fact that the IPv6 space is being routed doesn't necessarily mean that actual services are being offered over IPv6 – which may be the case here.

When we look at IPv6 adoption rates in the Nordic Region, we see a very large range from virtually 0% in Greenland and the Faroe Islands to more than 50% in Finland. (Note that the figures include a range because the different organisations measuring these rates use different methodologies.) With a world average of 32-40% IPv6 capability, the Nordic Region falls below average with the exception of Finland and possibly Åland. Despite Telia's large /20 allocation appearing in the routing system, the network is only about 5% IPv6 capable. Of the major providers in the region, those with more than 50% IPv6 capability include Elisa, DNA, Ålcom, Hi3G, Telenor and Nova. In the Faroe Islands, telecommunications company Føroya Tele was on a path of slow but steady IPv6 adoption, reaching 21% capability in January 2021; however, in the next two months it dropped to virtually zero percent and has hardly changed since (we have no further information about how or why this drop occurred).[12] While the region's generally low levels of IPv6 adoption are likely linked to its relatively high amount of IPv4, the amount of IPv4 consolidation we see with the larger (generally older) players means that other providers may still feel the pressure of IPv4 scarcity.

In trying to gain further insight, we look to the RIPE NCC Survey 2019,[13] which polled more than 4,000 network operators and other members of the technical community, including 250 from the Nordic Region. Not unexpectedly, we see a lower percentage of respondents from this region stating that they thought they would need more IPv4 address space in the next two to three years than the overall average among all respondents (36% compared to 46%). In thinking about IPv4 scarcity, the top main challenge among respondents from the Nordic Region was deploying IPv6 (at 31%), while the top main challenge among all respondents was dependency on IPv4. The reasons given for not deploying IPv6 were a mix, with a lack of business need being the most common.

Governments, regulators, Internet exchange points (IXPs) and local network operator groups (NOGs) all have a role to play in IPv6 deployment. As we've seen in other countries we've looked at, active support among these actors can contribute significantly to a country's overall Internet development and the ability to transition to the next-generation protocol. The Swedish regulator, PTS, released a report earlier in 2022 that identified two main obstacles to IPv6 deployment in the country – low demand for IPv6 in the public sector, and limited provision of IPv6-compatible accesses in the public electronic communications networks – and suggested a number of regulatory measures to try to boost deployment.[14] From those we spoke to in the industry, an active NOG in Finland, where topics such as IPv6 deployment have been on the agenda for many years already, may be a contributing factor to the higher level of deployment we see there.

12 *https://stats.labs.apnic.net/ipv6/FO*
13 *https://www.ripe.net/survey*
14 *https://www.pts.se/sv/dokument/rapporter/internet/2022/ipv6-i-sverige---inte-langre-tillrackligt-med-enbart-framjandeatgarder/*

Domestic and International Connectivity

Domestic Connectivity Between Networks

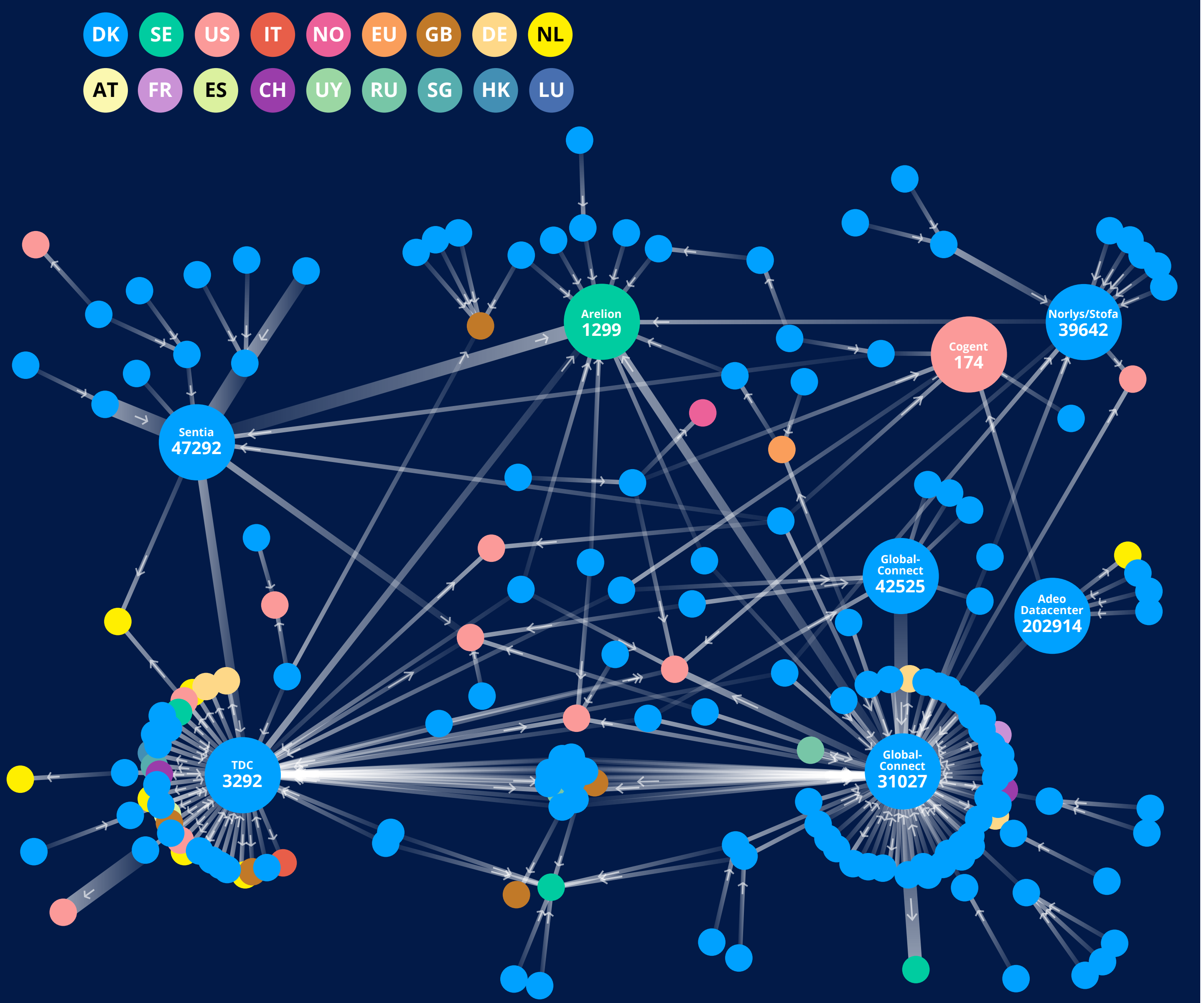
To understand the relationships that exist between different networks, we can investigate the interconnections within each of the countries using data from the RIPE NCC's Routing Information Service (RIS), which employs a globally distributed set of route collectors to collect and store Internet routing data. This shows us the available paths that exist between networks (as opposed to actual paths taken).

For each country, we plot how routes propagate from one network to another (arrows indicate the direction of BGP announcements, which is opposite to traffic flow) up to the point where the path reaches a foreign network. For each path, we discard the first few hops that detail how routes propagate through international networks; our focus is on routing inside each country and the connections to the outside world. The nodes in each figure are colour-coded according to the country in which the network (ASN) is registered, and the width of the lines is determined by the number of paths in which we see the connection between the different ASNs. Note that we only label the ASNs that we specifically mention in the text, and that the position of the different networks doesn't correspond to any kind of geographical layout; instead, these figures are a visual representation of the relationships between the networks in each country.

Due to the nature of Border Gateway Protocol (BGP) and RIS route collection processes, our view is limited to the routes followed by international traffic. We will only observe peering relationships between two service providers in a country when one or both partners announce the other's routes to a third party that further propagates the route. Most notably, we will not see peerings at regional IXPs, where the intention is to keep local traffic within the country or region. Nevertheless, graphing the connections that we can detect provides valuable insight into domestic connectivity.

Because the five countries in this report all have a fairly large number of ASNs, the following network diagrams have been restricted to the top 250 most observed links between ASNs. While this means that many smaller ASNs have been left out, as well as some less frequently seen paths between ASNs, the result still provides a view of the overall picture.

Figure 10:
Connectivity between networks in Denmark

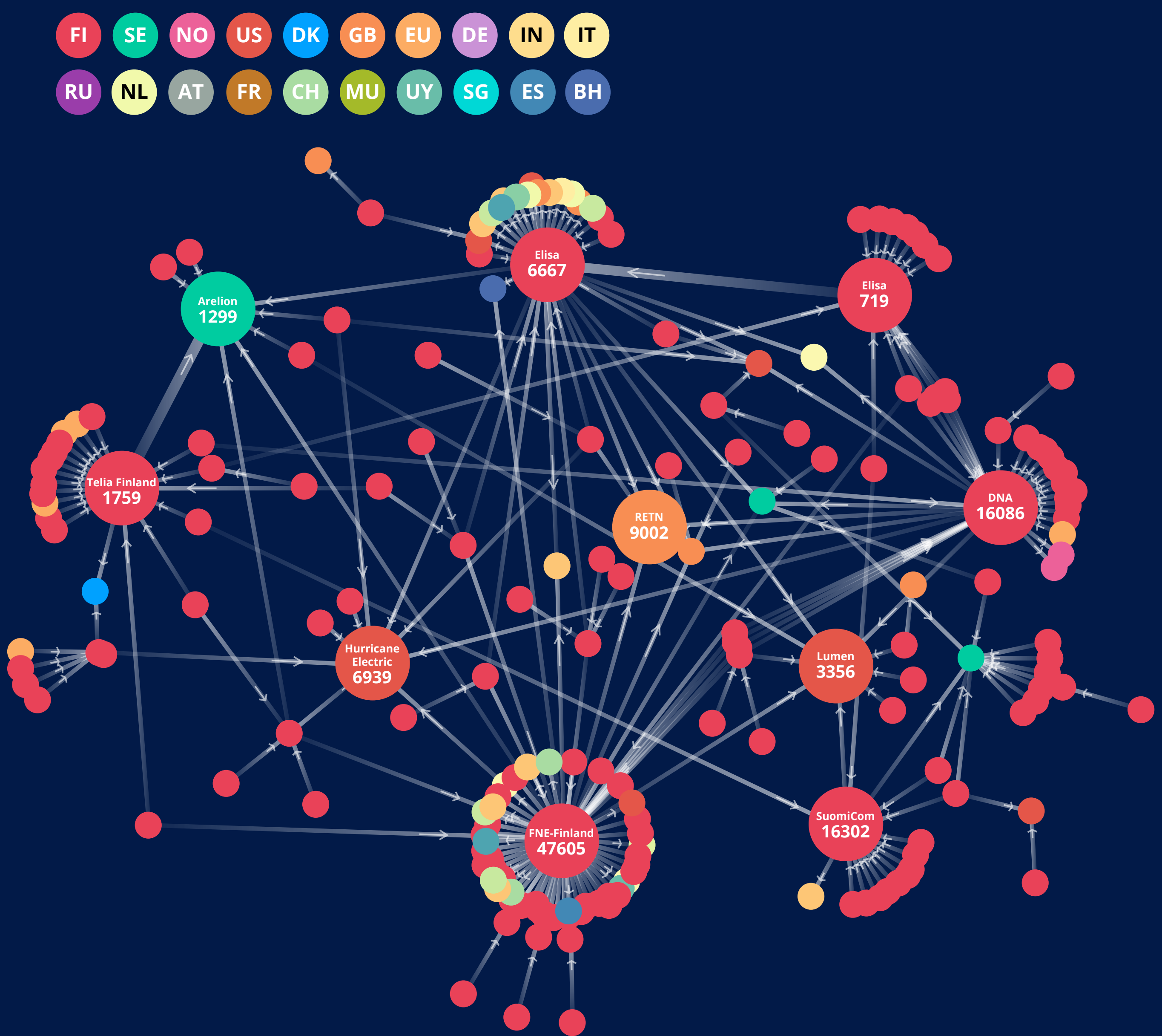


In Denmark, GlobalConnect connects many of the country's networks, predominantly via AS31027 (formerly Nianet), but also via AS42525, which has AS31027 as its sole upstream. TDC (AS3292) is the other major player, which connects the biggest number of consumers as it holds the most IPv4 addresses, but also connects a large number of business networks. Various networks connect to both GlobalConnect and TDC, which boosts resiliency.

Other networks providing connectivity are Sentia (AS47292), Norlys/Stofa[15] (AS39642) and Adeo Datacenter (AS202914). Arelion (AS1299, formerly Telia's carrier division) is one of the international transit providers for TDC, GlobalConnect, Sentia and Norlys/Stofa, but it also provides direct connectivity to some Danish networks. This is true of Cogent (AS174) as well.

15 While Norlys owns Stofa, it appears Norlys also provides connectivity under its own brand. Both are bundled in one LIR in the RIPE NCC's records, listed as Stofa; however, the bulk of Stofa's IPv4 space is announced by AS39642, which has been listed as Norlys in the RIPE Database since July 2022. We therefore use the name Norlys/Stofa, as it is difficult to distinguish between the two.

Figure 11:
Connectivity between networks in Finland

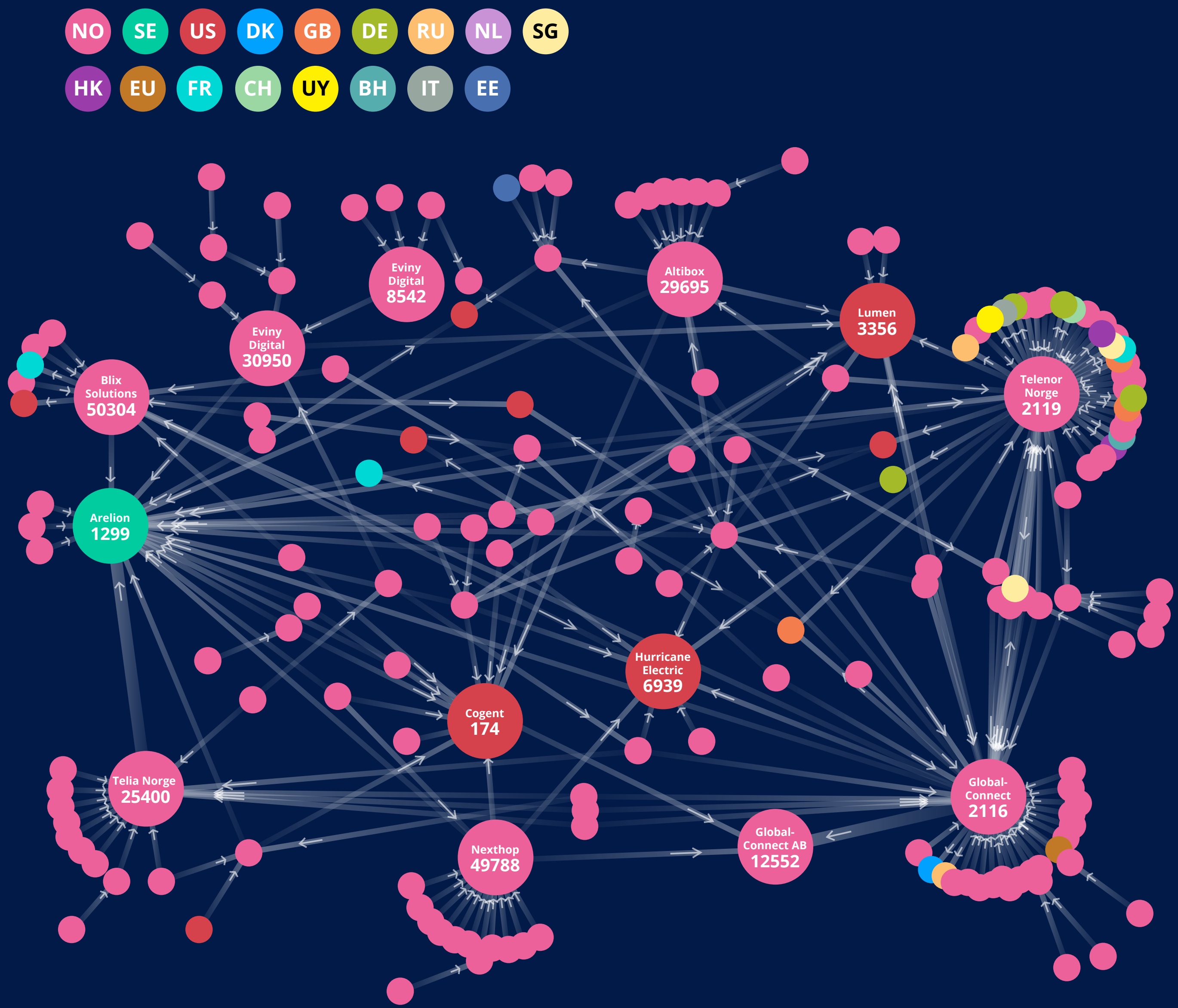


In Finland, we see how a large number of networks connect to FNE-Finland (AS47605). The provider only has a relatively small amount of IPv4 addresses itself, but plays a major role in connecting Finland through its national backbone network. Similarly, SuomiCom (AS16302) targets business users and connects a significant number of other Finish networks, while holding a modest number of IPv4 addresses itself.

The three biggest providers in terms of IPv4 space connect a fair number of other networks as well. Elisa operates two networks: AS719, which connects domestic networks, and AS6667, which also connects some domestic networks in addition to providing international connectivity via transit and peering. DNA (AS16086) and Telia Finland (AS1759) operate with one ASN, though Telia Finland does have Arelion (AS1299), the group's former carrier division, as its one and only upstream.

Next to these clusters, we see various networks that are multihomed (connected to two or more local ASNs), as well as networks which directly connect to transit providers like Lumen (AS3356), RETN (AS9002) and Hurricane Electric (AS6939) without passing through one of the local providers.

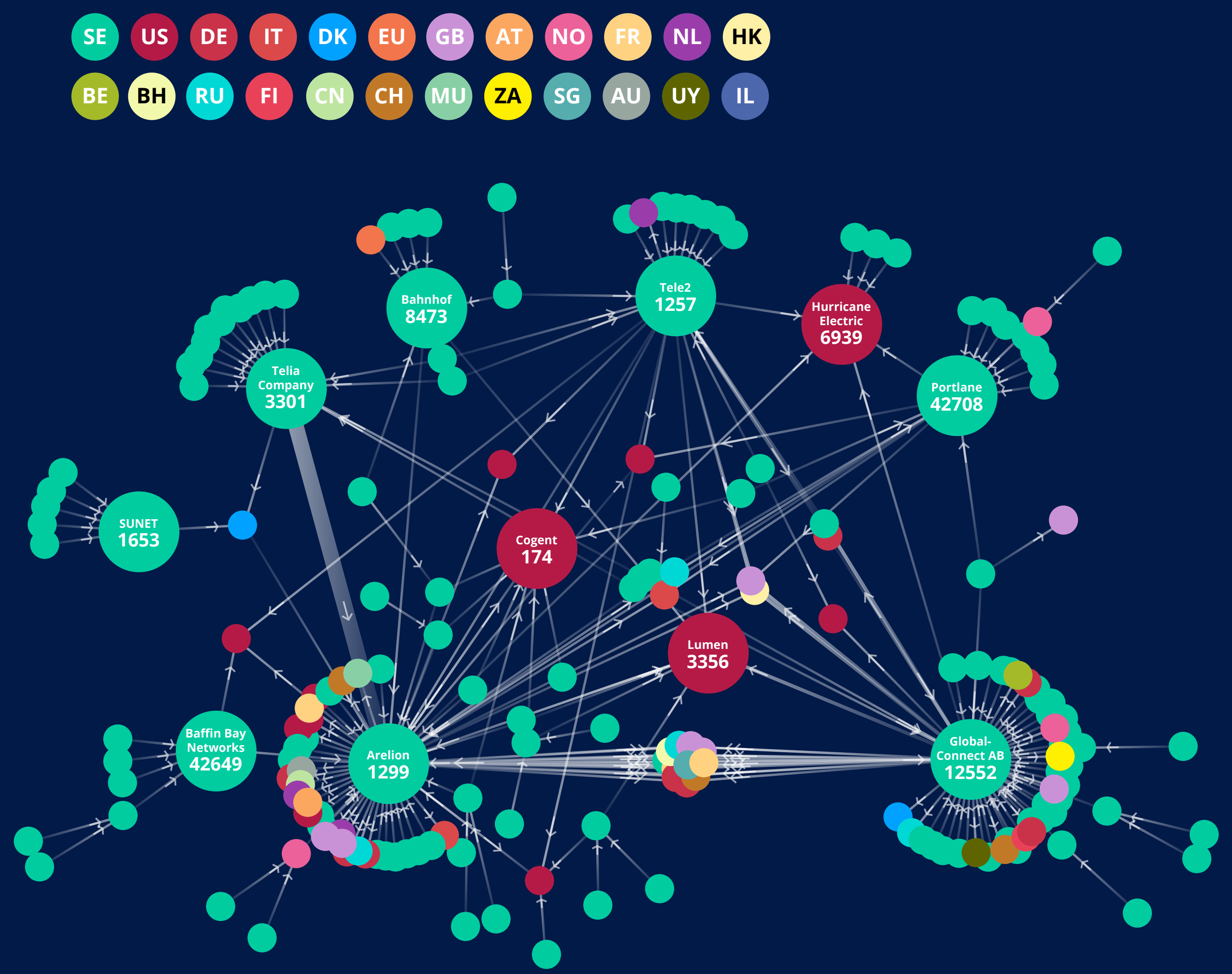
Figure 12:
Connectivity between networks in Norway



In Norway, the relatively large number of networks that are multihomed or connect directly to international providers like Cogent (AS174), Lumen (AS3356), Arelion (AS1299) (formerly Telia Carrier) and Hurricane Electric (AS6939) stands out. Nevertheless, there are still a sizeable number of networks that connect to just one of the larger providers: Telenor Norge (AS2119), GlobalConnect (AS2116), Telia Norge (AS25400), Altibox (AS29695), Nexthop (AS49788), Blix Solutions (AS50304) and Eviny Digital (AS30950 and AS8542).

For GlobalConnect (AS2116), we observe a large number of paths through GlobalConnect AB (AS12552), the Swedish branch; however, the reach of those routes is limited, as GlobalConnect AB announces them to peering partners at exchange points where the Norwegian branch of GlobalConnect is not present, with the wider Internet reached via transit providers.

Figure 13:
Connectivity between networks in Sweden

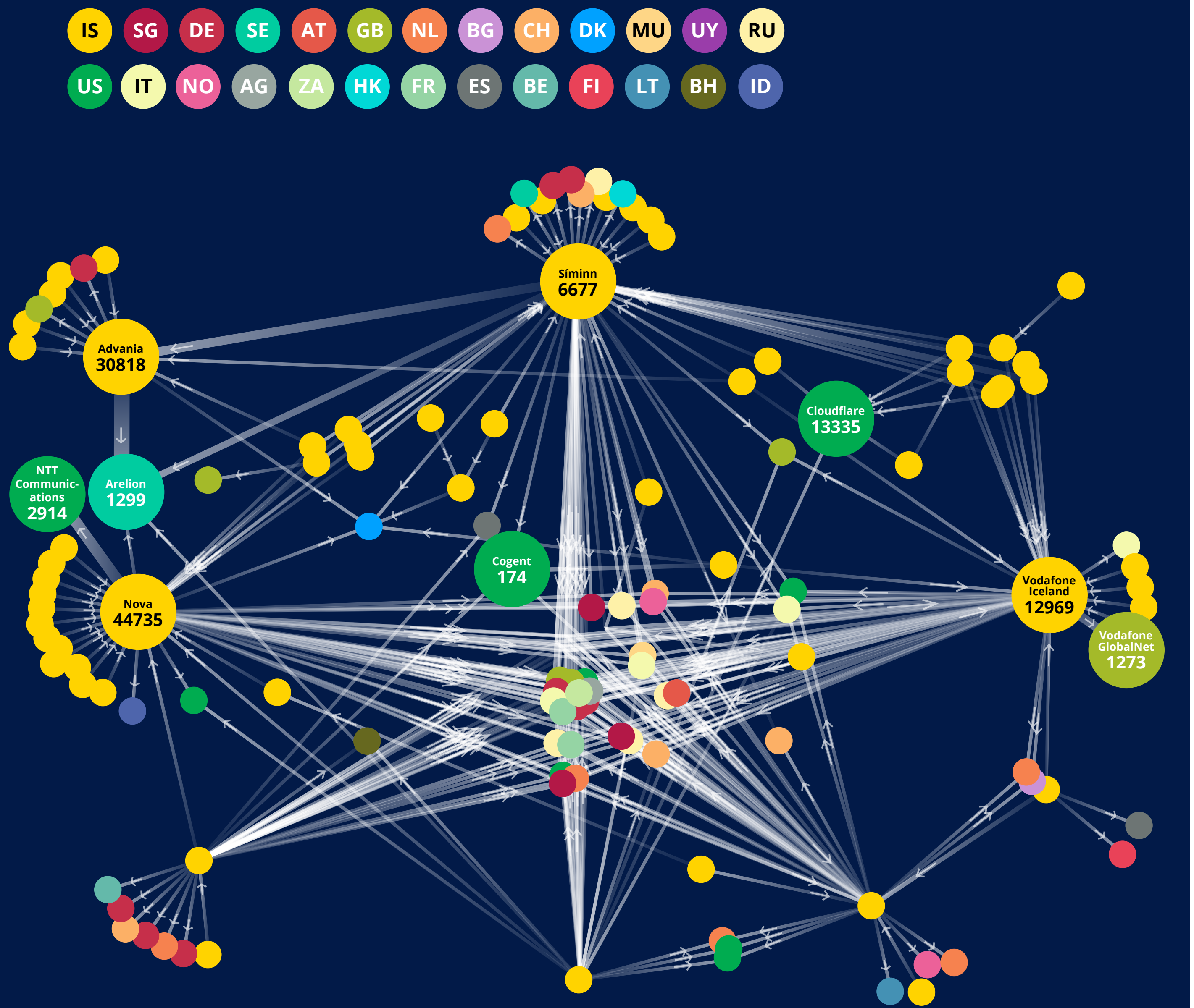


In Sweden, the large clusters around Arelion (AS1299) and GlobalConnect AB (AS12552) stand out. Arelion is also the main upstream for Telia Company (AS3301), which in turn also connects a significant number of Swedish networks.

Tele2 (AS1257), Portlane (AS42708), Bahnhof (AS8473) and Baffin Bay Networks (AS42649) are the other main providers connecting Swedish businesses, while SUNET (AS1653) provides connectivity to Swedish research networks.

From the international providers, we see Cogent (AS174), Hurricane Electric (AS6939) and Lumen (AS3356) connecting several Swedish networks directly, next to the main providers.

Figure 14:
Connectivity between networks in Iceland



In Iceland, we see how the larger providers have many foreign ASNs in common that carry their routes. This likely is caused by the presence of these ISPs at the AMS-IX and LINX Internet exchanges – locations where we also have RIS route collectors (networks at these IXPs will pick up Icelandic networks' routes via peering and pass these to RIS).

Domestically, Nova (AS44735), Advania (AS30818), Síminn (AS6677) and Vodafone Iceland (AS12969) connect most of the country's networks to the wider Internet. We also see that various networks are multihomed via two or more providers. Arelion (AS1299), Cogent (AS174), NTT Communications (AS2914) and Vodafone GlobalNet (AS1273) are notable upstreams. We also see how a number of networks propagate their routes via Cloudflare (AS13335) for DDoS mitigation.

With only a handful of networks in Åland and the Faroe Islands, and just a single network in Greenland (Tusass, formerly TELE Greenland), routing in these regions is fairly straightforward. The dominant providers have arranged transit from between one to three upstreams. The smaller providers are multihomed, either to two domestic providers or to a domestic provider and an international carrier. Ålcom is present at the public Netnod exchanges in Helsinki and Stockholm, where it peers with a dozen other networks. Føroya Tele is not connected at an IXP, but is present at private interconnect facilities in Copenhagen and London, where it connects to its transit providers.[16]

16 The domestic connectivity graphs for the three autonomous regions are available online: https://labs.ripe.net/author/suzanne_taylor_muzzin/ripe-ncc-internet-country-report-the-nordic-region/

International Connectivity

Extending our view, we now look beyond domestic connectivity to examine how the Nordic countries connect to the rest of the world. Internet connectivity comes in two forms: peering and transit. Peering usually happens at IXPs, where parties exchange routes to their respective customers. This helps keep local traffic local, or at least regional. To reach other destinations beyond a regional scope, ISPs need transit agreements with one or more parties that will route traffic to the rest of the world. This usually involves some hierarchy. Like a regional peer, the first upstream will be happy to route traffic to its customers if the destination is in one of its networks; however, if the destination is not among its customers, the first upstream will in turn route the traffic to its transit provider, which will apply the same process. Typically after two or three steps ("hops" from one network to another), traffic reaches a so-called Tier 1 network, which sits at the top of the hierarchy and requires no transit but has only peering relationships to other Tier 1 networks. Once traffic has been exchanged at the Tier 1 level, it goes down the chain on the other side to smaller ISPs until it reaches its final destination.

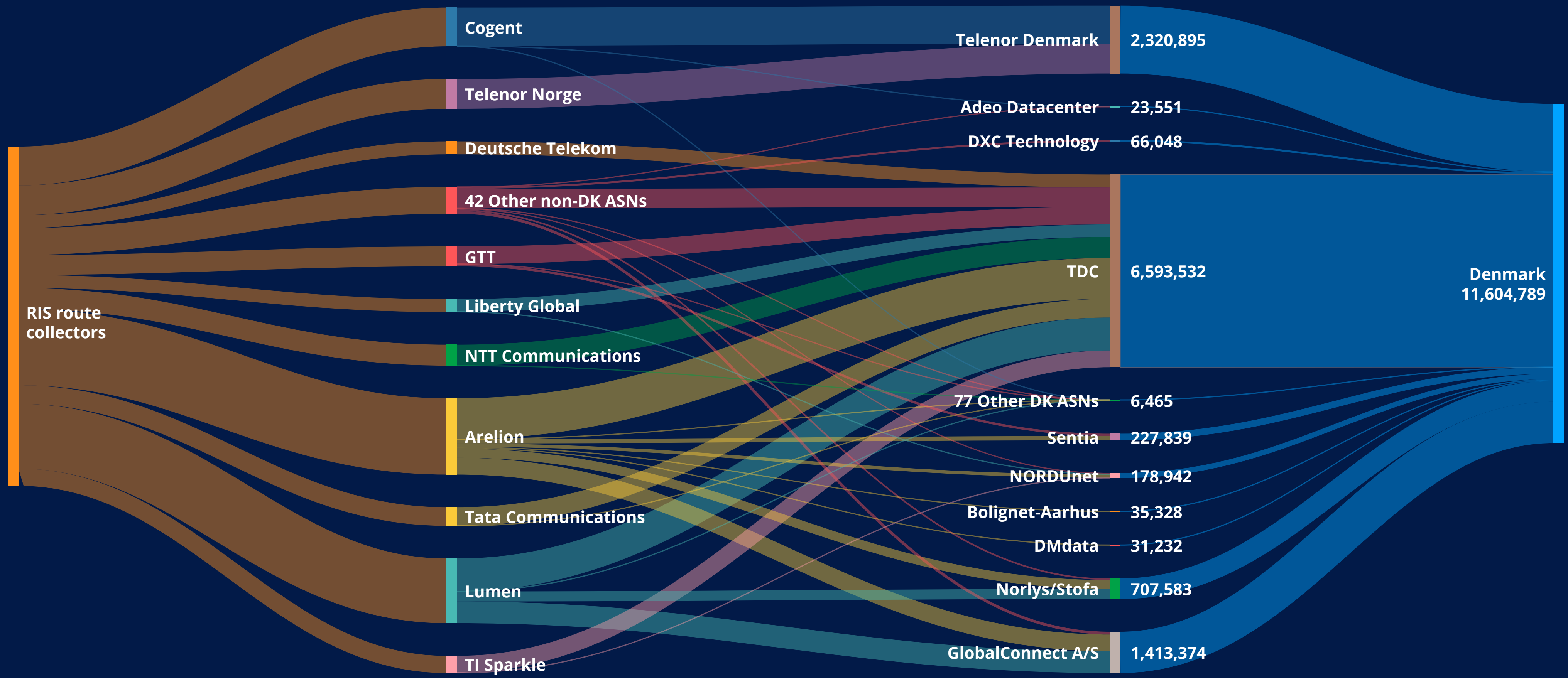
So while part of a network's international connectivity is taken care of via peering and medium-sized ISPs, the Tier 1 networks are instrumental in reaching all corners of the world. To assess which foreign ISPs are important in reaching a country, we again look to the RIPE NCC's Routing Information Service (RIS) to discover the AS paths that go through a Tier 1 network.[17] For each of these, we find the pair of networks on either side of the country's virtual border (i.e. the last network registered in a foreign country and the first network registered in the country of interest that the traffic passed through on its way from a Tier 1 network to its final destination).

The resulting figures are based on data that takes into account both the number of occurrences of each network pair, as well as the total size of the unique IP address space routed via each pair.

In the following figures, the organisations listed on the right are entry points to a country's IPv4 space. This includes both addresses held by the organisation itself as well as customers that operate their own networks. The numbers refer to the total number of IP addresses reached via this connection, and are therefore an indication of how many end users are served. As a result of multihoming, some IP networks may be reached via more than one entry point. The same is also true for the connections on the other end, between international and domestic networks. Only the top 10 transit providers and domestic providers are named; the rest are grouped into the category "other".

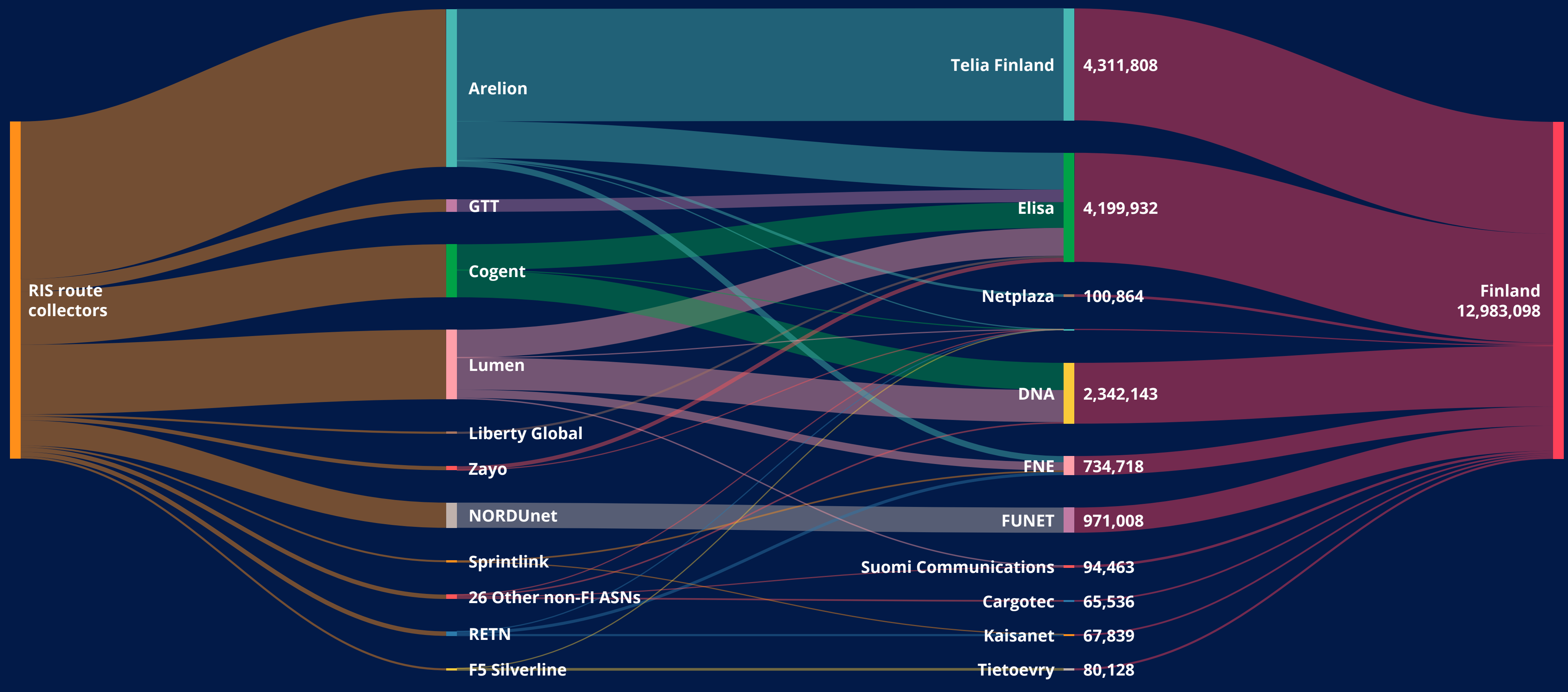
17 https://en.wikipedia.org/wiki/Tier_1_network#List_of_Tier_1_networks

Figure 15:
Denmark's international connectivity



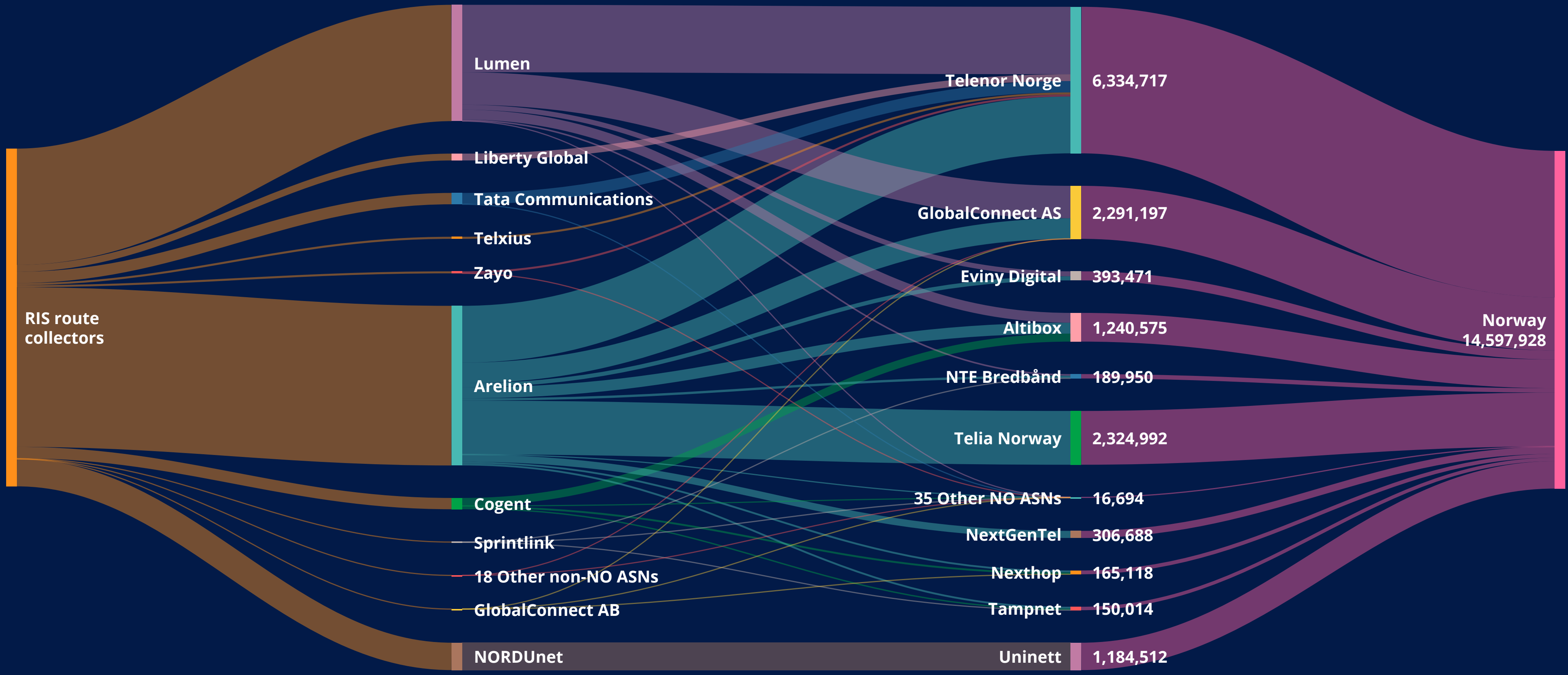
In Denmark, TDC provides connectivity to most users, both directly and indirectly. It receives transit from various ISPs, of which Arelion and Lumen are most commonly seen in RIS data. These two providers are also important for Norlys/Stofa and GlobalConnect. Telenor Denmark gets transit from Cogent but also through Telenor Norge. Compared to Sweden and Finland, NORDUnet serves a far smaller number of the IP addresses in Denmark; however, as the organisation is registered in the country, we can see here how Arelion, TI Sparkle and Liberty Global are among the main parties providing transit to the Nordics' educational networks.

Figure 16:
Finland's international connectivity



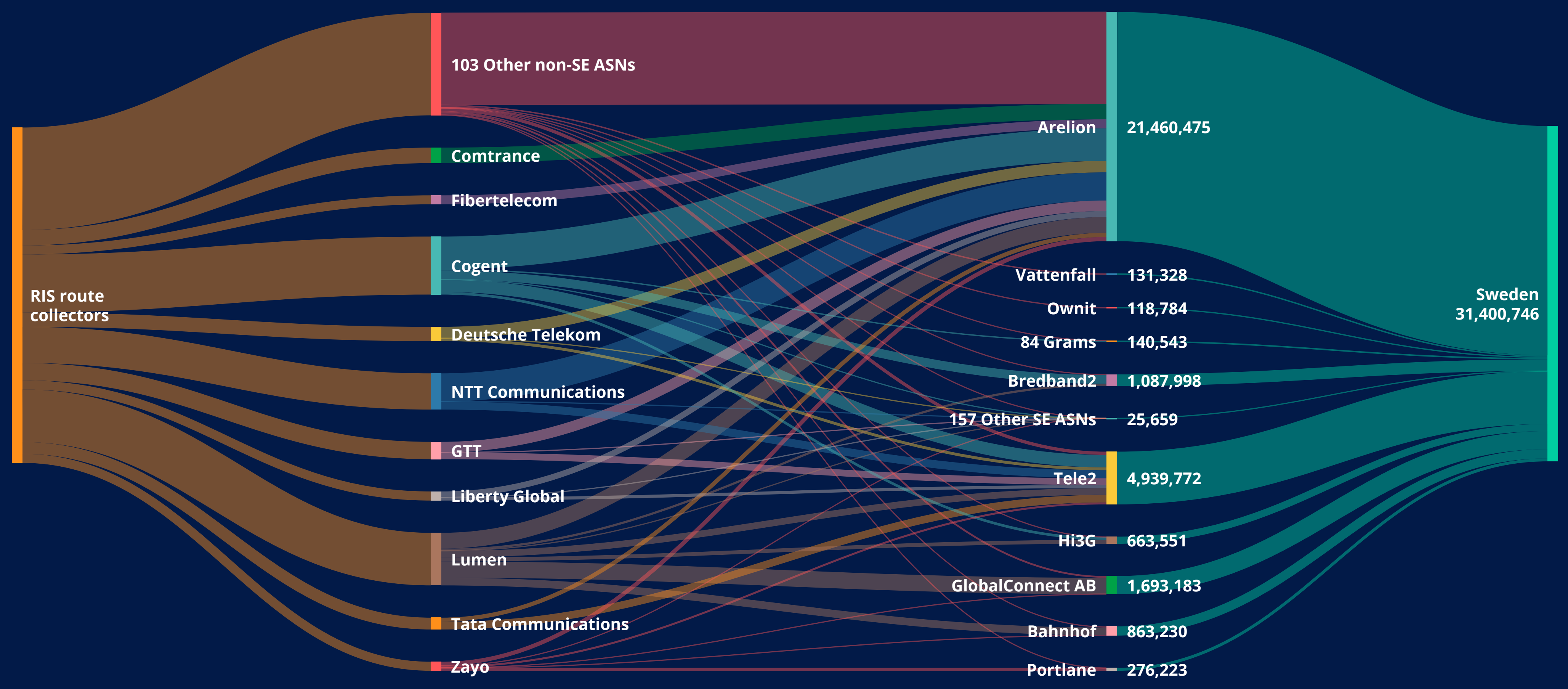
In Finland, we see how Telia Finland relies fully on Arelion (Telia Company's former, now independent, carrier division) for international transit. Similarly, and not unexpectedly, FUNET, which connects the research and education networks, has NORDUnet as its sole upstream. The other main providers – Elisa, DNA and FNE – display more diversified transit.

Figure 17:
Norway's international connectivity



In Norway, Lumen and Arelion are the dominant transit providers for Telenor Norge, GlobalConnect, Altibox and Eviny Digital. Cogent, Liberty Global and Tata Communications are observed less often. Not surprisingly, Telia Norway relies fully on Arelion (Telia's former carrier division). As in other Nordic countries, NORDUnet connects the local academic network, Uninett, to the rest of the Internet.

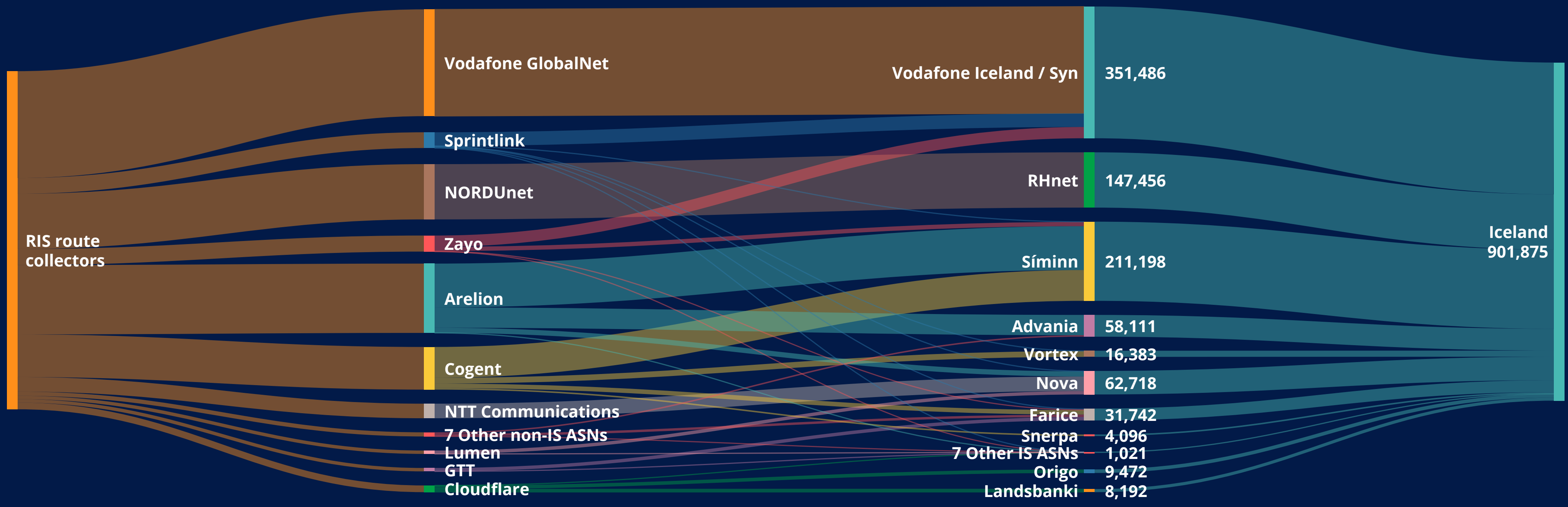
Figure 18:
Sweden's international connectivity



In Sweden, it's not surprising to see Arelion, a Tier 1 network, providing connectivity to the bulk of Sweden's IPv4 addresses – in particular, to the 2.6 million addresses held by Telenor Sverige. We can see how Arelion connects via peering with other Tier 1 networks like Cogent, NTT and Lumen. However, we also detect about 100 networks representing Arelion customers – ISPs that reach Swedish IPv4 space via transit agreements with Arelion.

At some distance from Arelion, Tele2, GlobalConnect AB, Bredband2, Bahnhof and Hi3G (Tre) are also instrumental in connecting Sweden to the international Internet.

Figure 19:
Iceland's international connectivity



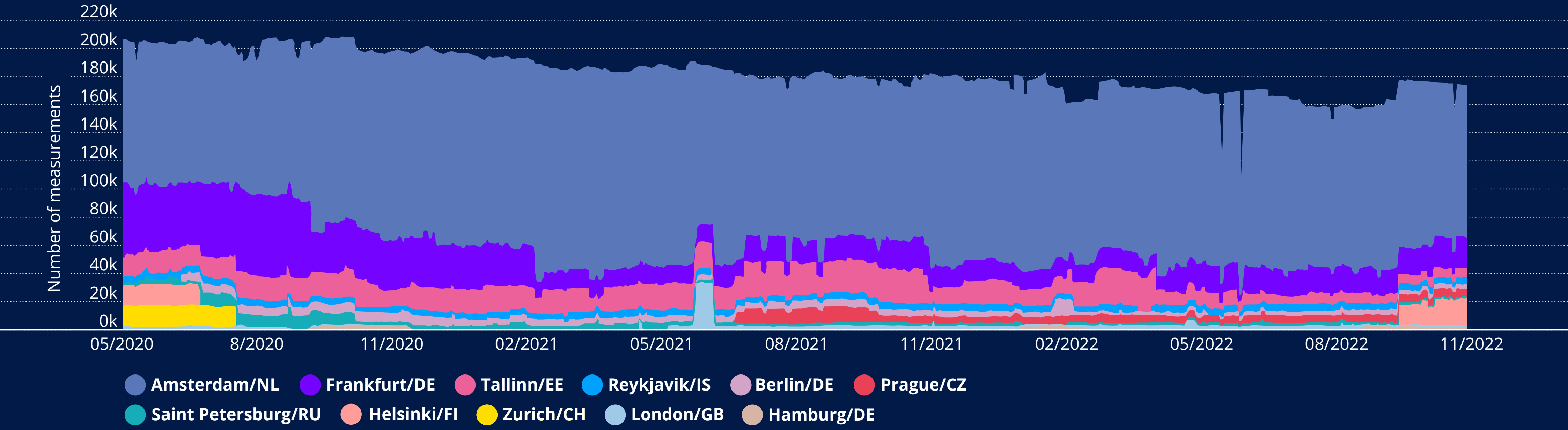
In Iceland, we see how the local Vodafone network (owned and operated by Syn) predominantly receives transit from Vodafone GlobalNet, but to some extent also from Sprintlink and Zayo. The education and research network, RHnet, relies 100% on NORDUnet, while Síminn, the privatised successor to the previously state-owned incumbent, receives transit from Arelion and Cogent.

In Greenland, the Faroe Islands and Åland, the situation is much simpler, as we saw in the domestic connectivity for these regions. In Greenland, Lumen is the sole upstream for Tusass. In the Faroe Islands, NEMA and Føroya Tele are the main providers, with NEMA relying on Vodafone Iceland as its upstream and Føroya Tele on Arelion, Cogent and TDC. In Åland, Ålcom's dominant upstream is Swedish Baffin Bay Networks, but it also has direct connections to Cogent and Sprintlink. Crosskey is reached via F5 Silverline, a DDoS protection service, and to a lesser extent via Finnish DNA. IP-Connect relies fully on the Swedish GlobalConnect AB.[18]

In general, the higher the number of different available paths we see into and out of a country, the better. This is because relying on a small number of dominant domestic providers to provide the vast majority of the connections into and out of a country creates the potential for bottlenecks and single points of failure, negatively impacting that country's Internet stability, regardless of how many upstream connections they have. In the five countries in the Nordic Region, we see a healthy level of interconnection overall, with most domestic providers receiving transit from more than one upstream provider. In the three autonomous regions, the situation is understandably simpler, as there are fewer domestic providers; however, the majority still have multiple upstream providers, providing a good level of redundancy – and therefore stability – to their international connectivity.

18 *The international connectivity graphs for the three autonomous regions are available online: https://labs.ripe.net/author/suzanne_taylor_muzzin/ripe-ncc-internet-country-report-the-nordic-region/*

Figure 20:
K-root locations reached from requests originating in the Nordic Region over time (IPv4)



Domain Name System, Traffic Paths and Routing Security

Reaching the Domain Name System

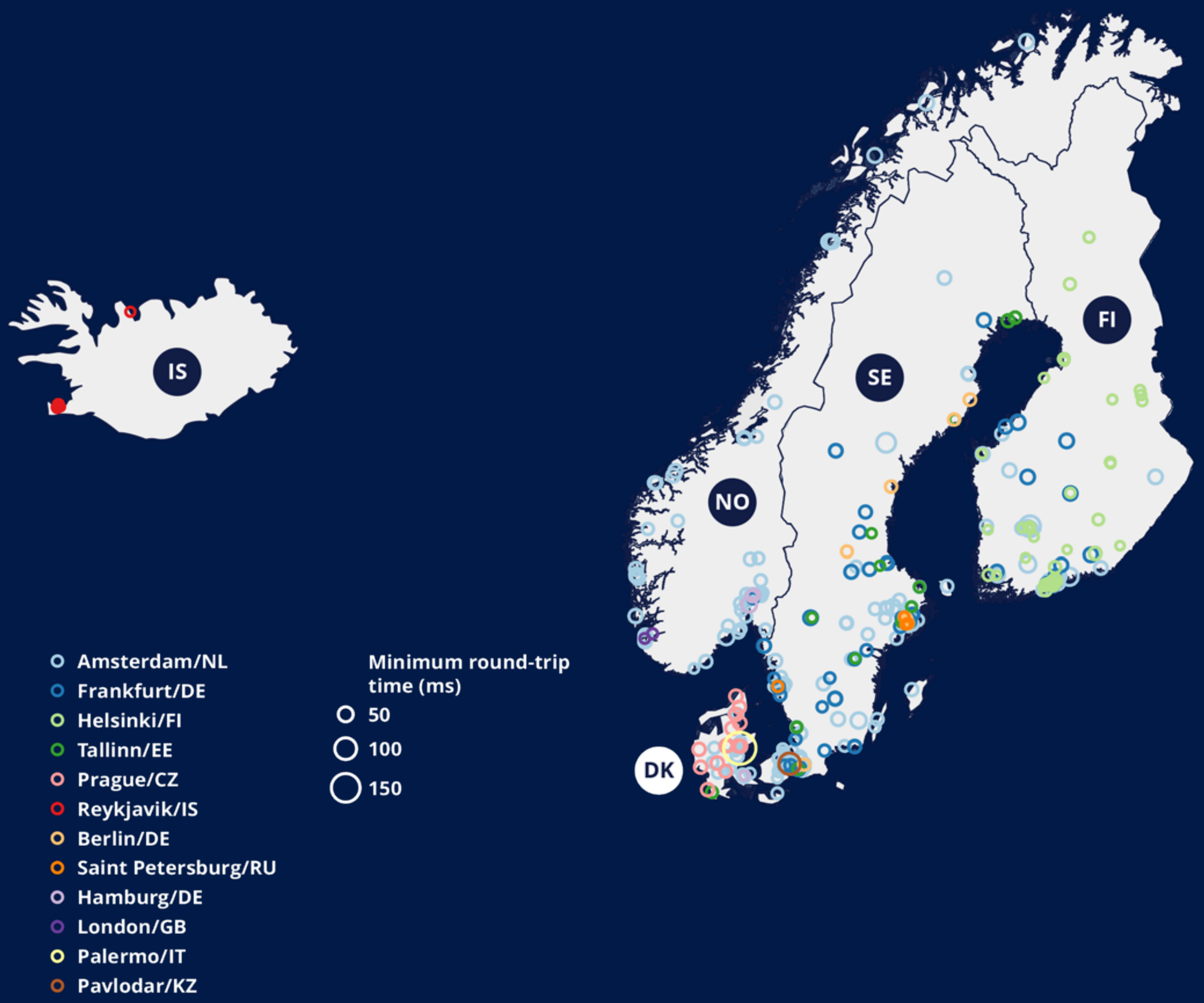
Turning now to investigate how traffic is routed to, from and within the Nordic Region, we first examine which local instances of K-root are queried from requests originating in the different countries. This gives us some insight into how the routing system considers the various options and decides which networks and locations will provide the best results. These measurements are based on the RIPE NCC's RIPE Atlas measurement platform, which employs a global network of probes to measure Internet connectivity and reachability (see the section on RIPE Atlas at the end of the report for more information about how to get involved).

K-root and DNS

K-root is one of the world's 13 root name servers that form the core of the Domain Name System (DNS), which translates human-readable URLs (such as https://www.ripe.net) into IP addresses. The RIPE NCC operates the K-root name server. A globally distributed constellation of these root name servers consists of local "instances" that are exact replicas. This set-up adds resiliency and results in faster response times for DNS clients and, ultimately, end users.

There are three K-root instances in the Nordic Region, in Iceland (Reykjavik), Greenland (Nuuk), and Finland (Helsinki). Unfortunately, there is only one RIPE Atlas probe in Greenland that was not functioning properly for these measurements, and no probes in the Faroe Islands, so we don't have data for those regions. As we can see in figure 20, most of the probes in the Nordic Region reached K-root instances in Amsterdam and Frankfurt, even though Helsinki and Tallinn are geographically closer for most probes. Interestingly, the Helsinki instance was not reached by the RIPE Atlas probes between late July 2020 and the end of August 2022, which illustrates how dynamic the anycast system is.

Figure 21:
K-root locations reached from vantage points in the Nordic Region



Border Gateway Protocol and Anycast

The K-root name server, like many other DNS servers, uses a technique called anycast whereby each individual instance of K-root is independently connected to the Internet via a local Internet exchange point or any number of upstream networks available at its location. Each instance communicates using the Border Gateway Protocol (BGP), which is designed to select the best path out of all the available options. Initially, the most important criterion here is path length, and the system will choose the path with the lowest number of intermediary networks. However, network operators can override the BGP decision-making process, often for reasons relating to costs or ownership. It is not uncommon for networks to prefer routes that may be longer but are less expensive due to peering arrangements via an Internet exchange point or a parent company.

We also looked into which K-root instances were queried by RIPE Atlas probes throughout the region on a given day, as shown in figure 21. Here we see that the K-root instance in Helsinki was exclusively reached by probes in Finland, and that about half of all probes in Finland reached this instance, with the remainder reaching Amsterdam and Frankfurt. All 13 of the probes in Iceland queried the Reykjavik K-root instance, while almost all of the probes in Norway reached the instance in Amsterdam. More than half of the probes in Sweden queried the instance in Amsterdam, with Frankfurt and Tallinn making up most of the remainder. An even larger majority of probes in Denmark also reached Amsterdam, with most of the remainder going to Prague. The one probe in Åland also reached the instance in Amsterdam. Although round-trip times to Amsterdam and Frankfurt are slightly longer than we see for Helsinki, they remain within acceptable limits.

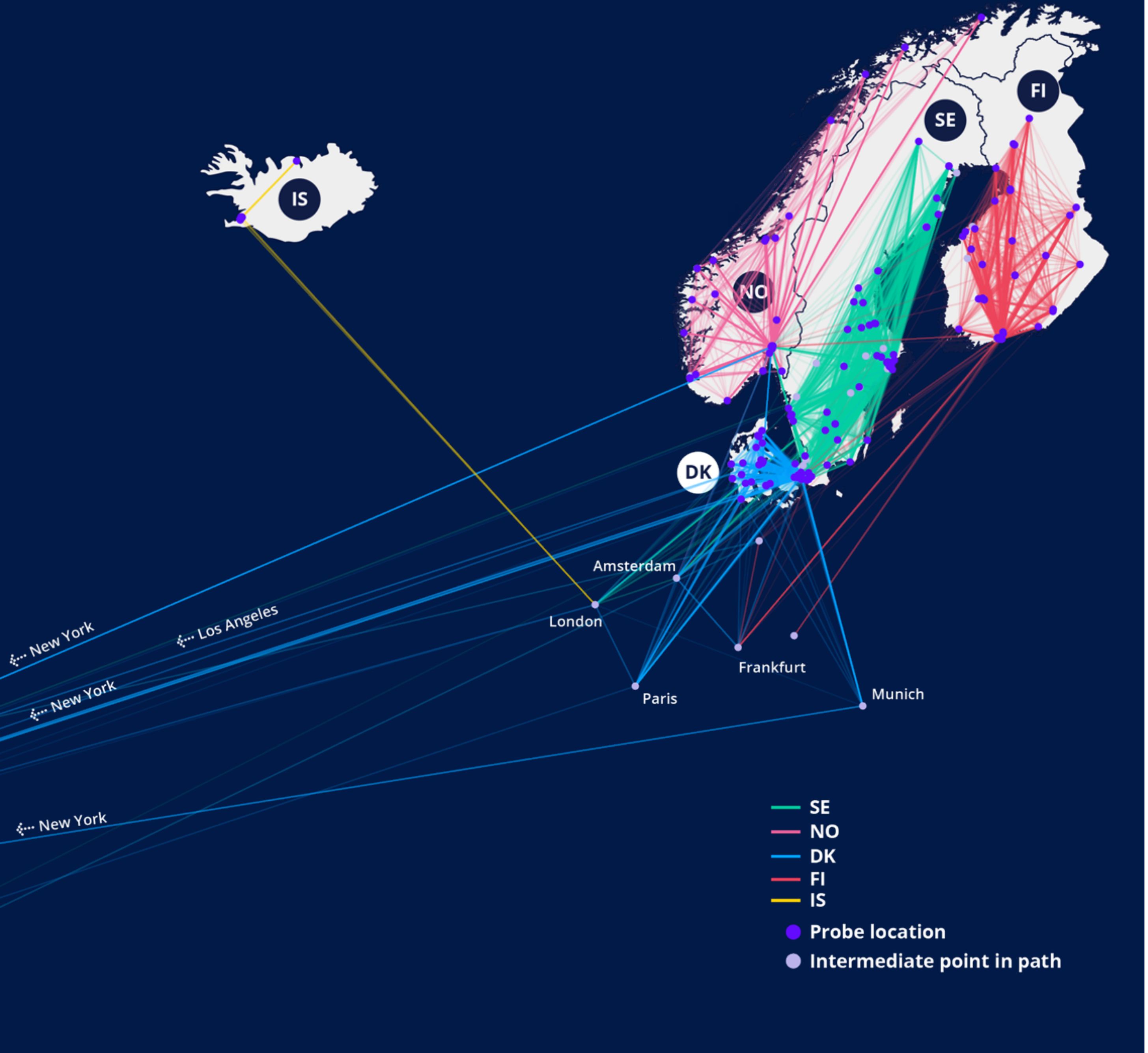
We also looked at which K-root instances were queried by probes within different networks in each of the countries (for those networks that host at least one RIPE Atlas probe). Generally, most networks have a preference for a particular K-root instance. Traditionally, the Border Gateway Protocol (BGP) decision-making process would ensure that once a particular path has been identified as being the best option, there is consistency across all the routers that are part of that particular network. Indeed, this is generally what we see in the Nordic Region, where most probes in a particular network end up querying the same root-server instance. One exception among the larger providers is the Tele2 network in Sweden, in which most probes queried the K-root instance in Frankfurt but some reached the instance in Amsterdam.

Also somewhat surprising is that all 24 probes in the Elisa network in Finland reached the K-root instance in Amsterdam rather than the instance in Helsinki. After investigating further, we saw several routes from Elisa's network pass through FICIX, the IXP in Helsinki which hosts the K-root instance. However, instead of querying the instance there, several of these routes then went through NORDUnet, which passed the packets to SURFnet (the Dutch NREN). In other cases, the packets were passed to another of Elisa's networks, which handed them over to Vodafone GlobalNet. In both of these cases, the query ended up at the K-root instance in Amsterdam. It appears that either the Elisa network does not know about the available K-root instance in Helsinki, or it simply prefers the routes via NORDUnet or its parent network.

We should note that these results, while considered generally representative, offer only a snapshot of measurements made on a single day in October 2022. Given BGP's dynamic nature, results can change constantly due to subtle changes in routing. It's also worth remembering that these results are for K-root only, and every DNS client will make its own decisions about which particular root name server to use. In cases where response times to K-root would be relatively slow, it's likely that clients would opt for faster alternatives among the other root name servers.

While some of the instances reached weren't the absolute closest in geographical terms, none were very far away and all resulted in fast response times. In general, we can say that K-root access in the Nordic Region appears to be very well optimised, especially in comparison to what we've seen in other countries we've looked at throughout the RIPE NCC service region.

Figure 22:
Paths between origin and destination in the same country for the Nordic Region (IPv4)



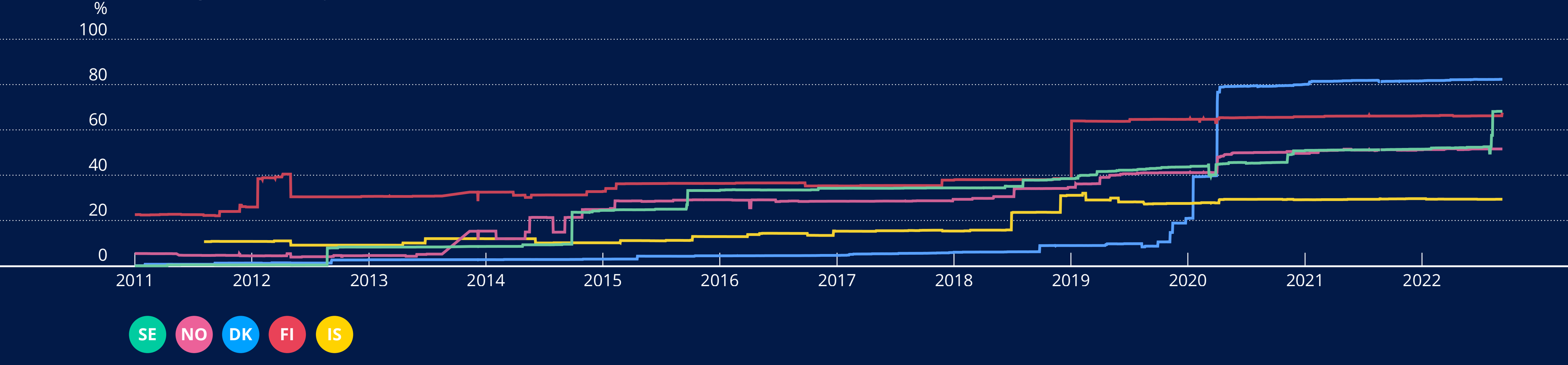
Regional Traffic Exchange

Again using data from the RIPE Atlas measurement network, we can investigate how some of the networks in the five countries exchange traffic with each other, and get some indication of where those exchanges take place. For this experiment, we performed traceroutes between a subset of the RIPE Atlas probes in each country. Figure 22 shows the location of the probes (indicated by the purple dots) and the paths followed by the traceroutes (indicated by lines of a different colour for each country).

In Norway, virtually all paths stay in the country – we do not detect foreign locations. Most paths also stay local in Finland, although a few detour via Denmark, Norway and major IXPs in Europe. In Iceland, 12 out of the 13 connected probes are located in the Reykjavik area, so there are far fewer paths to follow outside of the city; however, some of the paths show a detour via London. Lastly, in Sweden and especially in Denmark, we see a notable fraction of the packets travel all the way across the Atlantic – in some cases even as far as Los Angeles and Seattle – before returning to the Nordic Region. The latter situation is far from optimal, and suggests that local IXPs are perhaps not being used as much as they could be. We heard from one information source that, in the case of Finland at least, IXPs struggle with a lack of mid-sized ISPs, as smaller ISPs don't have a large number of peers and the larger ones prefer to exchange traffic over private network interconnects (PNIs) rather than at local IXPs.

Routing packets a long way to an exchange point, only to have them travel back to a destination close to the origin, is referred to as "tromboning". The farther a path extends from the origin/destination, the more inefficient the path is. In addition, these detours generally increase costs for the network operator and, more importantly, the additional distance travelled unnecessarily increases the risk of disruptions. It also creates additional dependencies on external providers, which could have regulatory implications.

Figure 23:
IPv4 address space covered by ROAs over time



It's worth noting, however, that the impact of the longer routes we see here, which would result in longer response times, is impossible to ascertain directly because it depends on how much traffic is actually flowing across them, which is not something we can measure. Instead, we can only discover which route traffic would take if a device in one network wanted to reach a device in another network within each country.

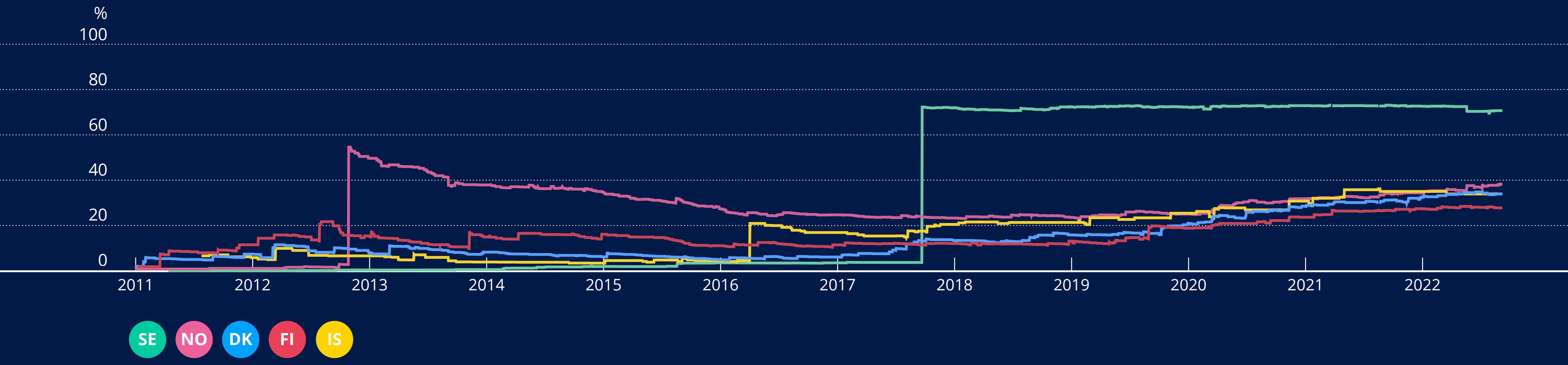
Routing Security

Beyond looking into the different routes available to traffic originating in the region, we can also investigate routing security in the region by looking at how effectively IP address space is protected by Resource Public Key Infrastructure (RPKI), a security framework that helps network operators make more secure routing decisions.

RPKI uses digital certificates called ROAs (Route Origin Authorisations) to prove a resource holder's right to announce IP prefixes (i.e. certifying that the resources were allocated or assigned to them by a Regional Internet Registry). This helps avoid the most common routing error on the Internet: the accidental announcement of an IP prefix by someone who is not the legitimate holder of that address space. Using the RIPE NCC's RIPEstat tool – which provides all available information about IP address space, ASNs, and related information for hostnames and countries – we can see what percentage of a country's IPv4 and IPv6 address space is covered by ROAs.

In looking at the IPv4 space in the five countries in the region, we see that Denmark made enormous progress in the first months of 2020, when coverage increased from 20% to 80% of the country's total IPv4 address space. Closer inspection tells us this was triggered by both Telenor and TDC creating ROAs for their prefixes in February and April, respectively. Similarly, the sharp rise in Finland in January 2019 is the result of Elisa creating ROAs for all its address blocks. The Finnish regulator, Traficom, encourages ISPs to create ROAs for their address space, which may help explain Finland's strong RPKI uptake. The increase in Sweden's coverage at the end of August 2022 was due to Tele2 adding ROAs to more of its announced IPv4 prefixes.

Figure 24:
IPv6 address space covered by ROAs over time



When it comes to IPv6, we consistently see lower rates of RPKI uptake. This is a result of the fact that less of the IPv6 that's been allocated is actually in use and being routed, as explained earlier. However, we see some reasonably high coverage rates in the Nordic Region. Norway peaked at above 50% coverage in November 2012 as Telenor Norge created a ROA for its /24 allocation. In subsequent years, the percentage dropped as more ISPs received IPv6 addresses but did not create ROAs, but it has been on the rise again since 2020, as more ISPs create ROAs for prefixes that were allocated in previous years. In Iceland, coverage improved in early May 2016, when four different LIRs created ROAs for their allocations. In Sweden, Telia's /20 dominates the IPv6 statistics. The percentage of space covered had been hovering around 72% after the ROA for this block was created in October 2017. In June 2022, we see a small drop of about 3% as IPv6 blocks obtained by Internet Vikings International are not covered by ROAs but do increase the total IPv6 space registered in Sweden.

With few operators, and relatively little IP address space, small changes in Greenland and the Faroe Islands have a big impact on coverage.[19] In November 2014, the two LIRs in the Faroe Islands – Føroya Tele and Kall (now NEMA) – both created ROAs for their allocations, thus achieving 100% coverage. This has since dropped with the arrival of two more LIRs. For IPv6, only Føroya Tele created a ROA for its /32 allocation in 2014, leading to 50% coverage. In subsequent years, this dropped when Electron and Kringvarp Føroya received their IPv6 /29 allocations but did not create ROAs. Finally, in September 2020, we see a last drop in coverage when Føroya Tele's /32 allocation was extended to a /29, thereby adding more overall IPv6 space without creating additional ROAs. (Note that we don't have reliable data for Åland due to complications with the country code used for this region's address space.)

19 Graphs for these two regions are available online: https://labs.ripe.net/author/suzanne_taylor_muzzin/ripe-ncc-internet-country-report-the-nordic-region/

Conclusion

With relatively healthy market competition, fast Internet speeds, good interconnection and some of the highest levels of Internet penetration in the world, the Nordic Region benefits from a very robust Internet landscape. Its early adoption of the Internet and extensive physical infrastructure, coupled with both private-sector and government investment, have resulted in a mature, developed Internet ecosystem. Despite this, broadband and mobile prices are very high throughout most of the region, which is not unexpected given the large expanses of remote, sparsely populated areas in this part of the world. Ambitious broadband strategies and continued investment in infrastructure mean this region is well positioned to maintain its standing in the coming years.

The five countries in the Nordic Region hold an extremely large amount of IPv4 address space given their populations. This likely contributes to the below-average IPv6 capability rates we see in this region, with the exception of Finland (and possibly Åland), despite large amounts of IPv6 being held. Although this region may not yet be feeling the same pressure when it comes to IPv4 scarcity and increasing prices on the secondary market that much of the rest of the world is experiencing in the wake of IPv4 run-out, it will still be important for the Nordic Region to improve its IPv6 capability in order to accommodate long-term growth as well as new and emerging technologies such as 5G, the Internet of Things, smart cities and more. It will be important for governments, IXPs, NOGs, network operators and decision makers to all do their part to deploy IPv6 more widely.

The networks in each of the five countries display a high level of interconnectivity, and this redundancy provides the overall system with resiliency. We also see a good amount of diversity in upstream providers, ensuring resilient connections to the rest of the global Internet, although there are a couple of examples of large domestic providers with a single upstream provider. In these cases, establishing connections to additional upstream providers would help prevent potential disruptions by eliminating bottlenecks or single points of failure.

Routing in the region is fairly optimised, although we do see some paths for local traffic extending to very distant locations across the Atlantic, suggesting that networks could make more use of the region's IXPs rather than exchanging traffic at more distant exchange points. Doing so would further reduce response times and decrease dependency on foreign infrastructure.

It's worth noting that all of the observations in this report are based on active paths, and we cannot know what "hidden" world of backups exists that would automatically take over in the case of any disruptions. Whatever redundancy does exist would provide the system with even more resiliency.

About the RIPE NCC

The RIPE NCC serves as the Regional Internet Registry for Europe, the Middle East and parts of Central Asia. As such, we allocate and register blocks of Internet number resources to Internet service providers and other organisations.

The RIPE NCC is a not-for-profit organisation that works to support the open RIPE community and the development of the Internet in general.

Data Sources

The information presented in this report and the analysis provided are drawn from several key resources:

RIPE Registry

This is the record of all Internet number resources (IP addresses and AS Numbers) and resource holders that the RIPE NCC has registered. The public-facing record of this information is contained in the RIPE Database, which can be accessed from https://www.ripe.net

RIPE Atlas

RIPE Atlas is the RIPE NCC's main Internet measurement platform. It is a global network of thousands of probes that actively measure Internet connectivity. Anyone can access this data via Internet traffic maps, streaming data visualisations, and an API. RIPE Atlas users can also perform customised measurements to gain valuable information about their own networks. https://atlas.ripe.net

Routing Information Service (RIS)

The Routing Information Service (RIS) has been collecting and storing Internet routing data from locations around the globe since 2001.
https://www.ripe.net/ris

The data obtained through RIPE Atlas and RIS is the foundation for many of the tools that we offer. We are always looking to improve our measurement platforms by expanding the diversity of the networks they cover and would like to have RIPE Atlas probes or RIS peers in networks that aren't already included. Please see the RIPE Atlas and RIS websites to learn more.

Other RIPE NCC Tools and Services

- RIPEstat: https://stat.ripe.net/
- RIPE IPmap: https://ipmap.ripe.net/
- K-root: https://www.ripe.net/analyse/dns/k-root

External Data Sources

We would like to thank the following person for providing additional background information included in this report around the Internet landscape in Finland:

- Aleksi Suhonen
  Internetworking Consulting