RIPE NCC
RIPE NETWORK COORDINATION CENTRE

RIPE NCC

Internet Country Report: Türkiye

November 2023

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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 Türkiye. We offer an analysis of the country's market landscape and state of development, examine Internet routing within the country, take a close look at its access to the global Domain Name System, and investigate connections between the major networks within the 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 Türkiye, 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 12th such country report 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.[1]

Highlights

- The market in Türkiye is heavily dominated by the local incumbent, making widespread competition somewhat difficult
- Despite only small amounts of IPv4 in the country, IPv6 capability is extremely low
- The influence of a small number of large providers is evident in the country's domestic connectivity, although international connectivity shows a good level of diversity
- Local traffic exchange could likely be improved if local Internet exchange points were more heavily used
- RPKI uptake, which is related to routing security, is extremely high in the region

1 *All RIPE NCC Internet Country Reports can be found at https://labs.ripe.net/country-reports*

The Market and Opportunity for Growth in Türkiye

The Market Landscape

At the crossroads of Europe and Asia, Türkiye holds a unique position within the RIPE NCC's service region. Its Internet landscape has ties to European countries, including two submarine cable links to Cyprus owned by the country's incumbent telco, Türk Telekom, and other cables linking it to Bulgaria and Greece,[2] while its Internet providers offer services extending to Europe, the Middle East, the Caucasus and Asia.

The major Internet service providers (ISPs) in the country offer both fixed broadband and mobile services. Aside from Türk Telekom, which offers fixed broadband as TTNET and mobile services under the TT Mobil brand, the other major providers include Turkcell, which operates its fixed division as Turkcell Superonline, and Vodafone Turkey, which operates its fixed division as Vodafone Net. TTNET is the largest fixed services provider, followed by Turkcell Superonline and then Vodafone Net,[3] while Turkcell is the mobile leader, with the remaining market split equally by TT Mobil and Vodafone Turkey.[4] In terms of mobile deployment, the country has not yet transitioned to 5G, although some experimental testing has started to take place in major cities.

Despite having liberalised the market in the late 1990s, Türkiye's regulatory body has been criticised for its inability to promote competition among Internet and mobile service providers. According to the European Commission's 2022 Türkiye Report, "The lack of financial and administrative independence of the regulatory authorities remains a concern. More transparency in spending and more allocation for improving a competitive and consumer friendly market is needed to ensure relevant competitive safeguards...Lack of sufficient competition in the broadband market remains a concern."[5]

As a result, much of the fibre infrastructure is still owned by Türk Telekom (308,000 km compared to other operators' 89,000 km as of 2020), making it difficult for new entrants to gain a foothold as they are forced to lease connectivity rather than being able to build their own infrastructure.[6] Despite this, a few competitors have managed to gain subscribers in recent years, including TurkNet and Millenicom, and approximately 10% of the market is now made up of independent operators. Several smaller providers also offer services in individual cities or on an even more local level.

Internet use in Türkiye continues to increase, with 83% of individuals using the Internet and 94% of households having access to the Internet at home, according to the latest ITU digital development figures.[7] In terms of Internet speeds, Türkiye ranks 111th globally in fixed broadband speeds and 69th in mobile speeds.[8]

The country benefits from reasonable costs for fixed and mobile broadband services. Fixed costs amount to 1.29% of GNI (gross national income), which is comparable to Spain, France, the UK, Poland and neighbours Bulgaria and Greece, yet is nearly twice as expensive as in Russia. Mobile broadband costs are less expensive, at 0.65% of GNI, comparable to Bulgaria, Greece and Russia, yet still two to three times as expensive as in much of Western Europe. However, both fixed and mobile broadband costs are well within the range of the affordability targets according to the ITU.[9]

The regulator, (Information and Communication Technologies Authority, BTK), along with the relevant government ministry, have been pushing for ISPs to extend their services to rural areas in the country; however, after the earthquake in February 2023, the focus has shifted from universal access to disaster management.

RIPE NCC Members and Local Internet Registries

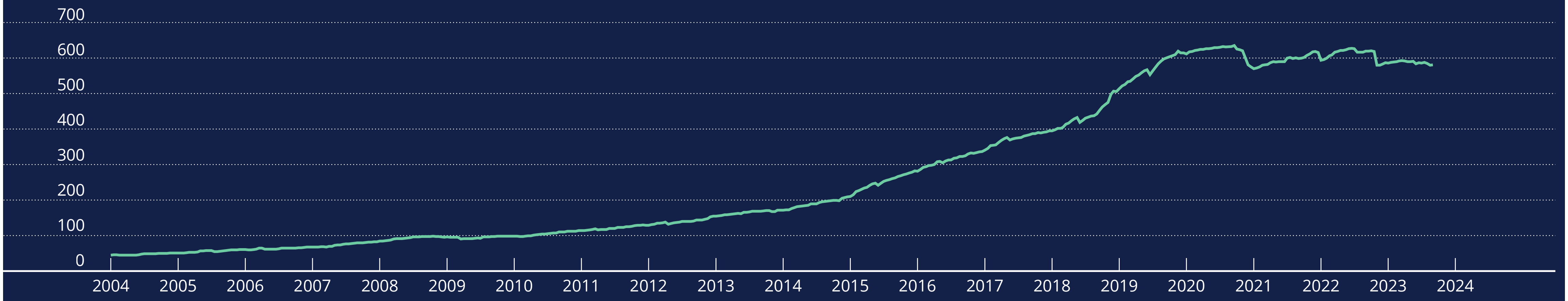
As the Regional Internet Registry for Europe, the Middle East and parts of Central Asia, the RIPE NCC can track the development of the local Internet over time by looking at the growth in the number of RIPE NCC members. RIPE NCC members include Internet service providers, content hosting providers, government agencies, academic institutions and other organisations that run their own networks in the RIPE NCC service region. The RIPE NCC distributes Internet address space to these members, which act as Local Internet Registries (LIRs) that may further assign IP addresses to their own end users.

Number of Providers and Other Organisations Running Their Own Networks

In general, a higher number of LIRs often signals a more diversified market, with a larger number of service

2 https://www.submarinecablemap.com/
3 https://www.hurriyetdailynews.com/telecom-companies-revenues-up-45-percent-184977
4 https://www.commsupdate.com/articles/2022/11/16/vodafone-turkey-and-tt-record-over-1m-mobile-net-adds-each-in-jan-sep-5g-tender-expected-soon/
5 https://neighbourhood-enlargement.ec.europa.eu/system/files/2022-10/T%C3%BCrkiye%20Report%202022.pdf
6 https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Events/2020/5G_EUR_CIS/5G_Turkey-final.pdf
7 https://www.itu.int/en/ITU-D/Statistics/Dashboards/Pages/Digital-Development.aspx
8 https://www.speedtest.net/global-index
9 itu.int/en/ITU-D/Statistics/Dashboards/Pages/IPB.aspx

Figure 1:
Number of Local Internet Registries over time



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. As a result, an increase in the number of LIRs doesn't necessarily translate into an increase in the number of Internet access providers (although 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).

As we can see from figure 1, the number of LIRs in Türkiye rose steadily between 2004 and 2014 before increasing at an even faster rate until 2020, when the number declined slightly and has remained at about the same level since. The sudden drops towards the end of 2020 and 2022 are both the result of additional LIR accounts closing; the actual number of members that closed was much smaller. The closure of additional LIR accounts likely corresponds to the RIPE NCC allocating the last of its IPv4 at the end of 2019, after which time only small amounts of recovered space became available via a waiting list.[10]

Network Growth and Diversity

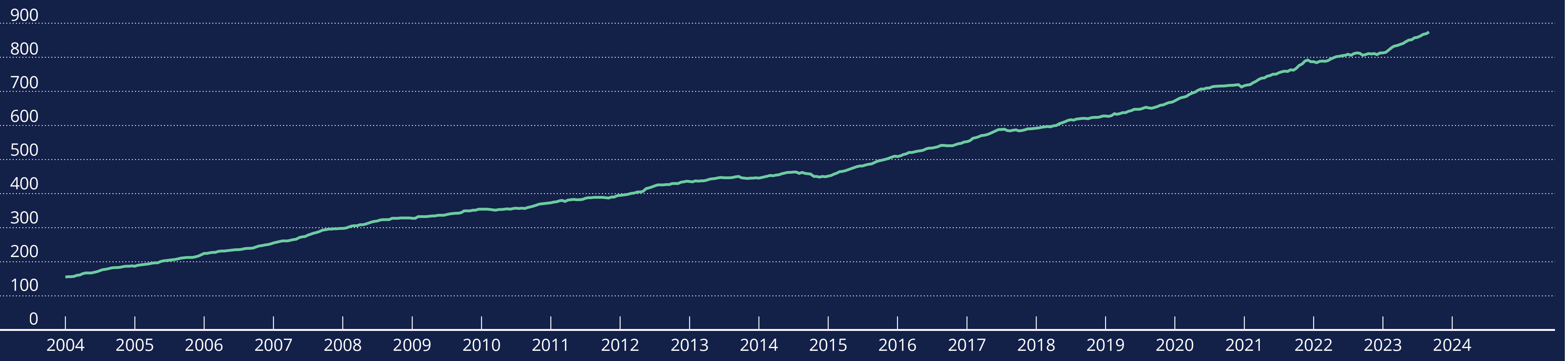
In general, a larger number of LIRs corresponds to a larger number of independently operated networks called Autonomous Systems, each of which is represented by an Autonomous System Number, or ASN.

Autonomous Systems

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 Autonomous Systems on the Internet today, each represented by a unique Autonomous System Number (ASN). 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.

10 https://www.ripe.net/publications/news/about-ripe-ncc-and-ripe/the-ripe-ncc-has-run-out-of-ipv4-addresses

Figure 2:
Number of networks over time



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 resilience.

In Türkiye, we see a steady rate of growth in the number of networks as the country's Internet landscape has grown. Comparing Türkiye to two other countries of similar population, there are slightly more networks by population compared to Iran and less than a third as many as we find in Germany. The latter, however, is an exceptional case, with a particularly robust and well-established Internet market. The continued growth we see in Türkiye is representative of a market that is continuing to evolve and increasing its potential for interconnectivity.

IPv4 in Türkiye

Until 2012, RIPE NCC members could receive larger blocks 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 and 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

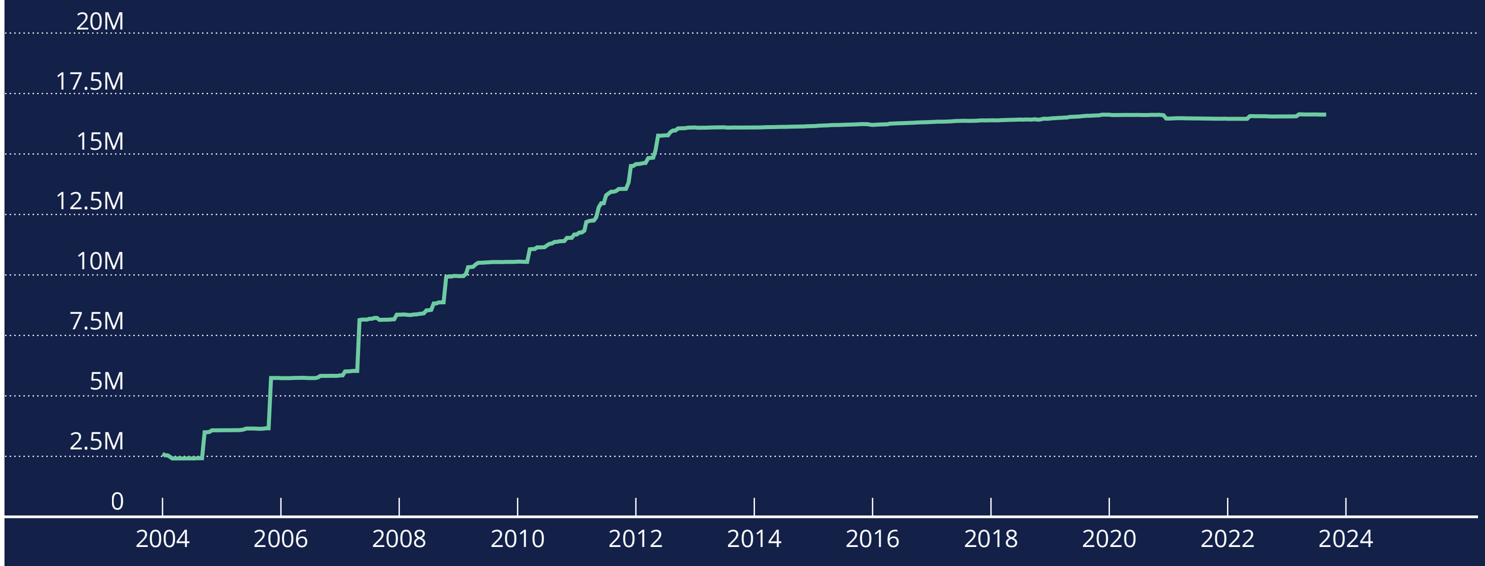
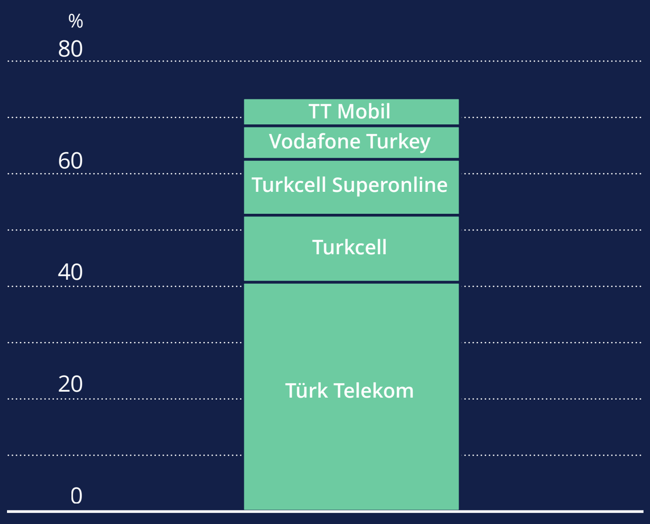


Figure 4:
Top IPv4 holders



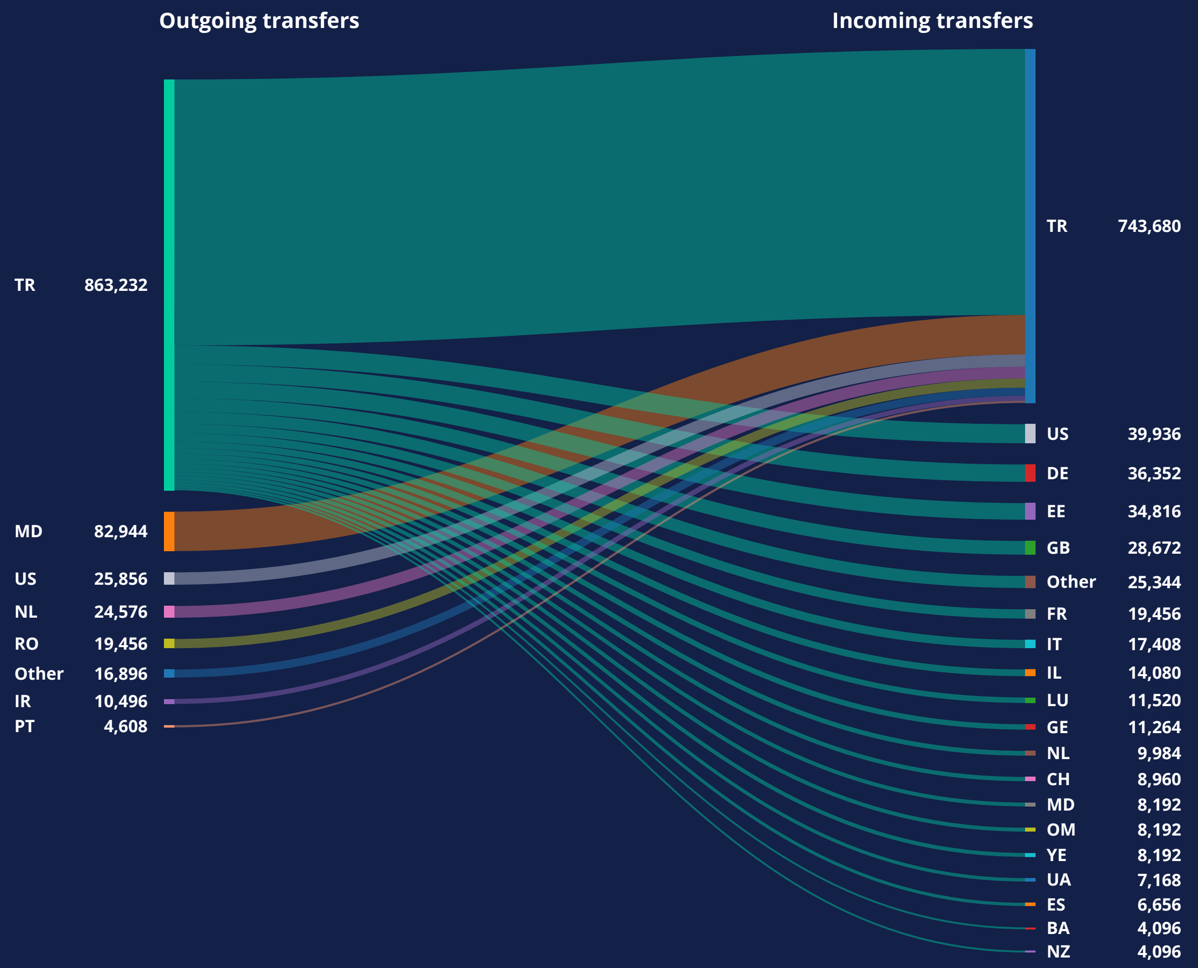
The change in policy in 2012 is strikingly evident in figure 3, where we see significant gains in the amount of IPv4 acquired until a sudden plateau in 2012, with very few gains since. The country currently has about 0.2 IPv4 addresses per capita. We see similar IPv4 per capita rates in some of the countries in the Middle East, including Bahrain, Oman, Qatar and Saudi Arabia. Türkiye has much more IPv4 per capita than the countries we looked at in Central Asia, yet at least two to three times less than we see across most of Europe. Generally, the amount of IPv4 corresponds closely to the history of the Internet's development within a country and how early on different providers began offering commercial services.

In figure 4, we can see the top five IPv4 holders in the country, all of which are among the largest providers of fixed and mobile services to end users. Türk Telekom's dominant position is obvious here; it holds more IPv4 address space than the next six companies combined. This is a fairly high amount of consolidation compared to what we've seen in previous country reports. While it's not unusual to see the dominant provider holding upwards of 40% of the country's address space, generally the next few companies hold greater amounts than what we see in Türkiye.

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.

Figure 5:
IPv4 transfers within, into and out of Türkiye since November 2012



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 Türkiye since the market became active. Note that this figure does not include resources that were obviously transferred as the result of mergers or acquisitions, or between related companies. In the category "Other", we also aggregate countries from or to which less than a /20 of IPv4 space (4,096 addresses) was transferred.

We can see that a large proportion of the transfers, comprising 558,848 addresses, were domestic transfers, in which addresses are transferred between two different entities within the same country. Despite its relatively low amount of IPv4 per capita, Türkiye has exported much more IPv4 address space out of the country than it imported from abroad: 304,384 addresses exported compared to 184,832 imported.

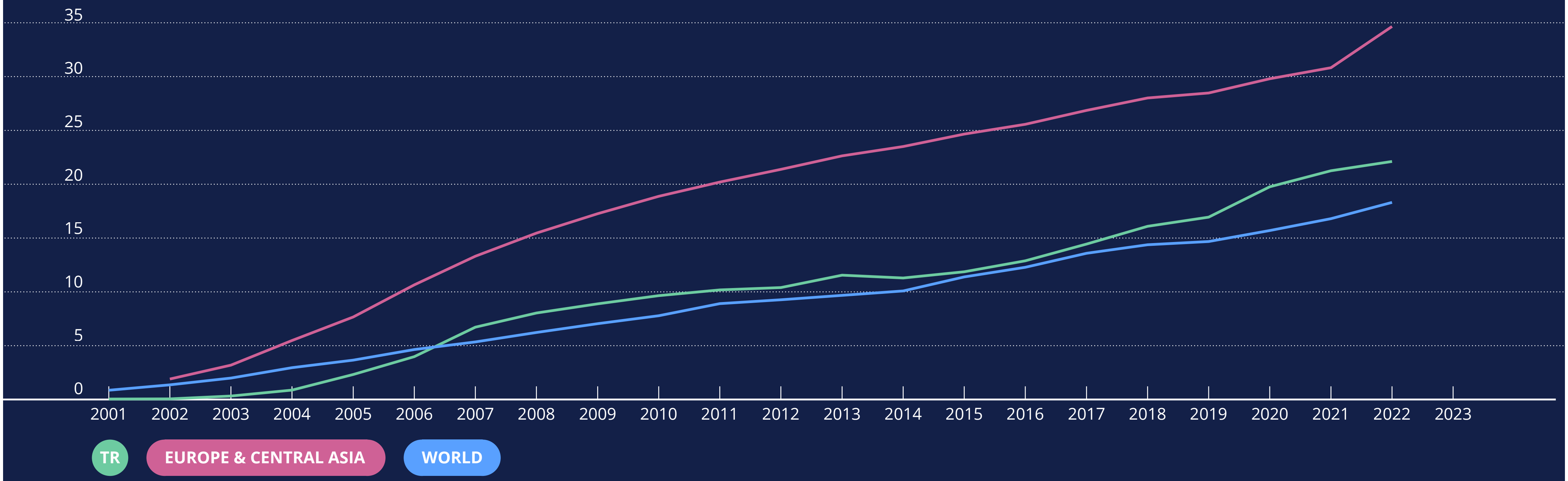
Looking at which organisations are responsible for the largest transfers, the top five organisations that were the biggest net importers of IPv4 address space via the secondary market, and the number of addresses imported, include:

Turkcell Superonline	119,552
Alkim Basin Yayin Iletisim	81,920
Bilintel	67,584
Vodafone Net	40,960
Geo Teknoloji	34,560

The top five organisations that were the biggest net exporters of IPv4 address space via the secondary market, and the number of addresses exported, include:

TR.NET	122,880
Bilintel	67,584
Profilo Telekom	65,536
Sim Net	40,960
Premier DC	34,560

Figure 6:
Fixed broadband subscriptions per 100 people over time



Source: World Bank

It's interesting to note that Bilintel, a hosting provider, appears in the top importers and exporters. It received a /16 of IPv4 space (amounting to 65,536 addresses) via a transfer in 2016. When the two-year holding period for transferred IPv4 space expired, it transferred these resources to Turkcell Superonline in two transactions, six months apart.

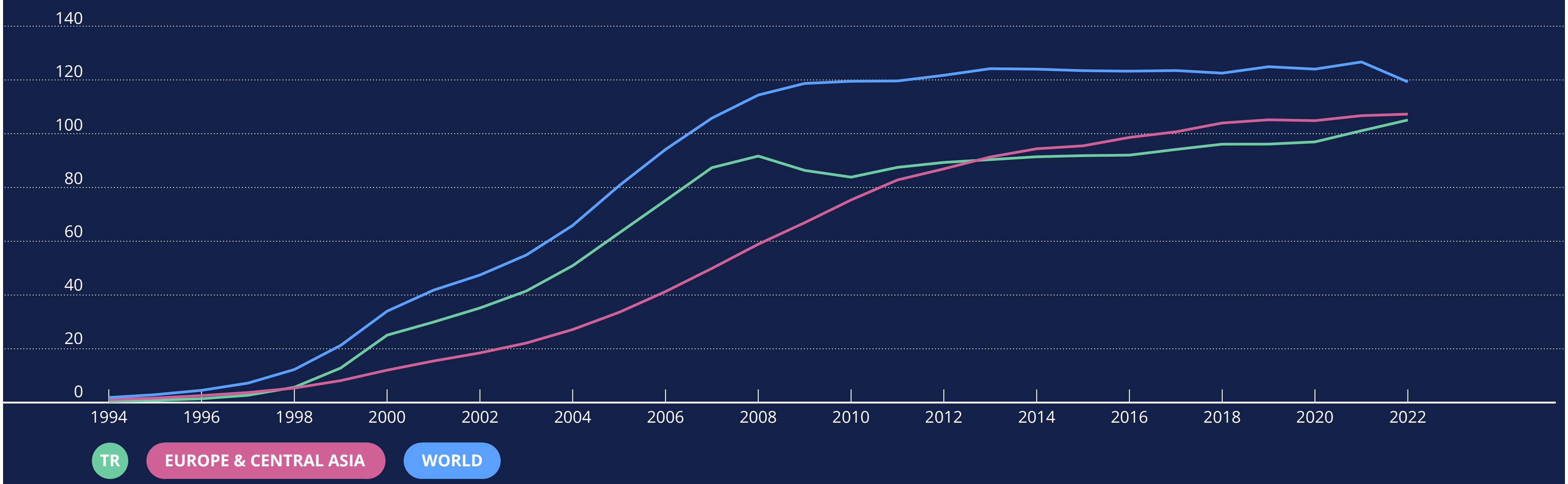
Internet Penetration and Potential for Future Growth

Internet penetration has continued to increase in Türkiye in recent years. The 94% of households with Internet access has increased from 88% just four years ago, while Internet use by individuals between the ages of 16-74 years increased from 75% in 2019 to 83% in 2021.[11] In looking at the number of fixed broadband connections per 100 people, we see that Türkiye overtook the world average in 2006 and remained slightly above for some time before making bigger gains around 2019; however, it remains well below the rate for Europe and Central Asia. (Note that fixed broadband connections are generally shared among several people in the same household, and the percentages we see in figure 6 will therefore never approach 100%.)

According to the OECD, the fixed broadband penetration rate was 25.2% in the second half of 2021, which was still significantly below the OECD average of 33.8%.[12]

11 https://neighbourhood-enlargement.ec.europa.eu/system/files/2022-10/T%C3%BCrkiye%20Report%202022.pdf
12 Ibid.

Figure 7:
Mobile subscriptions per 100 people over time



Source: World Bank

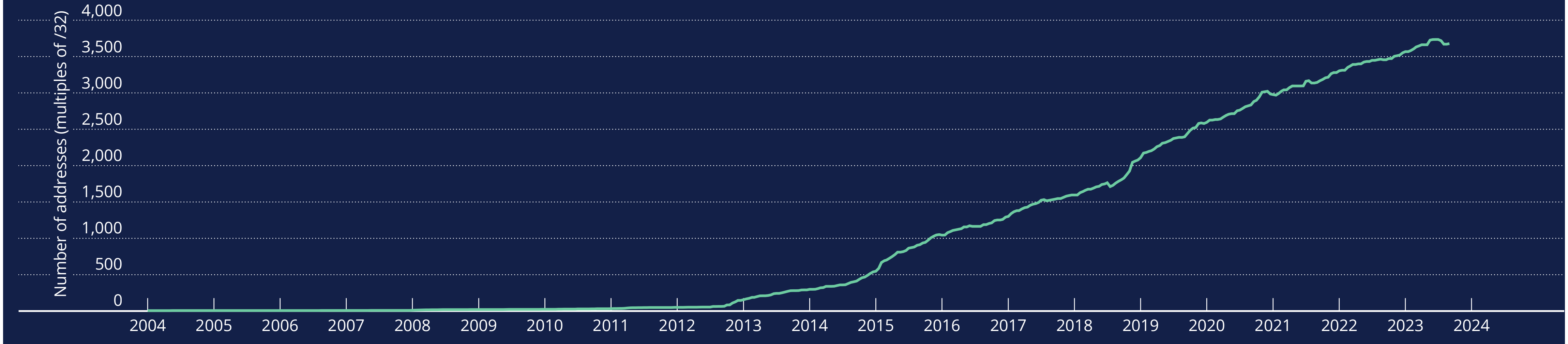
When it comes to mobile subscriptions, Türkiye was increasing at a similar rate to Europe and Central Asia, but both plateaued around 2008 with Türkiye at a significantly lower figure overall. At 106 subscriptions per 100 people as of 2022, Türkiye's rate was slightly below the world average of 108, but has been increasing at a faster rate again since 2020. Despite Türkiye's small gains over the past 15 years, there is still room for growth in the mobile market, and mobile broadband penetration has increased slightly in recent years, to 86.4% in the second half of 2021; the OECD average was 121.4% for the same period,[13] which is more in line with what we've seen in many of the other countries we've covered in our reports, including in Europe and the Middle East.

In the wake of IPv4 run-out and the growing cost of IPv4 on the secondary market, newly established providers are going to find it difficult to obtain the resources they need to enter the market and maintain healthy competition. 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.

Additional address space will also be 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.

13 Ibid.

Figure 8:
IPv6 holdings over time



IPv6 in Türkiye

Given the importance of IPv6 in maintaining the Internet's growth and innovation, we now turn to look at the current state of IPv6 deployment in Türkiye. (Because of the huge numbers involved in IPv6, we use the equivalent of a /32 of IPv6 in our calculations.)

It's interesting to note that only negligible amounts of IPv6 space were allocated to Turkish networks until the end of 2012. 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. Instead, the sudden increase we see in 2012 in figure 8 is almost certainly the result of the policy change in 2012, when LIRs began receiving an IPv6 allocation along with their final IPv4 allocation as standard practice. Therefore, even though we see a steady and steep increase in the amount of IPv6 space held by networks within the country over the past decade, this doesn't necessarily mean that these networks have actually deployed IPv6 and that the addresses are in use.

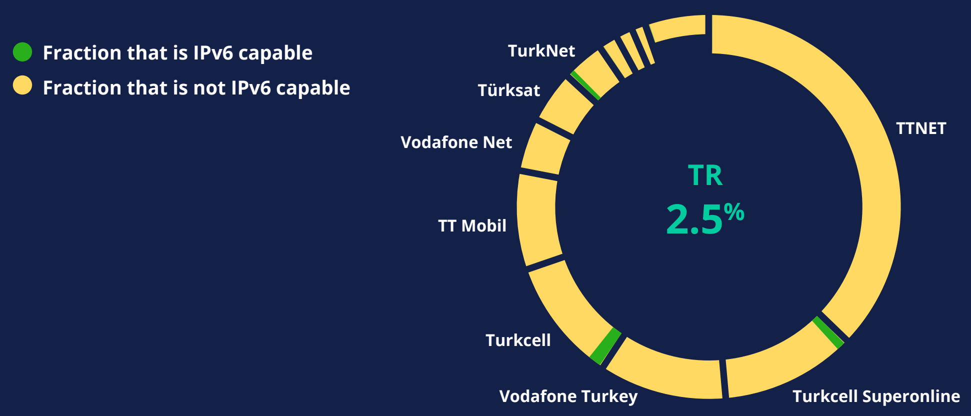
According to the RIPE NCC's Routing Information Service (RIS) – which employs a globally distributed set of route collectors to collect and store Internet routing data – this is exactly what we see happening in Türkiye, where only a fraction of the IPv6 space held by the country is actually being routed (i.e. being used). Of the 3,688 /32s' worth of IPv6 space allocated, we find that only 21.3% is in use (compare this to 93.8% of IPv4 space being 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). Due to the nature of IPv6 networking, it's also possible for a provider to serve a large customer base with a relatively small allocation.

The rate of IPv6 capability in Türkiye (which measures the percentage of users who can access content and services over IPv6) is between 2.5-3.6%, depending on the measurement methodology used. This is far below many of the countries in Europe and the Middle East, as well as the world average of 35-45%.[14] However, it's possible that IPv6 is starting to gain some traction; APNIC, Akamai

14 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/
https://www.akamai.com/internet-station/cyber-attacks/state-of-the-internet-report/ipv6-adoption-visualization

Figure 9:
IPv6 capability by network



and Facebook all report that most of the (albeit modest) growth happened in the third quarter of 2022, although figures have since plateaued.

In looking at the RIPE NCC Survey 2023,[15] which polled nearly 4,000 network operators and other members of the technical community, we see that of the 147 respondents from Türkiye, 35% said they had deployed IPv6 and 65% said they hadn't. Given the disparity between these figures and the country's overall small IPv6 capability rates, this suggests that respondents may have been from smaller organisations that don't affect the overall rate for the country much, or they may be routing IPv6 or have IPv6-capable web servers, but have not rolled out IPv6 to their end users. Overall, 49% of total survey respondents reported having deployed IPv6, and 57% in Eastern Europe.

The top reasons for deploying among Turkish respondents were wanting to be ready for future IPv6 demands (67%) and wanting to gain experience with IPv6 (65%), while only 14% said it was because of IPv4 scarcity (the survey average when it came to IPv4 scarcity was 13%). The main reasons given for not deploying included not being able to afford the risk of transition from IPv4, a lack of business need or other requirement to make the transition, a lack of configuration management tools for IPv6 and a lack of time.

In figure 9, we look at IPv6 capability by network, according to APNIC measurements averaged over a 90-day period. Each arc segment represents one network (ASN), with the length of each arc corresponding to the percentage of the country's Internet users in that network. Networks with fewer than 1% of users are aggregated into the single thinner arc (and only eight of the 11 networks with more than 1% are labelled, to avoid clutter). For each arc, the green part shows what fraction is IPv6 capable, while the yellow section represents the fraction that is not IPv6 capable.

As we can see, only TurkNet, Turkcell and Turkcell Superonline show any visible IPv6 capability. Even in these networks, however, the percentage of IPv6 capability is small overall: 14% of users in TurkNet, 11% in Turkcell and 7% in Turkcell Superonline. Notably, Türk Telekom shows no signs of IPv6 deployment in its TTNET and TT Mobil networks.

Public authorities in Türkiye began pushing IPv6 several years ago, and many government websites and applications are reachable over IPv6. In past country reports, we've seen the positive effect that regulatory efforts can have on IPv6 uptake; however, in our work as a network coordination centre, we know how important bottom-up efforts are in deploying IPv6, too. There was a Network Operators Group (TRNOG) in Türkiye about 10 years ago which was active for a time but has since died off. However, the RIPE NCC has been helping to coordinate the local network operators community in the country and organised the first TurkNOG event in March of this year, with an active mailing list having since been established. We hope that this effort will help encourage IPv6 deployment, among other practices, and facilitate information sharing between network operators.

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 ability to transition to the next-generation protocol as well as to overall Internet development.

15 https://www.ripe.net/participate/member-support/surveys/ripe-ncc-survey-2023

Domestic and International Connectivity

Domestic Connectivity Between Networks

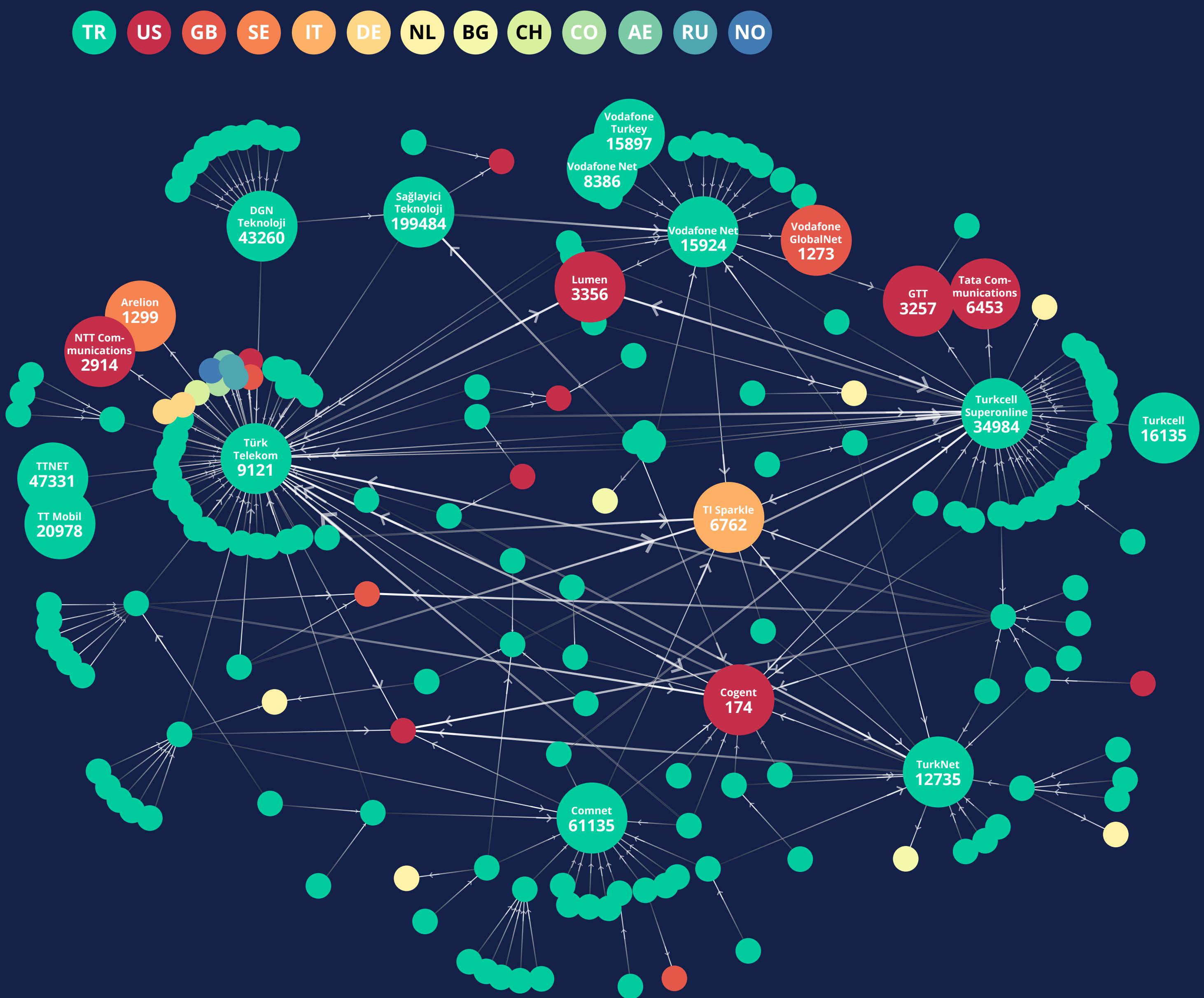
To understand the relationships that exist between different networks, we can investigate the interconnections within Türkiye, again using data from the Routing Information Service (RIS). This shows us the available paths that exist between networks (note that we cannot see which paths are actually taken).

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 the country and the connections to the outside world. The nodes in the 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, the figure is a visual representation of the relationships between the networks in the 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 the 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 Türkiye's domestic connectivity.

Because the number of networks in Türkiye is quite large, we've restricted the view of domestic connectivity to the top 250 most frequently observed connections between them. While this means that smaller networks 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 Türkiye



Türk Telekom (AS9121) and Turkcell Superonline (AS34984) are the predominant providers connecting other Turkish networks to the wider Internet, followed by Vodafone Net (AS15924), Comnet (AS61135) and TurkNet (AS12735). While a fair amount of Turkish networks connect to two or more other networks, we also see that many connect to only one of the big three providers.. In addition, some of the smaller networks connect directly to prominent international networks like Cogent (AS174) and TI Sparkle (AS6762). On the other hand, Tier 1 providers Arelion (AS1299), NTT Communications (AS2914), Lumen (AS3356), Vodafone GlobalNet (AS1273), Tata Communications (AS6453) and GTT (AS3257) only connect to Türkiye's three main providers.

It is interesting to see how DGN Teknoloji (AS43260) provides connectivity to 14 other networks, while it has no direct international connections of its own; instead, it relies exclusively on Türk Telekom (AS9121) and Sağlayici Teknoloji (AS199484) for external connectivity.

Finally, we observe how Türk Telekom, Vodafone Turkey and Turkcell all operate multiple networks. In the case of Türk Telekom, AS9121 is the primary network that provides connectivity to TT Mobil (AS20978), TTNET (AS47331) and more than 200 other networks. Vodafone's primary network is AS15924, the former Borusan Telekom, acquired in 2010 and now part of Vodafone Net. The network is seen providing connectivity to around 120 other Turkish networks, two of which are held by Vodafone as well: AS8386 (formerly Koç.net), and AS15897 (Vodafone Turkey), the network for mobile services. Similarly, Superonline (AS34984, once independent and now part of Turkcell) is the exclusive upstream for AS16135, Turkcell's mobile network.

A visualisation of domestic Internet connectivity, like we see in figure 10, should resemble a deeply interconnected web, with a large distribution of paths and interconnections that lack clear choke points or bottlenecks. Looking at the RIS data, we see 64% of Turkish networks connecting to only one other network. While these may have additional connections that are used predominantly for local traffic exchange and are therefore not visible in RIS, this is a fairly high amount of single connections (compared to 40% in Czechia and 24% in Poland, for example). More connections result in better resilience. In Türkiye, we see some significant clustering around a handful of domestic networks, and a modest level of diversity as a result of multihoming among multiple networks.

International Connectivity

Extending our view, we now look beyond domestic connectivity to examine how Türkiye connects to the rest of the world. Internet connectivity comes in two forms: peering and transit. Peering usually happens at Internet exchange points (IXPs) where parties exchange routes to their respective customers. This helps keep local traffic local, or at least regional.

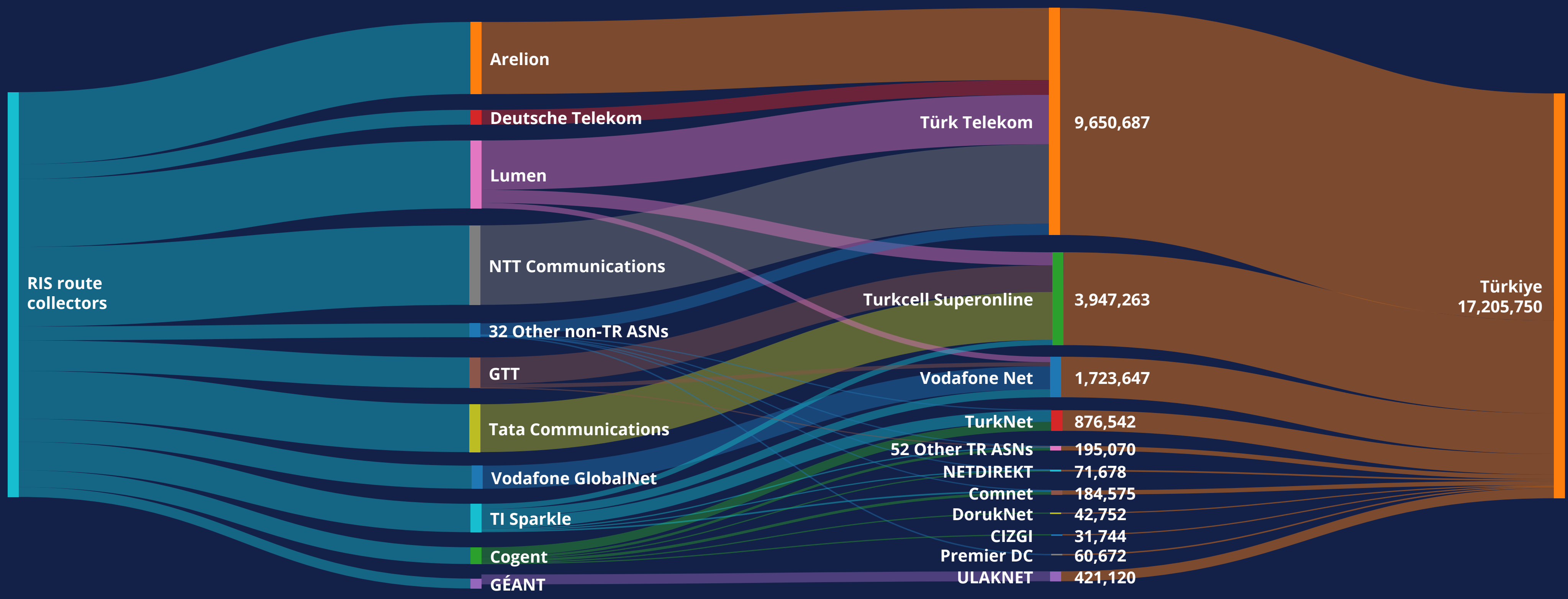
To reach other destinations beyond a regional scope, ISPs need transit agreements – one or more parties that will route traffic to the rest of the world. This usually involves some hierarchy. Like a regional peer, the first upstream will be happy to route traffic to its customers if the destination is 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 "hops" up the chain, 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 RIS to discover the AS paths that go through a Tier 1 network.[16] For each of these, we find the network pair on either side of the country's virtual border (i.e. the last network registered in a foreign country before the traffic enters the Tier 1 network, and the first network registered in the country of interest once the traffic has passed through the Tier 1 network).

The following figures look at how Turkish networks are reached through the large Tier 1 transit providers. They're 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. The organisations listed on the right are entry points to Türkiye's IPv4 and IPv6 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 TR ASNs".

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

Figure 11:
Türkiye's international connectivity (IPv4)

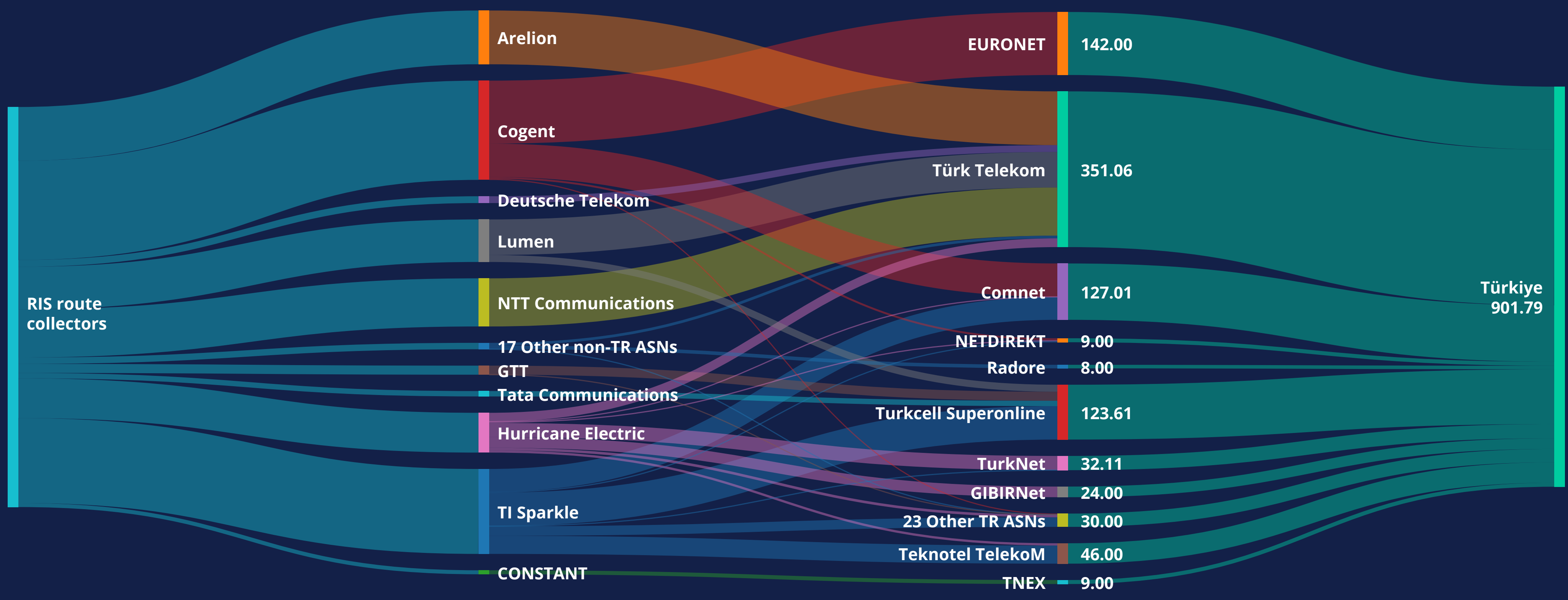


In figure 11, Türk Telekom's dominance is again clearly visible; more than half of the addresses held by Turkish networks pass through the provider. This is the combination of Türk Telekom's own users (including TTNET and TT Mobil) and third parties connecting via its network. Türk Telekom's main transit providers are NTT Communications, Arelion and Lumen, while Deutsche Telekom plays a lesser role.

Second in terms of directly and indirectly connected IP addresses is Turkcell Superonline, which relies primarily on Tata Communications, GTT and Lumen for international connectivity. Third in the top three is Vodafone Net, a subsidiary of Vodafone Turkey, which connects about 10% of IP addresses allocated to Turkish companies. It relies heavily on Vodafone GlobalNet for transit, though not exclusively (unlike what we've seen in other country reports); we also observe paths to Vodafone Net via Lumen, GTT and TI Sparkle.

TurkNet and ULAKNET connect most IP addresses in the remaining networks with international transit. TurkNet does so via Cogent and TI Sparkle; ULAKNET, the academic network, does so via GÉANT, Europe's backbone provider for national research and education (NREN) networks. Though not shown in the figure, we also see that ULAKNET receives international connectivity via TurkNet.

Figure 12:
Türkiye's international connectivity (IPv6)



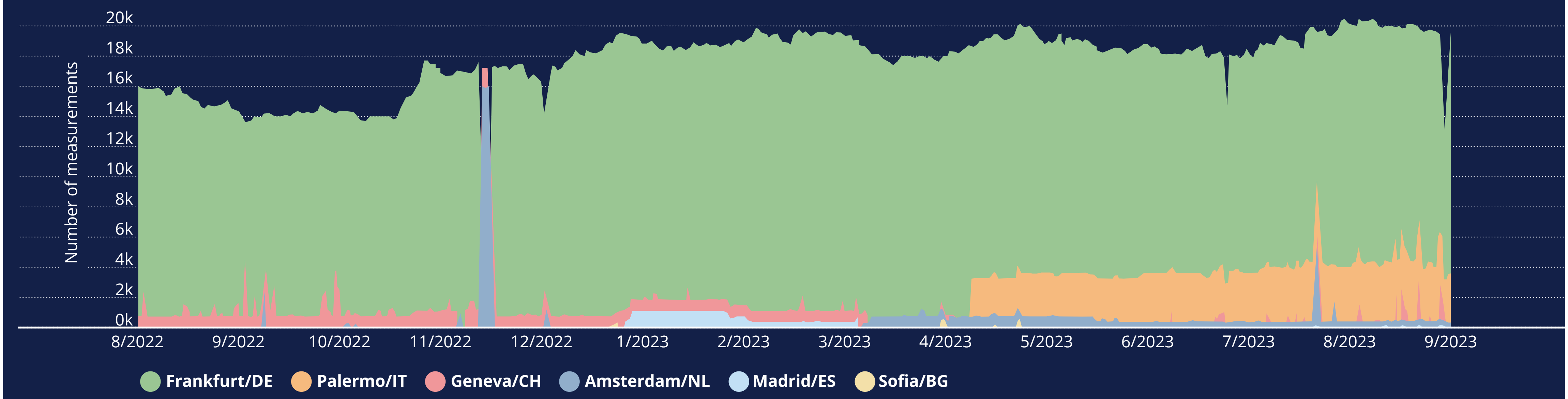
Because only a few percent of Turkish Internet users are capable of accessing the Internet via IPv6, the IPv6 Internet in Türkiye is understandably much smaller compared to IPv4; about 17% of networks (ASNs) that announce IPv4 prefixes also announce IPv6. The topology for domestic IPv6 connectivity is similar to that of IPv4 (as seen in figure 10): Türk Telekom and Turkcell Superonline connect most other Turkish networks, followed by Vodafone Turkey, Comnet and TurkNet.

However, when we look at international connectivity and the total number of IPv6 addresses reached via the different providers, things look slightly different, as seen in figure 12. Türk Telekom still dominates, connecting the equivalent of 351 out of 901 /32s of IPv6 space in Türkiye, but here we see EURONET and Comnet in second and third place, respectively. This illustrates how the link between the number of addresses and the number of connected users is much weaker in IPv6 than in IPv4; with an abundance of IPv6 addresses available, routing efficiency takes precedence over address space conservation, since every LIR can obtain a /29 of IPv6 space, regardless of the number of users it connects.

In terms of international IPv6 connectivity, Cogent, Hurricane Electric and TI Sparkle are the gateway for a number of networks, while Arelion, Lumen and NTT Communications connect only one or two Turkish networks.

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 country's international connections 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 Türkiye, we again see the continued dominance of the incumbent provider, which is responsible for a large proportion of the country's outside connections. However, there is still a fairly healthy level of interconnection overall; most domestic providers receive transit from more than one upstream provider. This provides a good level of redundancy – and therefore stability – to the country's international connectivity.

Figure 13:
K-root locations reached from requests originating in Türkiye 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 Türkiye, we first examine which instances of K-root are queried from requests originating in the country. 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, including 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 resilience and results in faster response times for DNS clients and, ultimately, end users.

There are no local K-root instances in Türkiye, but several exist in other nearby countries, including Greece, Bulgaria, Romania, Georgia, Armenia and Lebanon. Nevertheless, the RIPE Atlas probes in Türkiye mostly preferred K-root instances in Frankfurt, Palermo, Geneva and Amsterdam, as seen in figure 13. This is likely the result of BGP routing; in terms of topology (rather than geographical distance), Western Europe may be "closer" (i.e. have shorter AS paths) than the K-root instances in the region. We also don't know how widely each K-root instance is advertised, as this depends in part on the host. It's therefore possible that the K-root instances in Western Europe were more widely announced than those located in nearby countries.

Figure 14:
K-root locations reached from vantage points in Türkiye

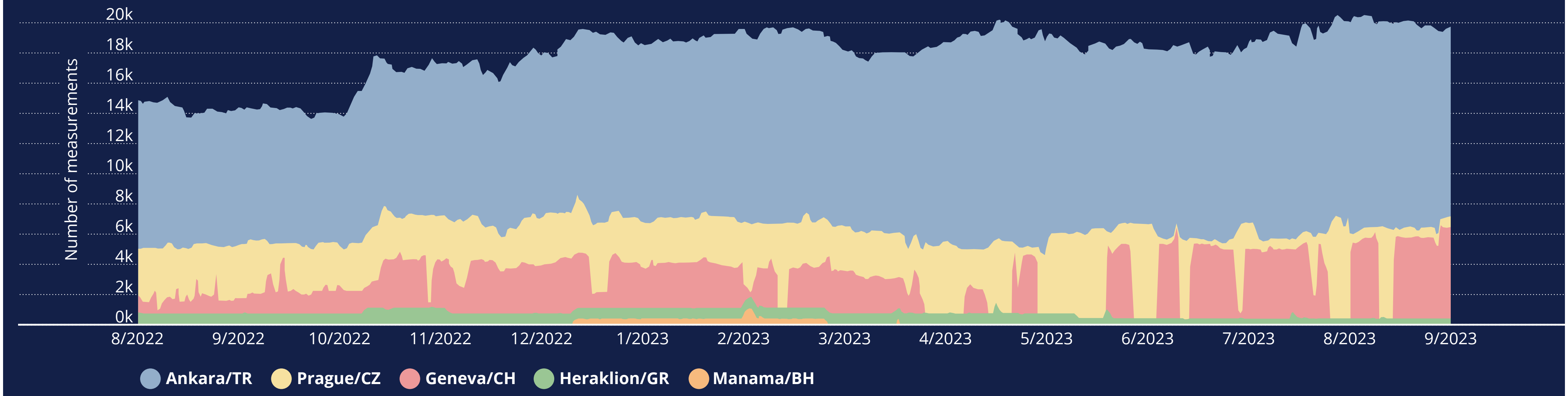
Border Gateway Protocol and Anycast

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 country on a given day, as well as their round-trip times, as shown in figure 14. As is evident in the figure, most of the probes are located in Istanbul and Ankara, giving only a limited picture. The round-trip times (RTTs) to the K-root instances in Frankfurt (a median of 40ms) and Amsterdam (60ms) are still acceptable, although Palermo (80ms) is on the high side of what we would consider optimal.

As mentioned, K-root is just one of the world's 13 root name servers, and every DNS client will make its own decisions about which particular root name server to use. Without a local K-root instance, it's likely that clients would opt for alternatives among the other root name servers. We therefore also looked at how probes in Türkiye reached L-root, another of the world's 13 root name servers, which is operated by ICANN and which has a local L-root instance in Ankara.

Figure 15:
L-root locations reached from requests originating in Türkiye over time (IPv4)



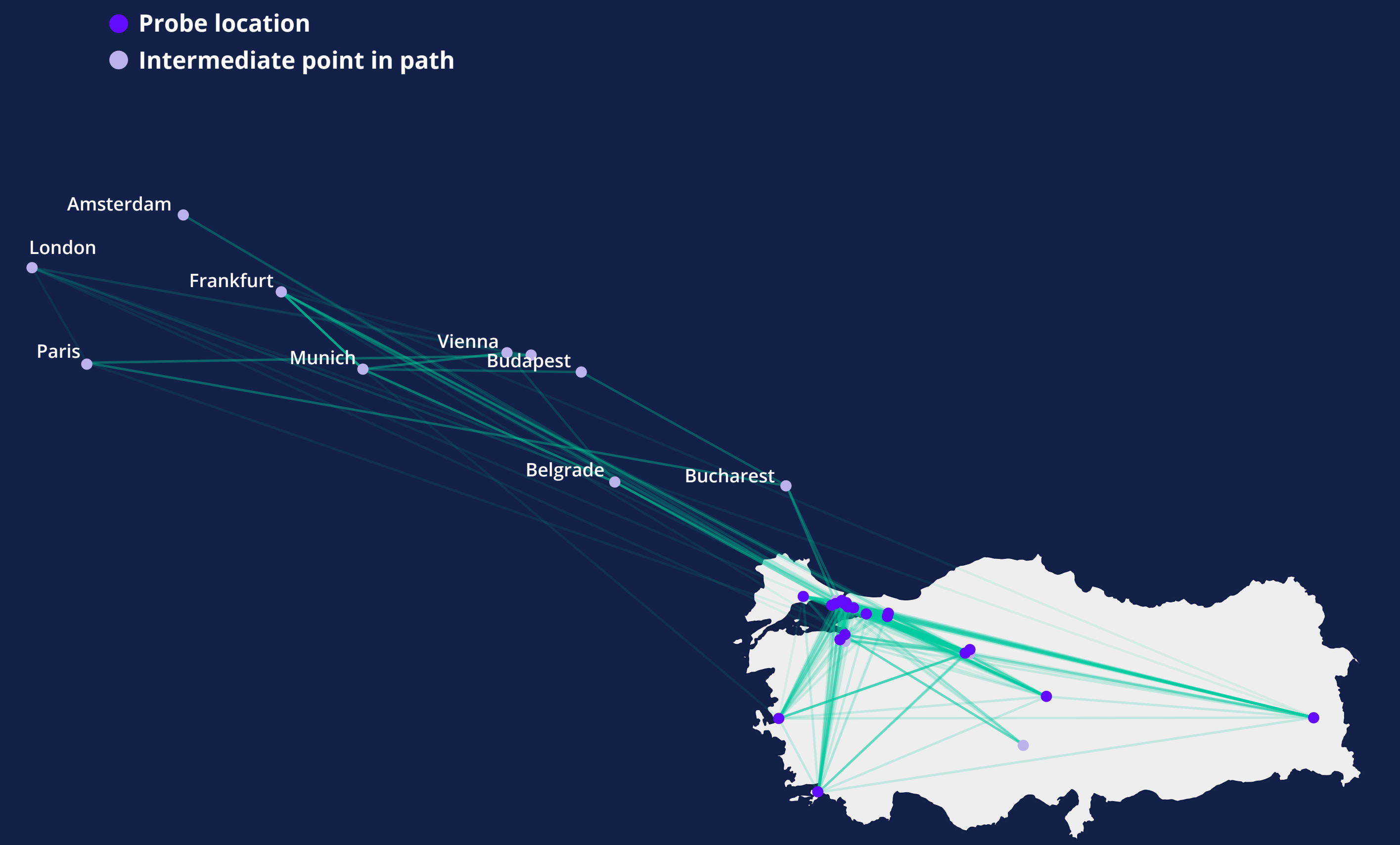
In figure 15, we get a very different picture of which L-root instances were reached by RIPE Atlas probes in Türkiye. We see that a majority of the probes did indeed reach the L-root instance in Ankara, with RTT ranges from 2-30ms, depending on the probe's location. With a median RTT of 30-40ms, the L-root instance in Prague is a little closer than the K-root instance in Frankfurt, while the L-root instance in Geneva (~50ms) is a little farther. The L-root instance in Manama is clearly a suboptimal choice (140ms), but it was only used for a few months and mostly by just one probe.

Interestingly, median RTTs to the L-root instance in Heraklion (reached by one probe) are comparable or higher than RTTs to Geneva from other probes in the Ankara region. That may be counterintuitive, given the much shorter geographical distance, but this is another example of Internet packets not necessarily following the shortest geographical route. A detailed check using RIPE Atlas revealed that, in this case, the packets are first routed over the GÉANT network via Budapest to Vienna, and then travel south again to Athens and Heraklion.

Finally, we looked at which K-root and L-root instances were queried by probes within different networks in the country (for those networks that host at least one RIPE Atlas probe). Generally, most networks have a preference for a particular root name server 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 Türkiye, where most of the probes in a particular network end up querying the same root name server instance. However, we see a few exceptions including Türksat and Turkcell Superonline, which each had probes that queried different K-root instances (Palermo and Frankfurt). We also saw probes in TurkNet reach different L-root instances (Geneva and Ankara). This is likely a result of BGP dynamics and reaching different edge routers in the probe's network.

We should note that these results, while considered

Figure 16:
Paths between origin and destination in Türkiye (IPv4)



generally representative, offer only a snapshot of measurements made on a single day in September 2023. Given BGP's dynamic nature, results can change constantly due to subtle changes in routing.

While the increase in round-trip times to root name server instances farther away (such as those in Palermo) is obvious, they are still acceptable and it's unlikely that an end user would experience any noticeable delay. Round-trip times to Manama, however, are quite high and better results could be achieved by routing to a closer instance. We should note that it's very common to see RIPE Atlas probes reaching root name server instances in the major IXPs in Europe (e.g. AMS-IX in Amsterdam, DE-CIX in Frankfurt and LINX in London) due to the host network peering there, and this generally doesn't cause suboptimal results.

Regional Traffic Exchange

Again using data from the RIPE Atlas measurement network, we can investigate how some of the networks in Türkiye 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 the country.

Figure 16 shows the location of the probes, the paths followed by the traceroutes, and the intermediate points reached in the paths. We can see that there are a number of paths between networks that do leave the country. When we looked further into the details, however, we found that these paths are the result of measurements towards two specific probes, in Nrp Teknoloji's and GIBIRNet's networks. Overall, it appears that most local traffic is indeed exchanged within the country, although not generally through the use of IXPs.

Türkiye has had several IXPs: TNAP, established by a coalition of smaller providers; DE-CIX, a multinational IXP with a presence in Istanbul; and IST-IX, established by Terremark and since acquired by DE-CIX.

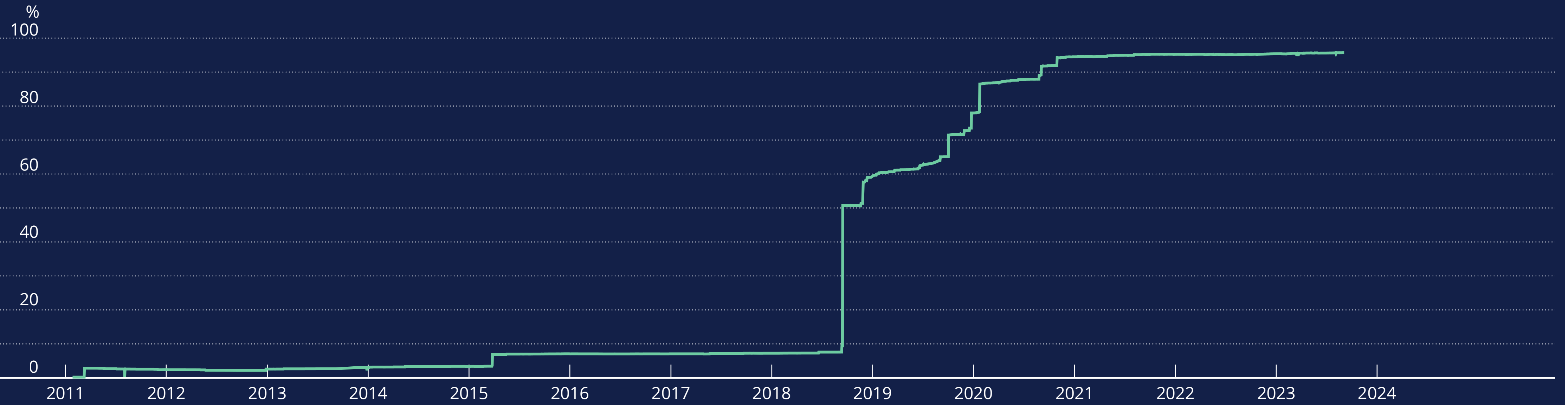
However, they don't seem to have a significant impact on local traffic exchange: transit arrangements, rather than peering, seem to dominate. In particular, the lack of influence of DE-CIX is noticeable in the measurements, even though many of the Turkish probes are located in the greater Istanbul area. From our understanding, this is largely the result of Türk Telekom not having an open peering policy at the IXP, as is the case with its presence at DE-CIX in Frankfurt and AMS-IX in Amsterdam. As the dominant provider in the country, its absence clearly has a major effect on the state of local peering within the country.

In some of the other countries we've looked at in the country reports, we've also seen a reluctance of larger providers, particularly incumbents that enjoy a large market share, to exchange traffic at local IXPs. However, the benefits of traffic exchange across local or regional IXPs are well-documented and include the economic benefits of much wider market exposure, lower costs for end users, faster connections, better user experience, and improved resiliency.

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.

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 the country. The distances we see taken by the longest paths in Türkiye are still relatively short compared to what we've seen in many other countries; overall, routing appears to be quite efficient in Türkiye despite the lack of use of IXPs.

Figure 17:
IPv4 address space covered by ROAs over time



Routing Security

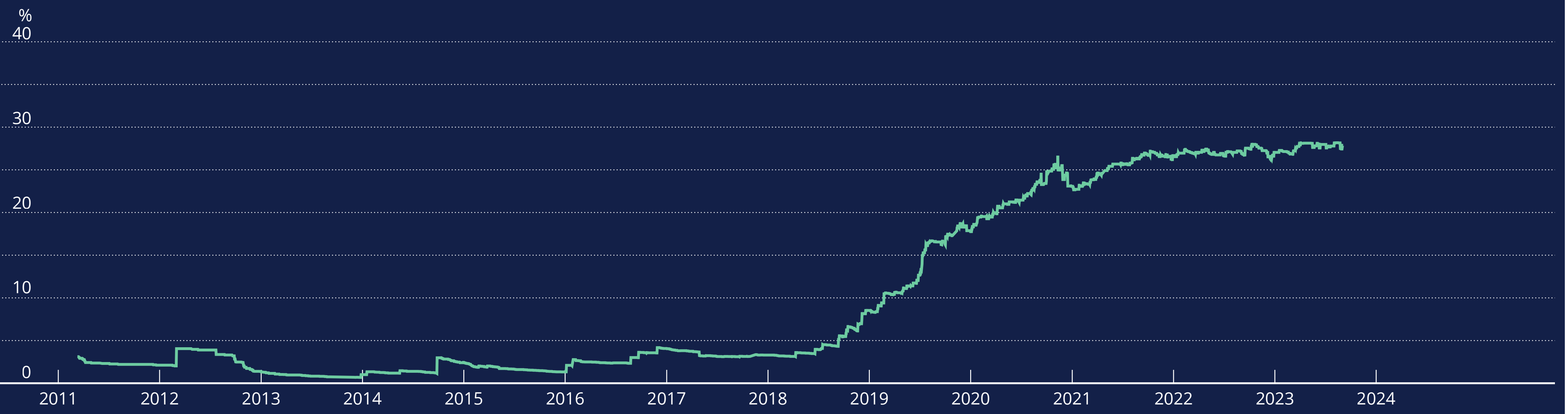
Beyond looking into the different routes available to traffic originating in the region, we can also investigate routing security in Türkiye by looking at how effectively IP address space is protected by Resource Public Key Infrastructure (RPKI), a security framework that helps network operators make 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). When network operators filter out the routes with invalid ROAs, 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 Türkiye, 96% of IPv4 address space registered to organisations in the country is covered by ROAs, which is among the highest we've seen in any of the countries we've looked at in our reports.

The largest leap forward happened in September 2018, when Türk Telekom's TTNET added ROAs for its address space, resulting in an increase of 40% coverage. Similar jumps took place when other large address space holders, like Turkcell Superonline, added ROAs.

Figure 18:
IPv6 address space covered by ROAs over time



When it comes to IPv6, however, things are lagging, with only 28% of the country's IPv6 address space covered. We consistently see lower rates of RPKI uptake with IPv6, which 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.

Conclusion

Türkiye's Internet ecosystem has made some advancements in recent years and continues to evolve. The incumbent still holds a large market share and controls access to much of the country's physical infrastructure, making competition more difficult than in some other parts of the RIPE NCC's service region. However, several smaller providers have also begun to gain subscribers and prices remain generally affordable.

With only small amounts of IPv4, plans to increase broadband penetration, and a mobile market that has not yet reached saturation and still shows signs of potential future growth, Türkiye needs to improve its IPv6 capability in order to accommodate long-term growth as well as new and emerging technologies such as 5G, IoT, the Internet of Things, smart cities and more. Governments and regulators, IXPs, NOGs, network operators and decision makers all need to do their part to encourage IPv6 deployment more widely, and this is certainly the case in Türkiye, as the country's IPv6 capability rates remain among the lowest in the world.

The networks in the country display a modest level of interconnectivity, which is important for keeping domestic connectivity stable and resilient. We see a decent amount of diversity in upstream providers, ensuring robust connections to the rest of the global Internet that mitigate against potential disruptions caused by bottlenecks or single points of failure.

Türkiye's access to the DNS via K-root could be further optimised if there were a local K-root instance hosted in the country; however, the response times to K-root instances elsewhere are reasonable and unlikely to cause issues for the end user. In addition, access to L-root is even better, given the presence of an L-root instance in the country. Routing is quite efficient, with a majority of the available traffic paths remaining inside the country. We do see some of the larger European IXPs being used, which is normal and not something that would result in noticeably longer response times; however, local IXPs could be more widely used. We also see an extremely high level of RPKI uptake (at least in IPv4 space), which helps promote routing security.

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 resilience.

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

Additional Information Sources

We would like to acknowledge the following people for providing background information included in this report about the Internet landscape in Türkiye:

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  Former TRNOG Board Member