RIPE NCC
RIPE NETWORK COORDINATION CENTRE

RIPE NCC

Internet Country Report: Bulgaria, Moldova and Romania

May 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 three countries in southeastern Europe facing similar opportunities and challenges: Bulgaria, Moldova and Romania. We offer an analysis of these countries' market landscapes and their state of development, examine Internet routing within the region, take a close look at their 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 these three countries in the RIPE NCC service region, we can present a comprehensive analysis of their unique Internet landscapes and potential for future growth in order to inform discussion, provide technical insight, and facilitate the exchange of information and best practices. This is the ninth 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

- All three countries display a healthy level of market competition and enjoy some of the lowest Internet access prices and fastest speeds in Europe
- Romania has been exceptionally active on the IPv4 secondary market, as the biggest exporter of IPv4 addresses in the RIPE NCC service region
- Despite holding large amounts of IPv6, Bulgaria and Moldova show very low IPv6 capability rates, and all three countries require further IPv6 deployment to accommodate future growth
- Routing appears to be quite well optimised in the region, although local Internet exchange points don't appear to be heavily used
- There is a reasonably high level of interconnectivity between the networks in each country
- For the most part, the countries benefit from a diverse array of upstream providers connecting them to the rest of the global Internet, although a few providers in Moldova and Romania are highly dependent on just one or two sources for their international transit

The Market and Opportunity for Growth in Bulgaria, Moldova and Romania

The Market Landscape

While the three countries covered by this report differ to quite a large extent in terms of geographical and population size, GDP, and membership in the European Union (EU), they face some similar hurdles when it comes to Internet development. All three struggle with losing skilled ICT workers to emigration, relatively low levels of Internet use compared to the rest of Europe, large urban-rural digital divides, and a relative lack of digital services such as e-government. Despite this, we also see healthy levels of market competition, low Internet access prices, and fast Internet speeds – and new investments are being made in both infrastructure and updated digital regulation.

In looking at the region's market landscape, Bulgaria's major operators include A1 Bulgaria, Telenor Bulgaria, which rebranded to Yettel Bulgaria in March 2022, and Vivacom (which grew out of a merger with the incumbent, Bulgaria Telecommunications Company). The market is dynamic and competitive, with PPF Group purchasing Telenor in 2018 and United Group buying Vivacom in 2020.

In Moldova, the broadband market is dominated by the incumbent, Moldtelecom, followed by StarNet, which provides access to much of the country's central regions, and Orange Moldova (which took over Sun Communications in 2016). Interdnestrcom is the main provider in Transnistria. A number of smaller players exist but rely on the larger operators' infrastructure. As a small country without major geographical obstacles, Moldova's infrastructure is quite robust and the country is well connected. The mobile market is dominated by Orange Moldova, with Moldcell and Moldtelecom covering virtually all of the remaining share.[1]

We also see a dynamic, competitive market in Romania, where RCS & RDS (which is owned by Digi Communications), Telekom Romania Communications (now Orange Romania Communications) and Vodafone Romania (which merged with UPC Romania in 2019 after the latter was acquired by the Vodafone Group) are the dominant players; however, a large number of independent "micro-ISPs" offer local services. Several international players serve the mobile market; in addition to Vodafone, Orange Romania bought a 54% stake in the country's incumbent, Telekom Romania Communications (formerly Romtelecom) from Deutsche Telekom subsidiary OTE in 2021,[2] and in late March 2022, Telekom Romania Communications rebranded to Orange Romania Communications. (Note that we still refer to the company as Telekom Romania Communications throughout most of this report, as the name change occurred after the data collection for the report took place.) The incumbent market share in Romania is one of the lowest in the EU, at 17%.[3]

Bulgaria and Romania are connected via the same submarine cable to Turkey, while Bulgaria has an additional connection across the Black Sea to Georgia.[4]

Two of the three countries in the report are included in the top ten when it comes to Internet speeds: Bulgaria ranks 7th globally for mobile speeds and Romania ranks 10th for fixed broadband speeds.[5]

In terms of the broader European landscape, Bulgaria and Romania rank at the bottom of the EU's 2021 Digital Society and Economy Index (DESI), which takes into account factors including connectivity, digital skills, e-government and more.

Bulgaria ranks 26th out of the 27 member countries in its overall ranking as well as in connectivity. With 59% of households subscribing to fixed broadband, it lags behind the European average of 77%. However, it has made small gains in recent years when it comes to fixed broadband network deployment, although its rural fixed very high capacity network (VHCN) coverage remains at just 1%, compared to a European average of 28%.[6]

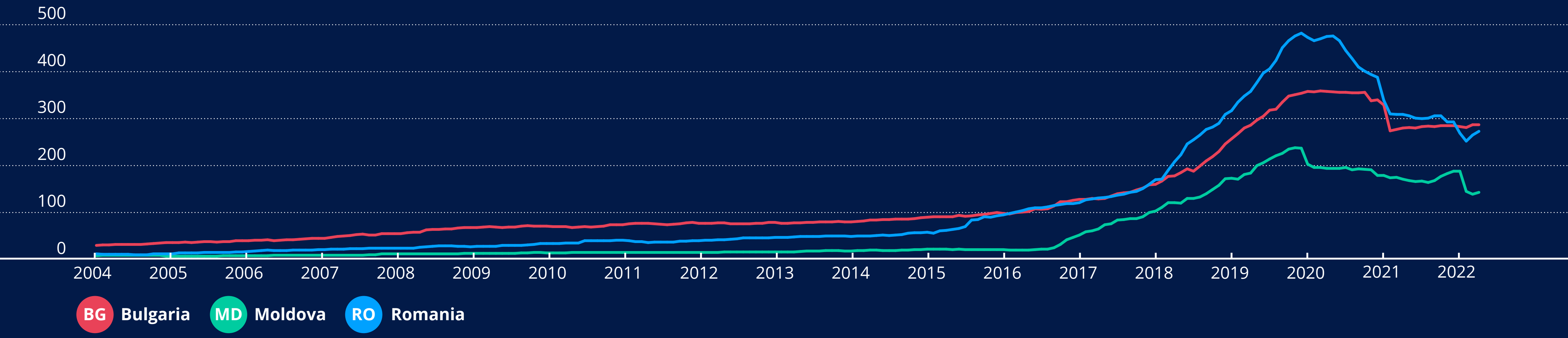
Romania ranks 27th overall, yet takes 10th place when it comes to connectivity, with 67% of households subscribing to fixed broadband. It actually ranks above the European average for fixed VHCN coverage, thanks to strong competition around infrastructure, and doubles the European average for rural VHCN coverage.[7]

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.

1 https://www.itu.int/en/ITU-D/Regional-Presence/Europe/Documents/Events/2021/Regional%20Innovation%20Forum/Moldova.pdf
2 https://www.romania-insider.com/orange-telekom-ro-takeover-oct-2021
3 https://ec.europa.eu/newsroom/dae/redirection/document/80552
4 https://www.submarinecablemap.com/
5 https://www.speedtest.net/global-index
6 https://ec.europa.eu/newsroom/dae/redirection/document/80475
7 https://ec.europa.eu/newsroom/dae/redirection/document/80496

Figure 1:
Number of Local Internet Registries over time



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.

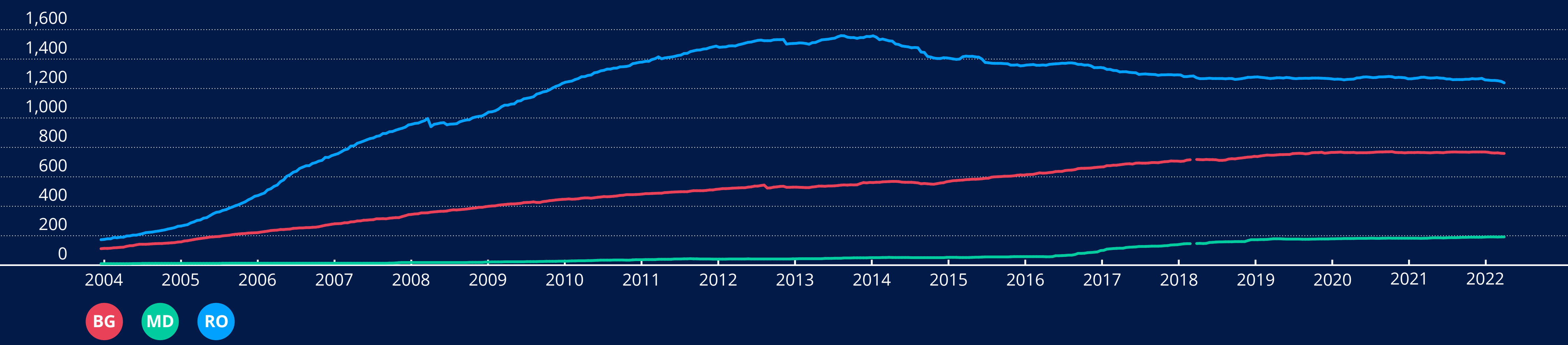
In addition, it's possible for the same organisation to hold several LIR accounts. This practice became a significant trend after 2012, when the amount of IPv4 address space being allocated was restricted as the remaining IPv4 address pool became smaller and smaller (as explained in more detail in the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

As seen in figure 1, there was steady but slow growth in Bulgaria, Moldova and Romania until 2015-2016. After 2016, all three countries saw a dramatic increase in the number of LIRs. This is almost certainly an effect of the change in RIPE policy that occurred after reaching the last /8 of IPv4 address space in 2012, after which time smaller organisations no longer received IPv4 from a sponsoring LIR but instead had to either become an LIR themselves or turn to the secondary market.

While we've seen a similar increase in the number of LIRs in other countries we've examined, the speed and magnitude of the growth we see here is particularly pronounced, especially in Romania. The subsequent decrease in the number of LIRs we see in the three countries is also unusual, as a large number of these additional LIR accounts closed once they received and transferred their final IPv4 allocations. Even so, the number of "additional" LIR accounts (multiple accounts held by the same member) remains relatively high in all three countries: as of March 2022, there were 209 members in Bulgaria holding a total of 287 LIR accounts, 53 members in Moldova holding 143 LIR accounts, and 181 members in Romania holding 284 LIR accounts.

Figure 2:
Number of networks over time



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 region. This provides us unique insight into the distribution and deployment of these networks across the Internet. In figure 2, we see a modest growth rate in Moldova, more pronounced growth in Bulgaria, and an unusually fast growth rate in Romania. However, we see the number of independent networks in Romania peaking around 2014 and then declining before plateauing from about 2018. Today, Bulgaria leads the three in terms of the number of networks when taking into account the countries' populations, with 1.8 as many networks as Romania and 1.4 as many as Moldova per capita. Generally, the growth and diversity we see here is a good indication of a more mature and competitive market with a good level of choice among larger and smaller service providers; however, a decline in the number of ASNs is not something we typically see in any given country.

Looking into the situation more closely, we discover that the decline in the number of ASNs in Romania is the result of a single company. (The company started out using the name Jump Management and has since been renamed to IPv4 Management, while operating a number of related companies along the way.) ASNs that had been requested by this company on behalf of its customers were reclaimed by the RIPE NCC, or moved to a different LIR – either because a different LIR had taken over sponsorship of the End User, or because the End User became a RIPE NCC member of its own. Comparing ASN registrations for just one of this company's LIRs from 1 January 2015 until 1 January 2017, we see that 246 ASNs were moved: while 128 went to another LIR in Romania, 27 moved to an LIR outside of Romania (including 11 to Moldova and 7 to Bulgaria), 51 were reclaimed and reassigned by the RIPE NCC to other organisations after a quarantine period, and 40 had been reclaimed but not yet reassigned.

**Figure 3:
IPv4 holdings over time**

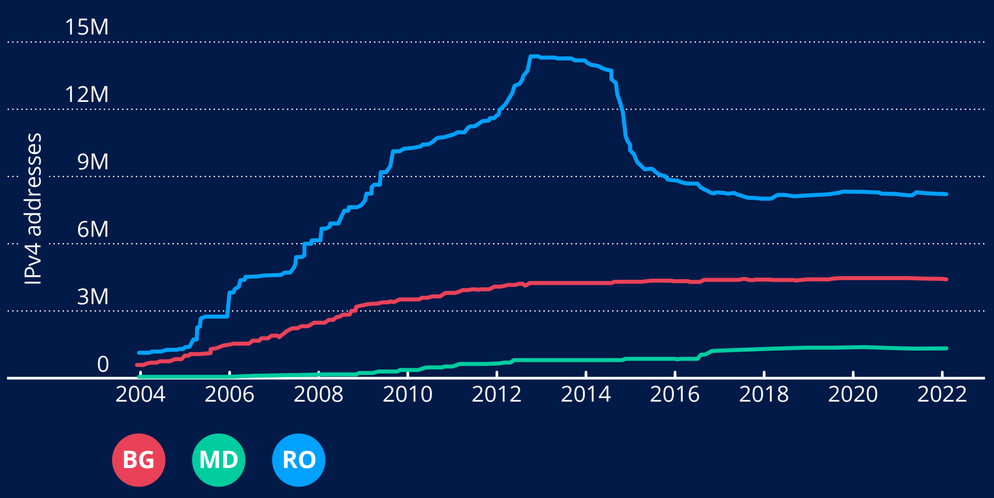
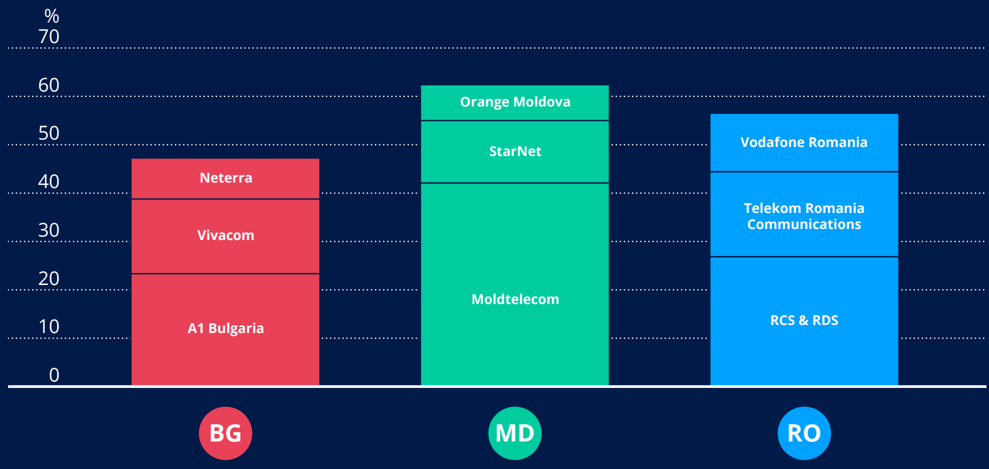


**Figure 4:
Top 3 IPv4 holders**



IPv4 in Bulgaria, Moldova and Romania

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 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).

Indeed, none of the three countries included in this report continued to accrue any significant amount of IPv4 address space after 2012. Up until that time, we saw modest growth in the amount of IPv4 allocated in Moldova and steady growth in Bulgaria. Once again, we see the most significant growth in Romania – much higher than in most of the other European countries we've looked at in past reports. Interestingly, we then see a dramatic decrease in Romania's IPv4 holdings in the first few years following the policy change in 2012. As we'll see later in the report, this is largely explained by Romania's activity in the IPv4 secondary market. The current holdings in each country correspond closely to their relative populations.

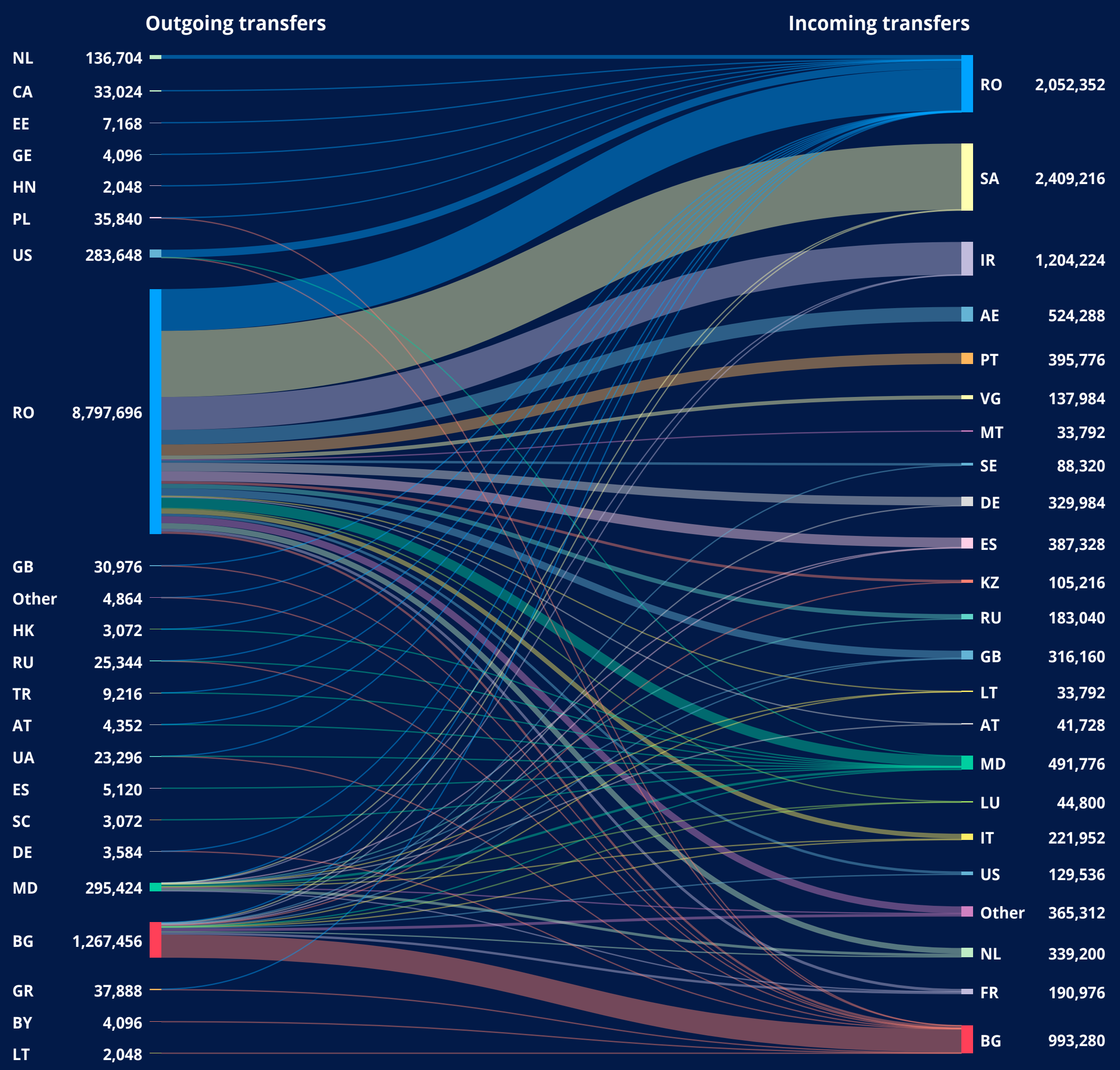
Typical to what we've seen in other countries, there is a fair bit of consolidation of the IPv4 holdings within the three countries. This is particularly the case in Moldova, where, as of March 2022, Moldtelecom held 42% of the country's IPv4 resources. This isn't surprising, given the company's history as the incumbent telco.

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.)

Figure 5:
IPv4 transfers within, into and out of Bulgaria, Moldova and Romania between October 2012 and March 2022



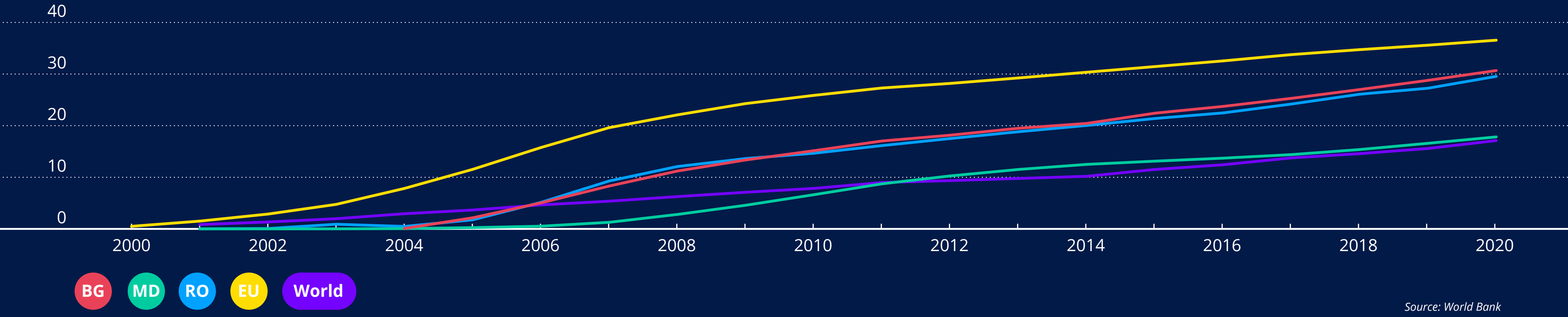
While we see very few resources being transferred into and out of Moldova in terms of absolute numbers, the country imported nearly 200,000 more addresses than it exported and the IPv4 it has imported accounts for approximately 30% of its total IPv4 address space. We see more activity in Bulgaria, but it exported about 274,000 more than it imported and its imported IPv4 accounts for less than 4% of its total IPv4 address space. We also see that the vast majority of Bulgaria's transfers (more than 828,000) were domestic transfers, whereby addresses are transferred between two different entities within the same country.

Of the three countries, Romania has clearly dominated the IPv4 secondary market ever since the IPv4 policy change in 2012. In fact, it has been the source of more IPv4 transfers on the secondary market than any other country in the RIPE NCC service region and is a net exporter by far, having exported nearly 7.3 million addresses (5 million of which were exported within the first three years after the change in IPv4 policy). It also imported just over 500,000, with another 1.5 million in domestic transfers. An additional 393,216 addresses – part of a large allocation that had originally been made to the UK's Department for Work and Pensions – were imported as legacy addresses and, as such, were not recorded in the transfer statistics. We only see the subsequent transfers of those addresses that were made to Saudi Arabia once the status was changed from "legacy" to "allocated".[8]

Of the 1.5 million domestic transfers that took place within Romania, more than 900,000 originated with the company that operated under the name Jump Management. While some of these were regular transfers, many were also the result of individuals or organisations who had leased IPv4 addresses from this company purchasing back the use of the resources. Similarly, 99% of the 372,992 addresses that were transferred to Moldova from Romania originated with this same company. One of the top recipients of IPv4

8 *See question four in the FAQ: https://www.ripe.net/manage-ips-and-asns/legacy-resources/legacy-internet-resources-faqs*

Figure 6:
Fixed broadband subscriptions per 100 people over time



Source: World Bank

addresses in Moldova was Moldtelecom, which received 332,032 addresses from this company.

The top three biggest net importers of IPv4 address space via the secondary market in each of the three countries, and their net increases, include:

Bulgaria:
- Vivacom: 154,624
- Bulsatcom: 92,160
- PON.BG: 60,672

Moldova:
- Moldtelecom: 332,032
- ITNS: 51,200
- Global Fiber Communications: 33,792

Romania:
- Vodafone Romania: 262,144
- RCS & RDS: 133,120
- Netprotect: 67,840

Internet Penetration and Potential for Future Growth

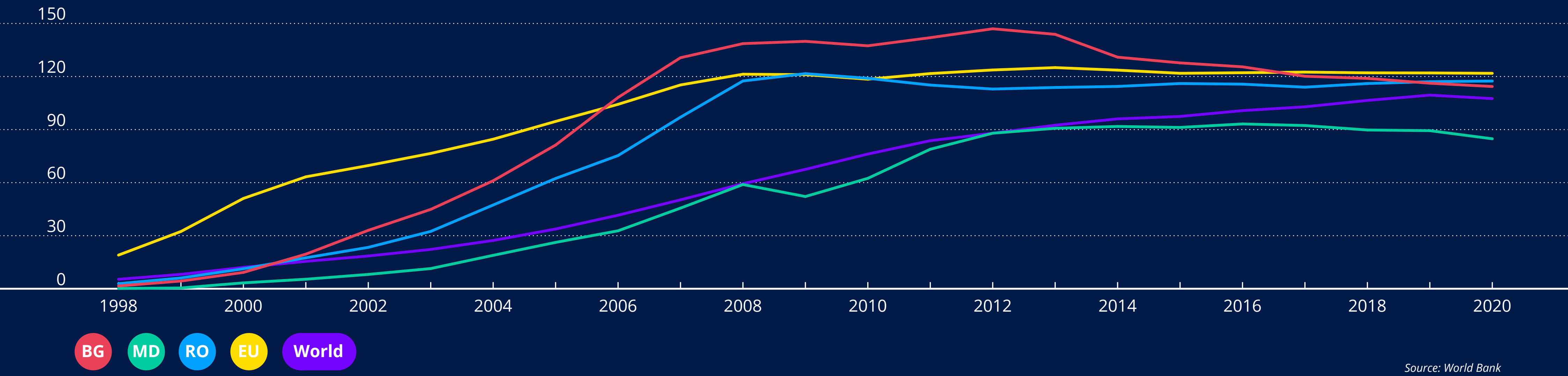
Bulgaria, Moldova and Romania all have moderate amounts of IPv4 compared to other countries in the RIPE NCC service region, and all three have very similar amounts per capita: 0.6 addresses per person in Bulgaria, 0.5 in Moldova and 0.4 in Romania. This is in line with the moderate but steady growth in IPv4 holdings we saw in Bulgaria and Moldova, and while we might have expected to see much more IPv4 per capita in Romania, given its sharp increase in IPv4 in the years leading up to 2012, this was balanced out by the equally large amounts it subsequently transferred to other countries since that time.

Given this, we wouldn't expect a severe lack of IPv4 to have a major effect on Internet penetration in the region. However, as we can see in figure 6, fixed broadband subscription rates in the three countries are significantly lower than the EU average. (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%.)

This is the case despite Bulgaria's broadband prices falling below the European average.[9] Similarly, Romania falls behind the EU average in fixed broadband subscriptions despite ranking first in the EU for broadband pricing when considering fixed, mobile and converged packages together,[10] suggesting that neither IPv4 availability nor cost may be the dominant factor here. Instead, both Romania and Bulgaria have some of the largest urban-rural gaps in the EU when it comes to fixed broadband subscription, which likely contributes to the lower penetration rates we see in those countries.[11] At the same time, it's interesting to note that Romania is one of the leading countries in the EU when it comes to households with a fast (>100 Mbps) broadband connection.[12]

9 https://ec.europa.eu/newsroom/dae/redirection/document/80475
10 https://ec.europa.eu/newsroom/dae/redirection/document/80496
11 https://ec.europa.eu/newsroom/dae/redirection/document/80552
12 https://ec.europa.eu/newsroom/dae/redirection/document/80552

Figure 7:
Mobile subscriptions per 100 people over time



Source: World Bank

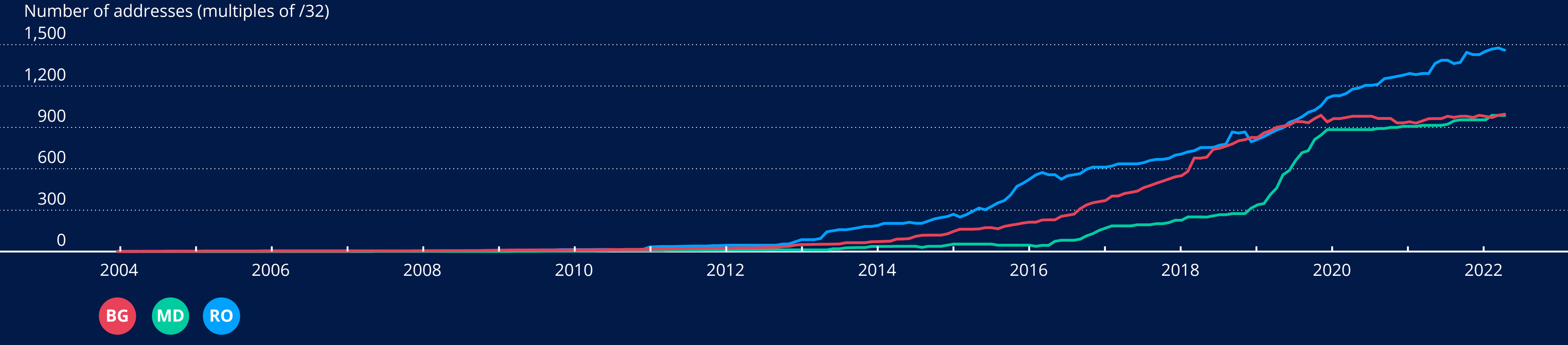
When it comes to mobile subscription rates, Bulgaria's and Romania's are closer to the European average, while Moldova's rate is lower. Although mobile data is relatively expensive in other parts of eastern Europe, Moldova has the seventh-cheapest mobile data services in the world, according to one source, which would suggest that cost is not the major contributing factor.[13] However, it's possible that cost may play a larger role than it seems, given the country's lower GDP per capita compared to its neighbours.

While we see broadband subscription rates continue to increase, mobile subscriptions have plateaued for more than a decade, not only in the three countries but also throughout the EU, which is likely an effect of market saturation.

While all three countries have moderate amounts of IPv4 address space to serve their populations, IPv4 run-out means that broadband providers will struggle to serve their growing numbers of customers and, with more mobile customers than IPv4 addresses, mobile providers are likely relying on address-sharing techniques to serve even their current customer base. Technical workarounds that allow multiple users to share a single IP address, such as carrier-grade network address translation (CGN), are in widespread use in mobile broadband connectivity. However, there are well-documented drawbacks to address-sharing technologies, and deploying IPv6 remains the only sustainable strategy for accommodating future growth and reaching the EU's 2030 connectivity targets[14] – not to mention supporting emerging technologies such as 5G, the Internet of Things, smart cities and more.

13 https://www.cable.co.uk/mobiles/worldwide-data-pricing/
14 https://futurium.ec.europa.eu/en/digital-compass/digital-infrastructures

Figure 8:
IPv6 holdings over time



IPv6 in Bulgaria, Moldova and Romania

Usually, we see the amount of IPv6 in a country roughly correspond to (though not equal) its IPv4; however, we see a significant deviation here, with Moldova holding much more IPv6 space in comparison to its IPv4 holdings. We see Moldova's particularly steep growth in 2019 in figure 8. 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 seems to be the case with the three countries in this report, particularly Moldova. Out of the 139 IPv6 blocks registered to Moldova at the start of 2022, only 29 (or 21%) are seen in the routing system. For both Romania and Bulgaria, we see 44% of their IPv6 blocks being routed. Given the high number of additional LIRs we see in Moldova at the end of 2019, it's likely that RIPE NCC members opened these additional LIR accounts to obtain their final IPv4 allocations and took the opportunity to obtain an IPv6 allocation at the same time (which is standard procedure), even though they had no immediate use for it.

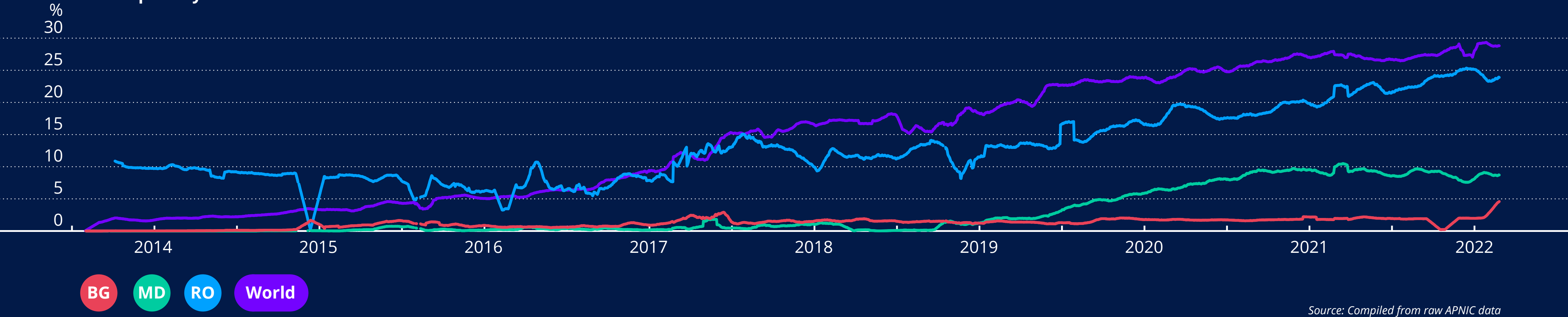
There is very little market consolidation in IPv6 in the three countries, with small amounts of IPv6 spread out among different organisations, rather than a small number of organisations holding a significant percentage of the country's IPv6 space.

Despite the amount of IPv6 held by the three countries, we see adoption rates of only 2-4% in Bulgaria and 7-9% in Moldova, while Romania stands at 23-27%, which is closer to the world average of 30-37%.[15] When the RIPE NCC reached its final /8 of IPv4 address space in 2012, Romania led the world in IPv6 adoption. This was due in large part to one of the biggest providers in the country, RCS & RDS, deploying IPv6 to its customers in time for the World IPv6 Launch in June 2012.[16] However, after Romania quickly reached a 10% adoption rate, deployment plateaued and there was no further significant increase until 2017, when the country started to make gains once more.

15 *Note that exact figures differ between organisations, which use different measurement methodologies. Sources: APNIC: https://stats.labs.apnic.net/ipv6*
Facebook: https://www.facebook.com/ipv6
Google: https://www.google.com/intl/en/ipv6/statistics.html#tab=per-country-ipv6-adoption

16 *https://www.internetsociety.org/resources/deploy360/2014/case-study-how-romanias-rcsrds-deployed-ipv6/*

Figure 9:
IPv6 capability over time



Source: Compiled from raw APNIC data

We can see the evolution of IPv6 capability for the three countries in comparison to the world average in figure 9. Unfortunately, the data is only available starting in October 2013, after the significant increase in IPv6 capability that began in Romania in 2012. Still, it is very clear how Romania scored above the world average until 2016, and how it has continued to increase in line with the world average in the years since. (We don't have any information about the temporary drop seen at the end of 2014.) Meanwhile, we see moderate improvements in Moldova between 2019 and 2021, and very recent progress in Bulgaria, which increased from about 2% in February 2022 to around 5% by the end of March. The data suggests this increase was due to Vivacom's adoption rates increasing from 1% to 10% during that time.

In trying to gain further insight, we look to the RIPE NCC Survey 2019,[17] which polled more than 4,000 network operators and other members of the technical community, including 124 total respondents from Bulgaria, Moldova and Romania.

A significantly higher proportion of survey respondents in the three countries (63%) said that they expect their organisation to need more IPv4 address space in the next two to three years compared to the total average among all survey respondents (53%). However, cost is clearly a factor in the region, with 42% listing the cost of buying IPv4 as the main challenge facing their organisation when it comes to IPv4 scarcity. While 17% of respondents in the three countries said they were fully deployed when it comes to IPv6 (compared to the survey average of 22%), another 22% said they had no plans (in line with the survey average of 23%) and another 48% said they had or were working on a plan, were currently testing, or had just started deployment.

However, while 44% of respondents in Bulgaria, Moldova and Romania collectively said they plan to obtain IPv4 on the secondary market and 19% planned to move to IPv6, these figures are significantly lower than the total survey average across all respondents of 61% and 37%, respectively – indicating that while the price of IPv4 address space on the current secondary market may be cost-prohibitive for many providers in the region, deploying IPv6 doesn't appear to be a priority either. The reasons given for not deploying IPv6 were a mix among respondents from the three countries, 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. From those we spoke to in the industry, there's little sense of community and information sharing among the technical operators in Bulgaria and Moldova, although Romania does have an active NOG (RONOG). Perhaps this contributes to less of a push for IPv6 deployment in Bulgaria and Moldova in particular, with many operators seeing little business incentive to make the switch from IPv4 and, in some instances, lacking the technical expertise or an ability to share best practices that would further support deployment.

17 https://www.ripe.net/survey

Domestic and International Connectivity

Domestic Connectivity Between Networks

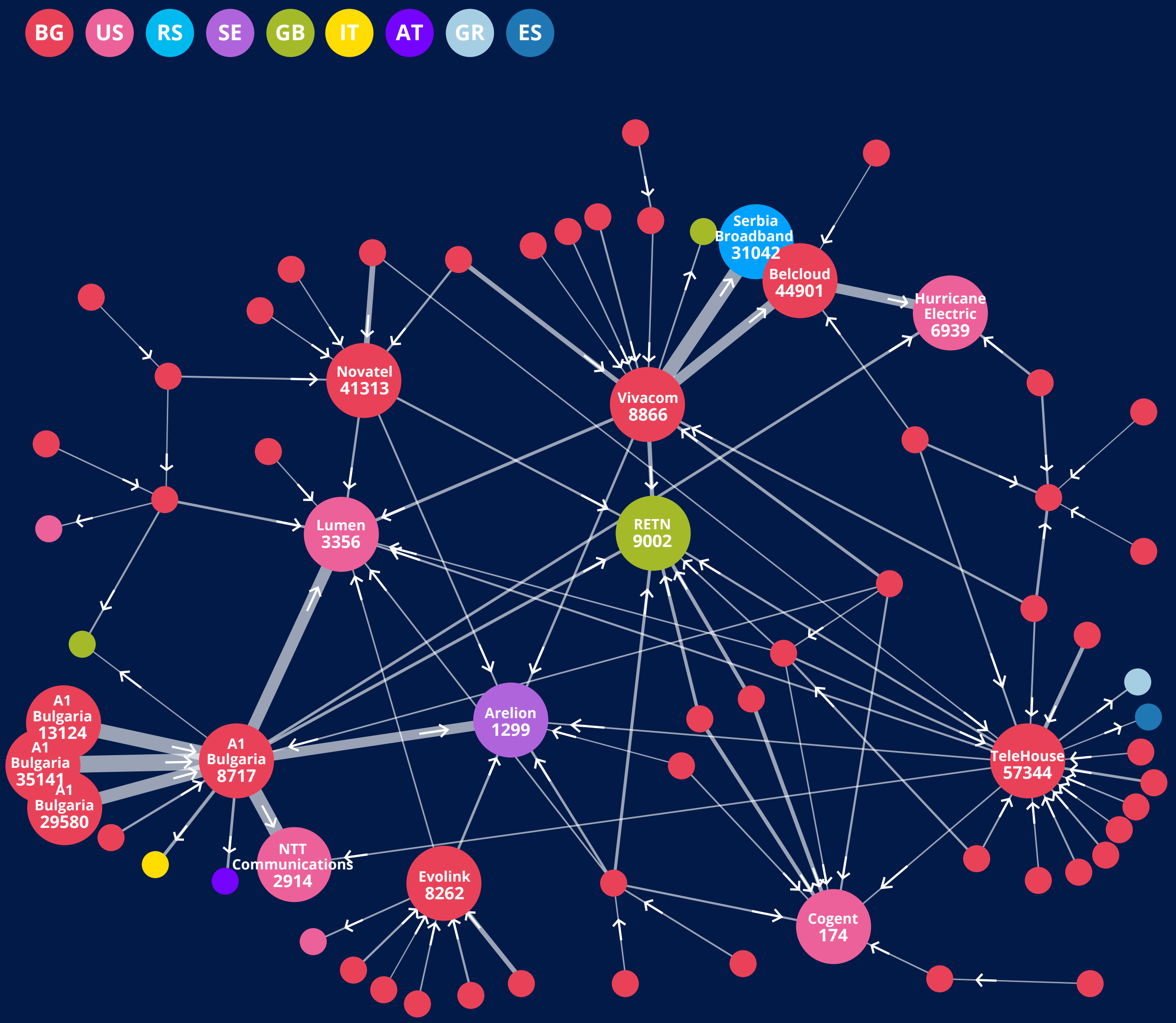
To understand the relationships that exist between different networks, we can investigate the interconnections within each of the countries using data from the RIPE NCC's Routing Information Service (RIS), which employs a globally distributed set of route collectors to collect and store Internet routing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

For each country, we plot how the routes propagate from one network to another (arrows indicate the direction of BGP flow, 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 three countries in this report all have a fairly large number of ASNs, the following network diagrams have been restricted to the top 100 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 Bulgaria**



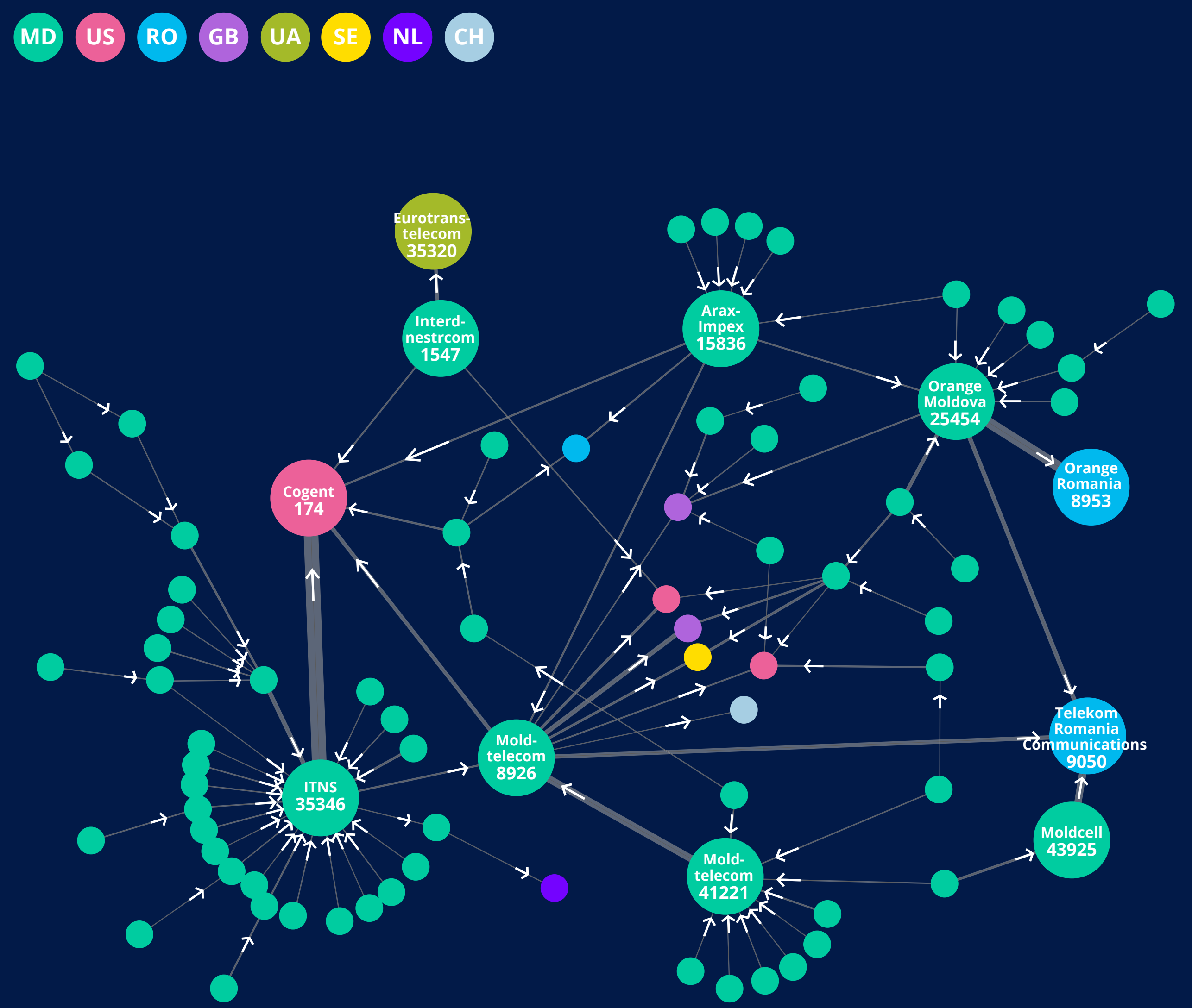
In Bulgaria, we see how A1 Bulgaria operates with four major networks. AS8717 is the main network that provides international connectivity, while AS13124, AS35141 and AS29580 receive connectivity via AS8717. This could have been done to accommodate different business units, but hints at a history of mergers and acquisitions. For example, AS13124 was originally assigned to blizoo, the cable operator that A1 Bulgaria acquired in 2015.

We can also see how Vivacom (AS8866), TeleHouse (AS57344), Evolink (AS8262) and Novatel (AS41313) play a major role in connecting other Bulgarian networks. (We also note that Bulgarian Telecommunications Company, BTC, is still listed as the owner of AS8866 in the RIPE Database, but is referred to as Vivacom throughout this report.)

In terms of international connectivity, Cogent (AS174), Lumen (AS3356), RETN (AS9002) and Arelion (formerly Telia Carrier, AS1299) stand out, with each connecting between seven and nine domestic networks in this view (and even more networks when we look beyond the top 100 paths). NTT Communications (AS2914) and Serbia Broadband (AS31042) are connected to fewer Bulgarian networks, but we do see a significant number of paths passing through them.

Also noteworthy is that Bulgarian Belcloud (AS44901) plays a significant role in Vivacom's connectivity. Belcloud, in turn, mostly relies on Hurricane Electric (AS6939) for transit, making Vivacom indirectly dependent on Hurricane Electric as well.

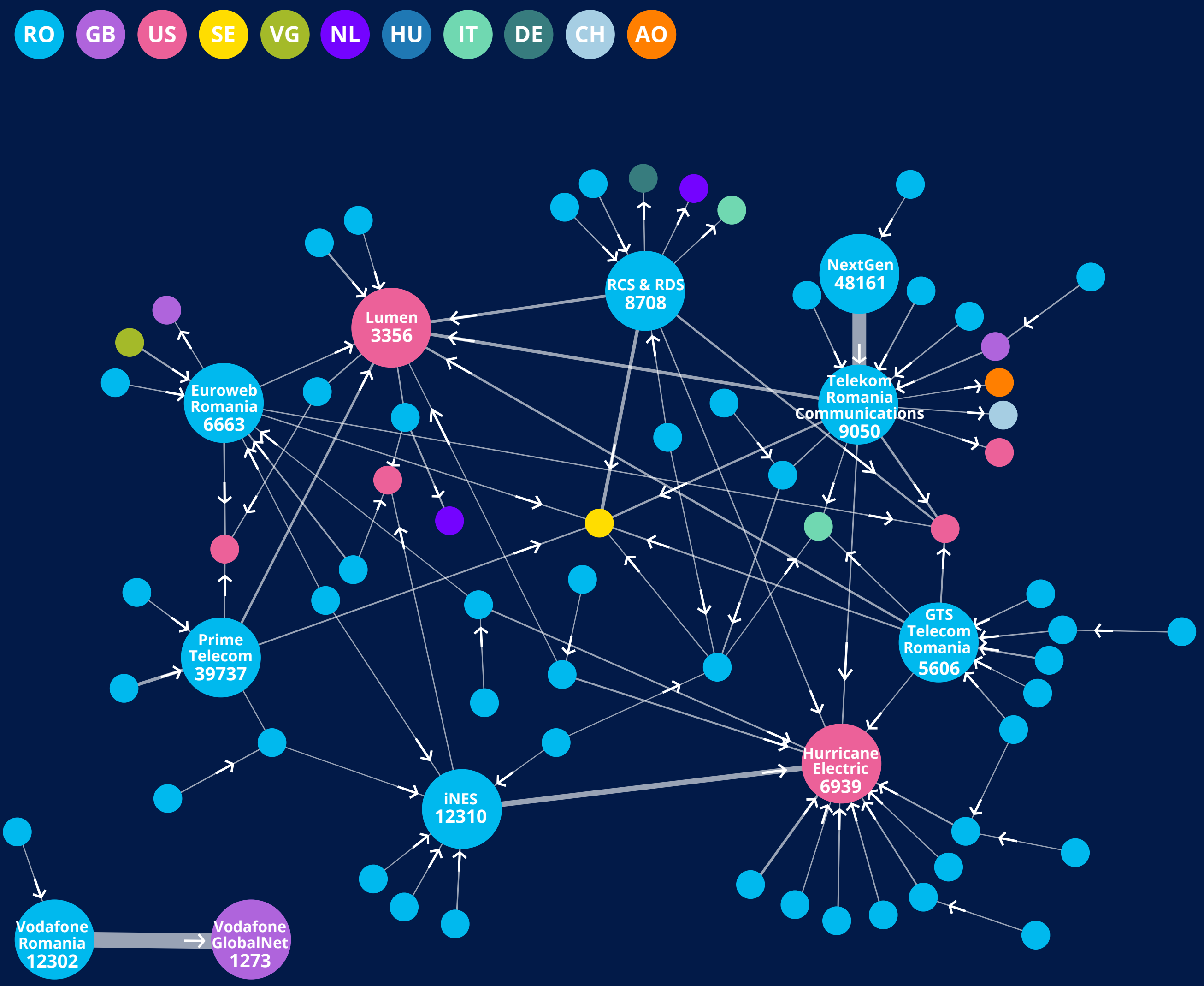
Figure 11:
Connectivity between networks in Moldova



In Moldova, we find ITNS (AS35346) provides connectivity to many local networks, which is what we expect for a company that provides IT services and solutions to corporate customers. Figure 11 shows how ITNS strongly depends on Cogent (AS174) for international connectivity. We also see how Moldtelecom (AS41221), Orange Moldova (AS25454) and Arax-Impex (AS15836) connect other networks to the wider Internet. Moldtelecom operates with two ASNs: the first (AS41221) provides connectivity to the local networks and the second (AS8926) connects to international transit providers, thus providing global connectivity to AS41221 and its customers.

It's worth noting how Moldovan networks also use service providers in neighbouring countries for their international transit. For example, Orange Moldova has a strong dependency on Orange Romania (8953), while Telekom Romania Communications (9050) (now Orange Romania Communications) provides transit to Moldtelecom, Orange Moldova and Moldcell (AS43925). Additionally, Interdnestrcom (AS1547) depends to a great extent on Eurotranstelecom (AS35320), which is based in Ukraine. (Interdnestrcom's other upstreams aren't visible here because they're not included in the top 100 most observed paths).

Figure 12:
Connectivity between networks in Romania



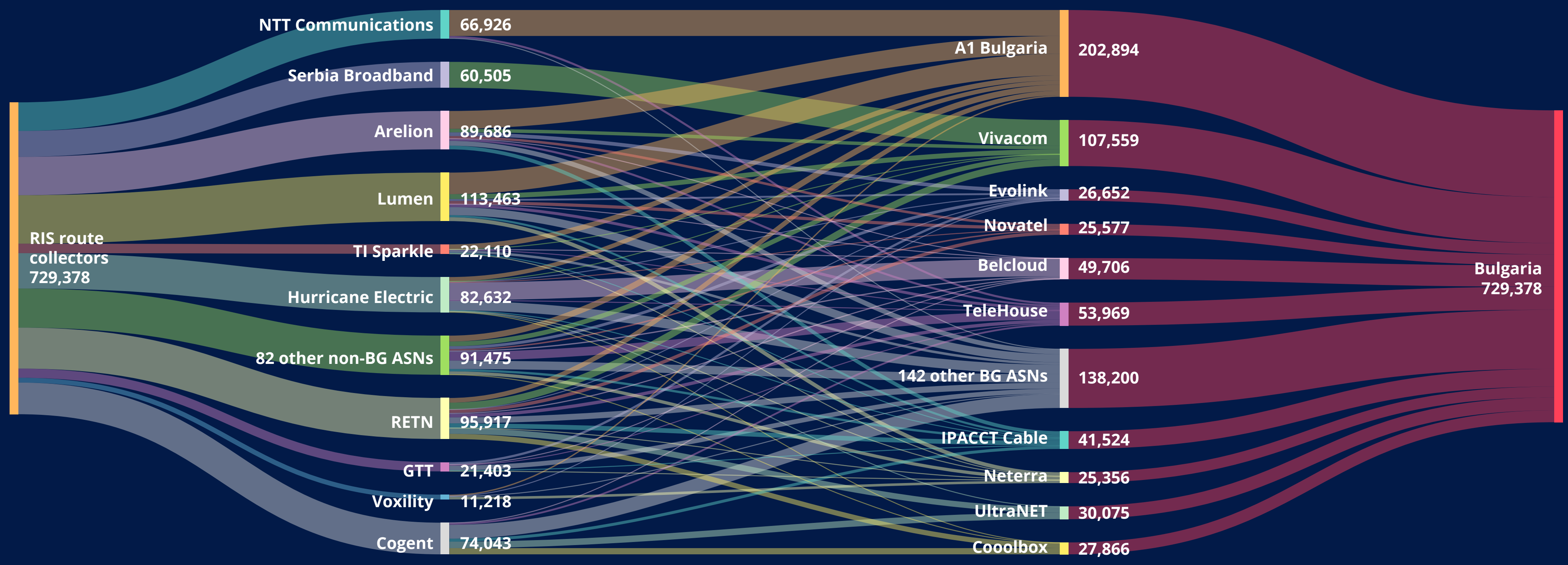
In Romania, we see somewhat less prominent clustering of local networks around the larger providers compared to Bulgaria and Moldova. Instead, we see more networks with a direct connection to a major international provider. Hurricane Electric (AS6939) stands out, with connections to 13 Romanian networks shown in figure 12, while the complete data shows that 79 Romanian networks are dependent on them in total – four times as many as are seen connecting to Lumen (AS3356).

The main Romanian providers connecting other domestic networks are RCS & RDS (AS8708), Telekom Romania Communications (AS9050), GTS Telecom Romania (AS5606), iNES (AS12310), Prime Telecom (AS39737) and Euroweb Romania (AS6663). Vodafone Romania (AS12302) also connects a sizeable number of small businesses, but as most of these links fall outside the top 100 most observed, they aren't included in figure 12. We do, however, see Vodafone Romania's heavy dependency on Vodafone's global backbone network (AS1273).

Finally, the connection between Telekom Romania Communications and NextGen (AS48161), which holds the fifth largest number of IPv4 addresses in the country, stands out clearly. In the full data, we also see a small number of paths from NextGen through GTS Telecom and Euroweb Romania.

A visualisation of domestic Internet connectivity, like we see in these figures, should resemble a deeply interconnected web, with a large distribution of paths and interconnections that lack clear choke points or bottlenecks. Indeed, this is generally what we see in Bulgaria, Moldova and Romania, although we do see some heavy dependencies on certain upstream providers.

Figure 13:
Bulgaria's international connectivity



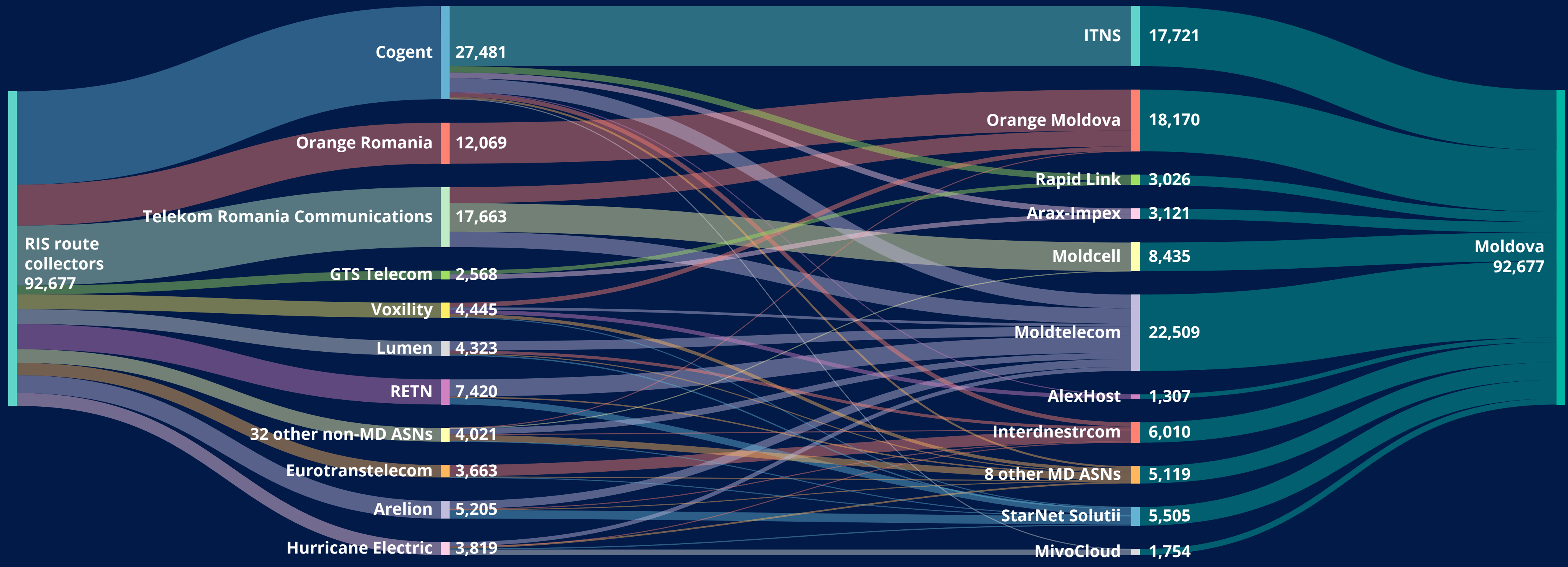
International Connectivity

Extending our view, we now look beyond domestic connectivity to examine how the three countries connect to the rest of the world. To investigate this, we again turn to the RIPE NCC's Routing Information Service (RIS). We look at the routes collected by RIS for IP networks in each country and identify the last foreign and first domestic network encountered in these paths. This gives us an overview of which operators provide international connectivity into each country. The numbers listed in these figures are the number of routes that include each network.

The main operators in Bulgaria all have a variety of upstream providers. A1 Bulgaria largely depends on NTT Communications, the Swedish provider Arelion (formerly Telia Carrier) and Lumen (which acquired Level 3), but we also see paths through TI Sparkle, Hurricane Electric and RETN.

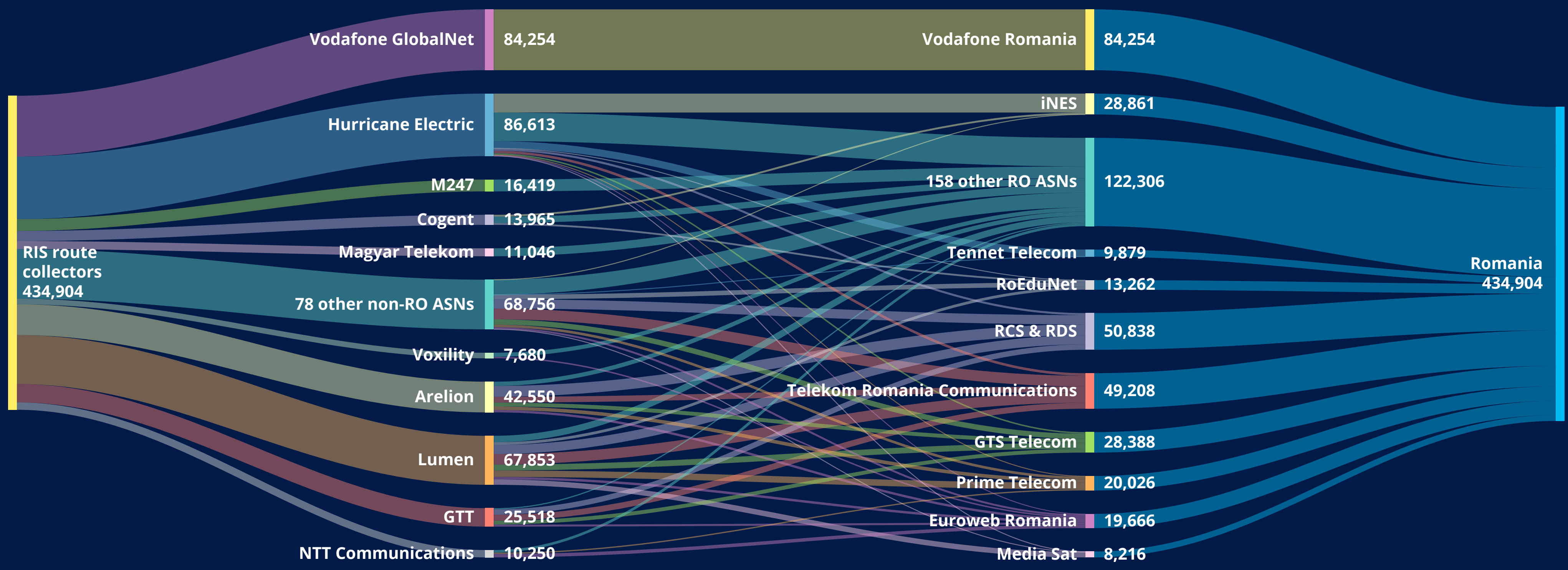
In looking at Vivacom, we see Serbia Broadband as the most used international upstream provider, followed by RETN and Lumen. The connection between Vivacom and Serbia Broadband makes sense, as United Group owns both. Vivacom indirectly also has international connectivity via Belcloud, which we see predominantly receiving transit from Hurricane Electric.

Figure 14:
Moldova's international connectivity



In Moldova, we see a mixed picture. Moldtelecom, Interdnestrcom and StarNet Solutii have diverse international connectivity, including to well-known transit providers Cogent, Lumen, RETN and Arelion, among others. Interdnestrcom also receives connectivity from the Ukrainian provider Eurotranstelecom. On the other hand, INTS is seen to rely exclusively on Cogent, while Orange Moldova appears to rely heavily on Orange Romania and Moldcell is seen to rely almost exclusively on Telekom Romania Communications.

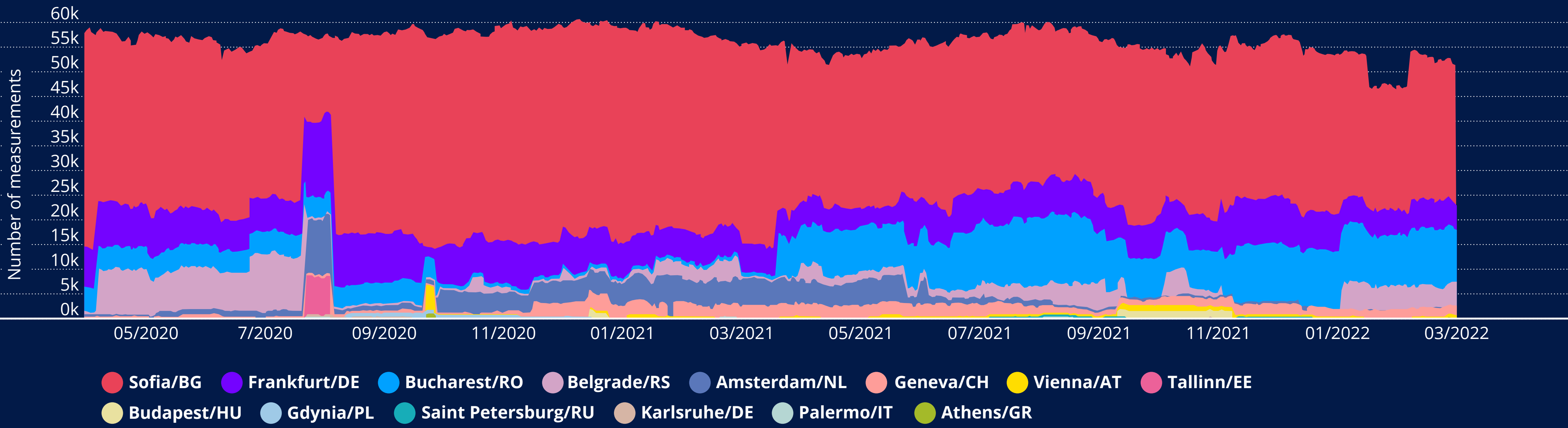
Figure 15:
Romania's international connectivity



In Romania, we see a variety of upstream providers for the local ISPs. Hurricane Electric, Arelion, Lumen and GTT are the primary transit providers. As an exception, we see that Vodafone Romania relies exclusively on its parent company's global network for international connectivity.

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 three countries included in this report, and particularly in Bulgaria and Romania, the visualisations paint a positive picture. In Moldova, we see a few heavy dependencies on just one or two upstream providers, which could be improved by multihoming to additional providers.

Figure 16:
K-root locations reached from requests originating in Bulgaria, Moldova and Romania over time (IPv4)



Domain Name System, Traffic Paths and Routing Security

Reaching the Domain Name System

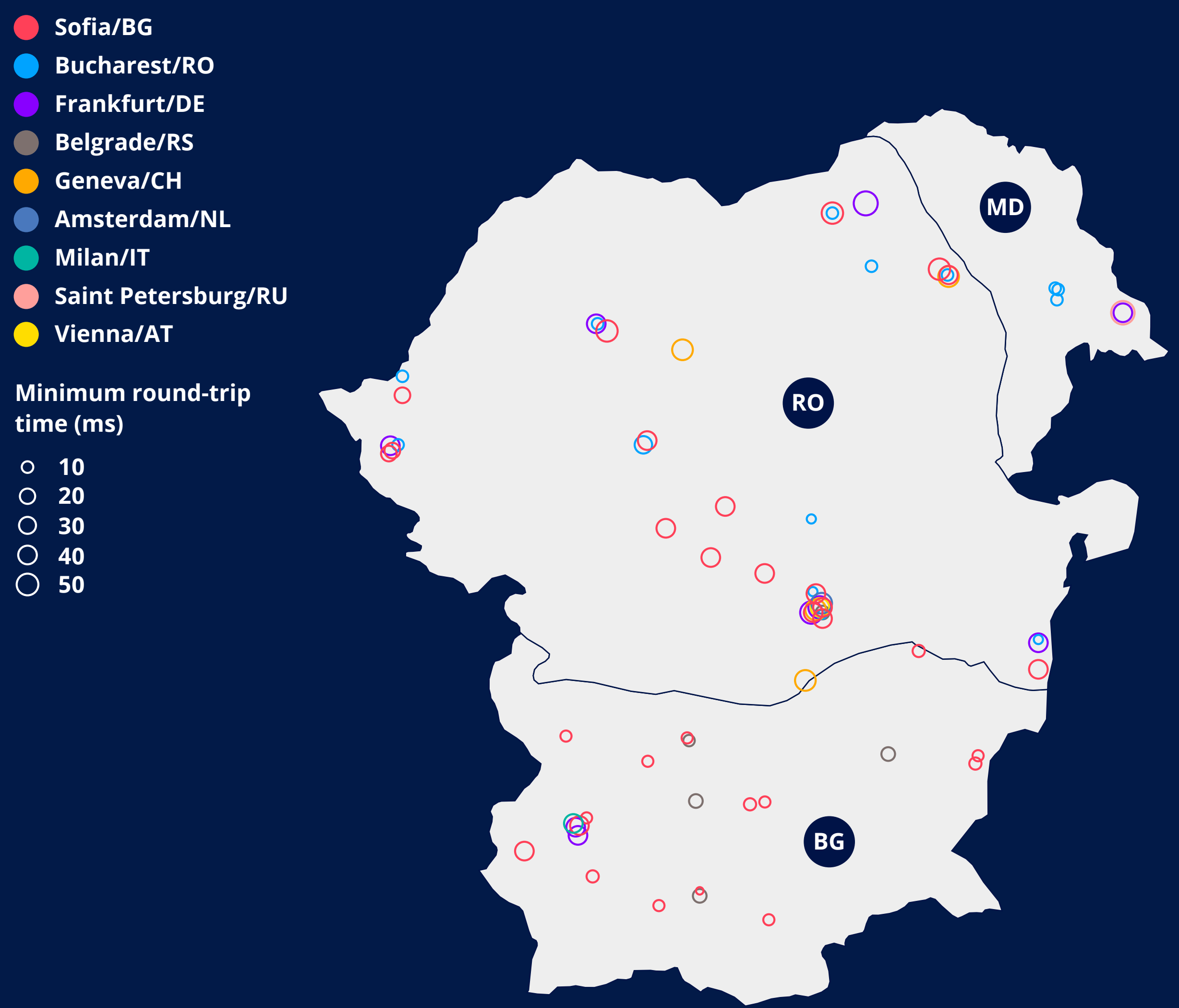
Turning now to investigate how traffic is routed to, from and within Bulgaria, Moldova and Romania, we first examine which local instances of K-root are queried from requests originating in the three countries. This gives us some insight into how the routing system considers the various options and decides 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 two K-root instances hosted in the region: one in Sofia and one in Bucharest. As seen in figure 16, the instance in Sofia is heavily favoured, with the instances in Bucharest and Frankfurt handling the vast majority of the rest of the requests. Instances in Belgrade, Amsterdam and Geneva are also seen to a lesser degree at different times.

Figure 17:
K-root locations reached from vantage points in Bulgaria, Moldova and Romania

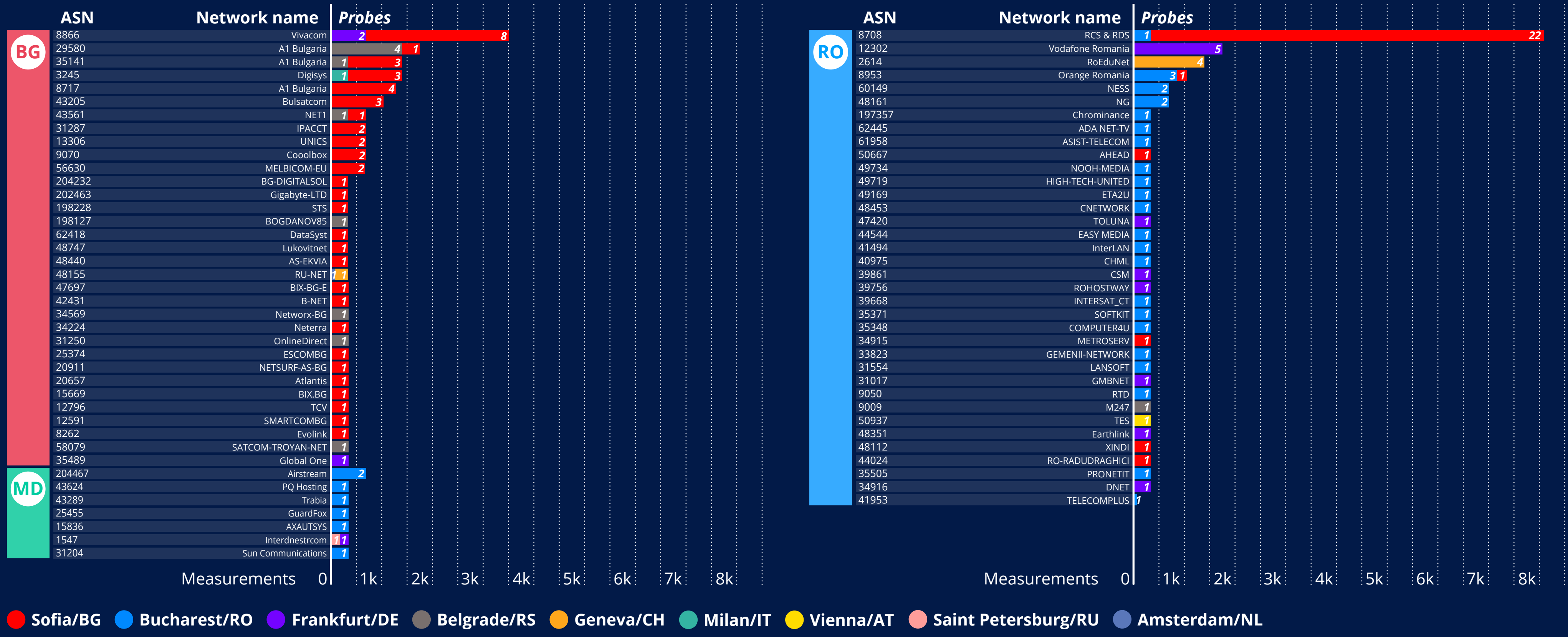


We also looked into which K-root instances were queried by RIPE Atlas probes in the three countries on a given day, as shown in figure 17. It's not surprising to see that the vast majority of probes in Moldova queried the K-root instance in Romania, given that Moldova doesn't host a K-root instance within its borders. However, it's interesting to note that slightly more probes in Romania reached the K-root instance in Sofia than the one in Bucharest, even though a large number of the RIPE Atlas probes were located in Bucharest as well. The round-trip times we see for the probes in Romania that reached Sofia are also higher than we would expect, given the geographical proximity between the two. This may indicate that the packets are not following the shortest path, but are instead being routed via an exchange point abroad before reaching Sofia.

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.

Figure 18:
K-root locations reached from different networks in Bulgaria, Moldova and Romania (IPv4)

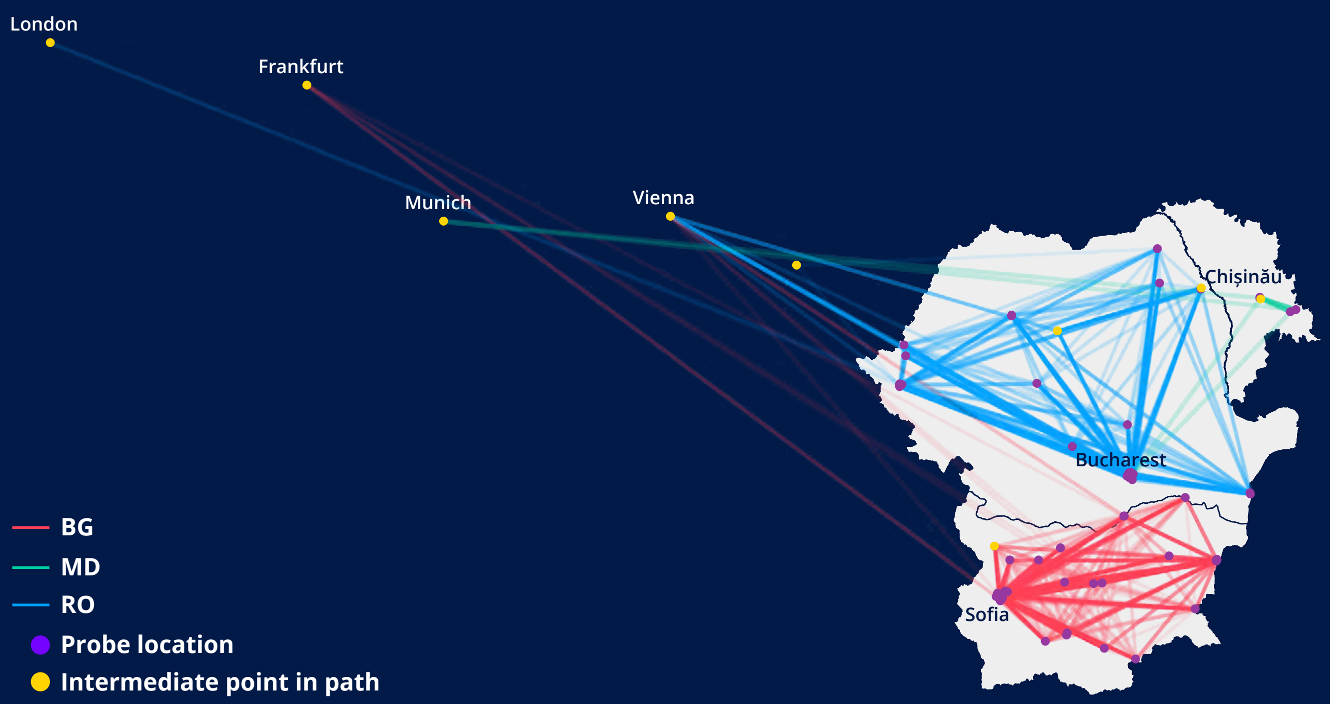


To investigate this further, we looked at which K-root instances were reached by probes in different networks within each country (for those networks that host at least one RIPE Atlas probe). While probes in a few different networks in Romania reached the K-root instance in Sofia, we can see that the vast majority of those measurements originated in a single network: RCS & RDS. As there doesn't appear to be an obvious link between RCS & RDS and Bulgaria, it's unclear why the probes in this network would prefer the K-root instance in Sofia over the one in Bucharest.

We should note that these results, while considered generally representative, offer only a snapshot of measurements made on a single day in March 2022. Given BGP's dynamic nature, results can change constantly due to subtle changes in routing.

While some of the instances reached weren't the absolute closest in geographical terms, none were far away and all resulted in very fast response times. In general, we can say that K-root access in all three countries appears to be very well optimised compared to what we've seen in other countries we've looked at in our country reports.

Figure 19:
Paths between origin and destination in the same country for Bulgaria, Moldova and Romania (IPv4)



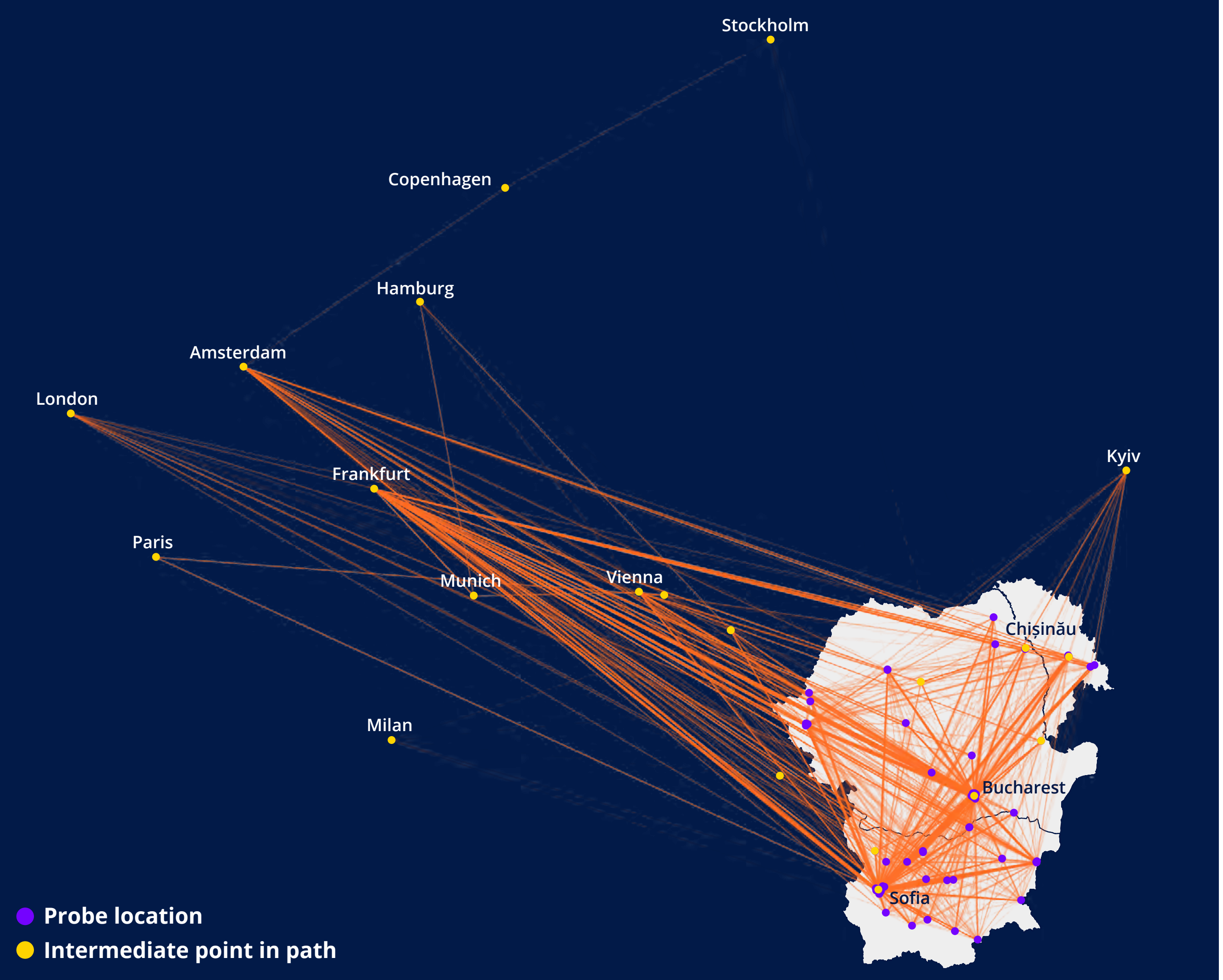
Regional Traffic Exchange

Again using data from the RIPE Atlas measurement network, we can investigate how some of the networks in the three 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 within each country. Figure 19 shows the location of the probes (indicated by the purple dots), the intermediate points detected in the traceroutes (indicated by the yellow dots) and the paths followed by the traceroutes (indicated by red lines for Bulgaria, green lines for Moldova and blue lines for Romania).

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.

We can see how, generally speaking, most of the domestic traffic stays inside each country. Some paths, however, take a detour via Vienna, Munich, Frankfurt or London. In addition, some of the traffic between probes in Moldova goes through neighbouring Bucharest. While not ideal, the distance is much shorter than diverting traffic to major IXPs in western Europe – something we commonly see in the other countries in the RIPE NCC service region that we've looked at – so the impact on round-trip times will be limited.

Figure 20:
Paths between origin and destination in the region (IPv4)



Next, we expand our measurements to include traceroutes between probes throughout all three countries in order to get a better understanding of how traffic is exchanged within the region as a whole. We can see that a lot of the traffic still remains within the region, relying on such connections as that between Bucharest and Sofia. However, we also see regional traffic relying much more on foreign IXPs, particularly those in Amsterdam, London and Frankfurt. This suggests that the ISPs hosting these probes, or their respective transit providers, do not peer locally much, but instead exchange traffic at the major exchange points in western Europe.

It's worth noting 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 three countries.

Routing Security

Beyond looking into the different routes available to traffic originating in the region, we can also investigate routing security in the three countries 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,

Figure 21:
IPv4 address space covered by RPKI over time

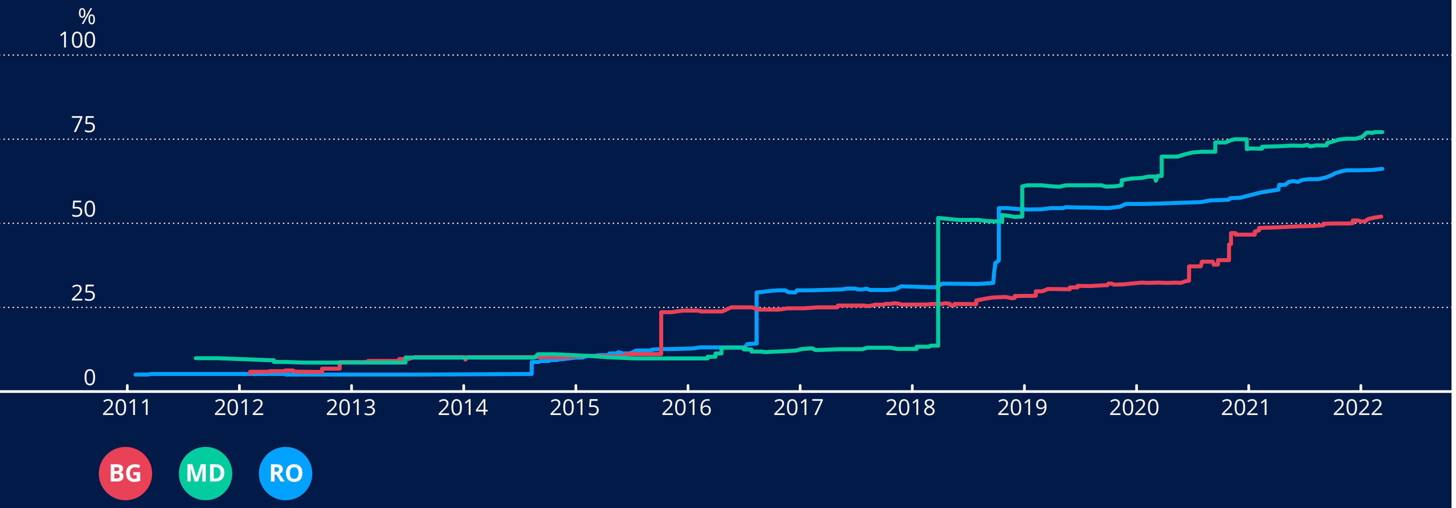
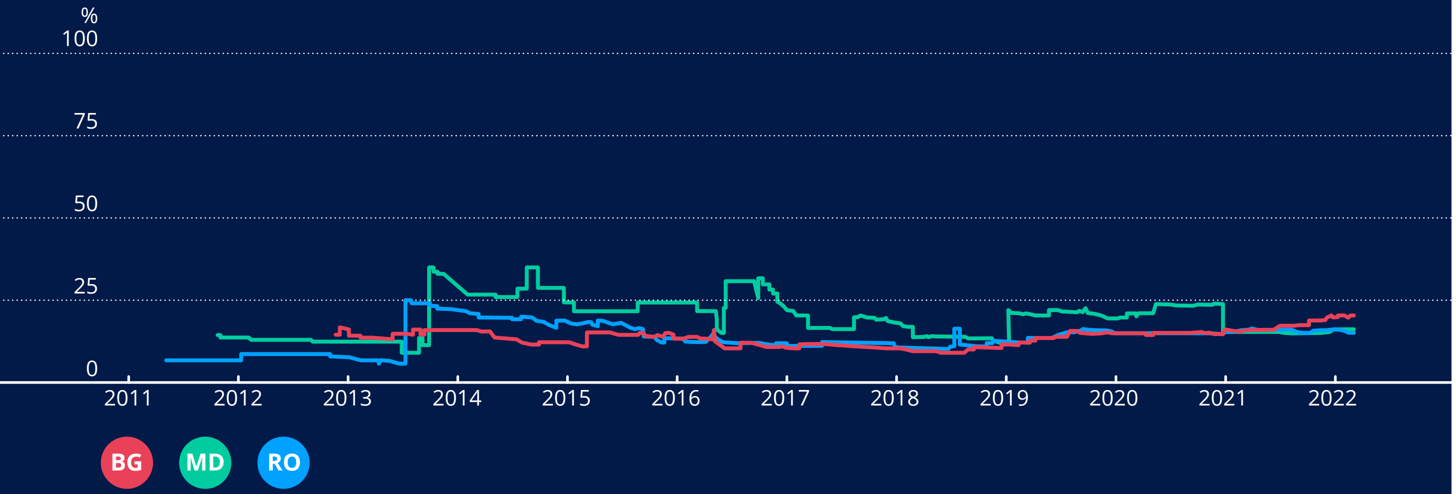


Figure 22:
IPv6 address space covered by RPKI over time



ASNs, and related information for hostnames and countries – we can see what percentage of a country's IPv4 address space is covered by ROAs.

We see moderate coverage of IPv4 address space with RPKI in Bulgaria, Moldova and Romania in figure 21. In comparison to other countries we've looked at in our country report, the level of uptake in these three countries is lower than we saw in France, Greece and Portugal but significantly higher than in Spain and Italy.

As large operators begin creating ROAs for their address space, we can see large jumps in the overall uptake within the individual countries, including Vivacom in September 2015, Telekom Romania Communications in August 2016, Moldtelecom in March 2018, and RCS & RDS in September 2018.

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. The amount of IPv6 address space that is covered by RPKI is very similar in Bulgaria, Moldova and Romania.

Conclusion

Bulgaria, Moldova and Romania all benefit from competitive and diversified markets that have contributed to inexpensive broadband connectivity and fast broadband speeds. Despite this, broadband and mobile Internet penetration remains low compared to the rest of Europe, and large urban-rural divides remain a significant obstacle in boosting connectivity across the region. Further investment in infrastructure is likely needed in order to reach the EU's 2030 connectivity targets.

While the countries hold large amounts of IPv6, all three (but particularly Bulgaria and Moldova) lag behind the world average in IPv6 capability, despite the fact that Romania led the world in 2012. A lack of business incentive along with a lack of technical expertise appears to be a contributing factor to low IPv6 capability rates. We've seen how, both in Romania and more recently in Bulgaria, deployment by just a single large provider can improve a country's overall capability rates. Stimulation measures on the part of public authorities and community incentivisation from local NOGs and IXPs have also played a significant role in boosting IPv6 adoption among all providers within other countries in the RIPE NCC service region – factors that we don't see as much evidence for in the three countries in this report and which would likely help improve IPv6 adoption rates, as well as other things like routing security.

Routing is quite well optimised in the three countries, with almost all domestic traffic paths staying within national borders. However, we see regional traffic paths between countries detouring to Internet exchange points in western Europe rather than taking advantage of local exchange points, which would further reduce response times and decrease dependency on foreign infrastructure.

The networks in each of the three 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 the upstream providers, ensuring resilient connections to the rest of the global Internet. However, there are a few cases where redundancy could be improved among individual networks by establishing connections to additional upstream providers to mitigate against potential disruptions by eliminating bottlenecks or single points of failure.

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 is 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 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 people for providing additional background information included in this report around the Internet landscape in Moldova and Romania:

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