REPORT

Making Cents of IPv4

Cost and Capacity Considerations on Using CGNAT, for Regional and Rural Service Providers

TABLE OF CONTENTS

INTRODUCTION — BRIDGING THE DIGITAL DIVIDE

Bridging the digital divide to provide broadband connectivity to unserved or under-served communities is an economic and technical challenge for service providers across the globe — the pandemic has intensified the urgency to address the inequities and dilemmas of uneven broadband access. Worldwide, this urgent need has resulted in many government-led funding initiatives to spur the build-out to these communities with many service providers announcing new network initiatives in response.

A Critical Capability, if Overlooked, Adds Long-Term Cost

Major broadband initiatives have many build-out funding priorities. One critical capability that can add unexpected cost is the need for IP addresses for their subscribers. Operators that overlook this critical capability in their build-out strategy risk being subjected to high price and scarce availability of IPv4 addresses and may miss the opportunity to create a more efficient plan for eventual migration to IPv6. Across the globe, IPv4 addresses have been fully allocated, and the cost of addresses on the open market has skyrocketed. Now, just adding 10,000 new subscribers could cost as much as $320,000 or more for additional IPv4 addresses — a cost that could be applied to other build-out priorities and will continue to increase as the subscriber base grows over time.

A More Efficient Approach

Carrier-grade network address translation (CGNAT) allows for the oversubscription of IPv4 addresses so that one IPv4 address can serve many subscribers. This enables cash-strapped communications service providers to extend existing IPv4 investments and minimize the cost of additional IPv4 addresses.

> This report provides analysis and reference tables to aid service providers evaluating their IPv4 options and starting a plan for IPv6 migration.

ADDING
10,000 NEW SUBSCRIBERS

MAY COST
$320,000
FOR ADDITIONAL IPv4 ADDRESSES

GLOBAL RUSH FOR BROADBAND

Service providers are expanding their coverage and services to support more subscribers and households. The following is a summary of global status of internet access and infrastructure initiatives to narrow the digital divide.

Underserved Rural America

In the US, somewhere between six and 12 percent of the population — as many as 42 million people primarily located in rural areas — do not have access to or cannot afford broadband internet service.[1] Recent FCC-led initiatives such as the Rural Development Opportunity Fund (RODF) and Connect America Fund (CAF) are intended to encourage broadband network buildout to those unserved and underserved populations.

The Digital Divide in Europe

In the EU, household broadband access coverage increased to 86% in 2019. Rural areas remain challenging as 10% of households are not covered by any fixed network and 41% are not covered by any next-generation access technology.[2] The EU supports many member initiatives to expand broadband coverage, including the European Investment and Structural Funds I(ESIF), the European Fund for Strategic Investment (EFSI) guarantees and European Investment Bank (EIB) lending and Connecting Europe Broadband Fund (CEBF), and others.

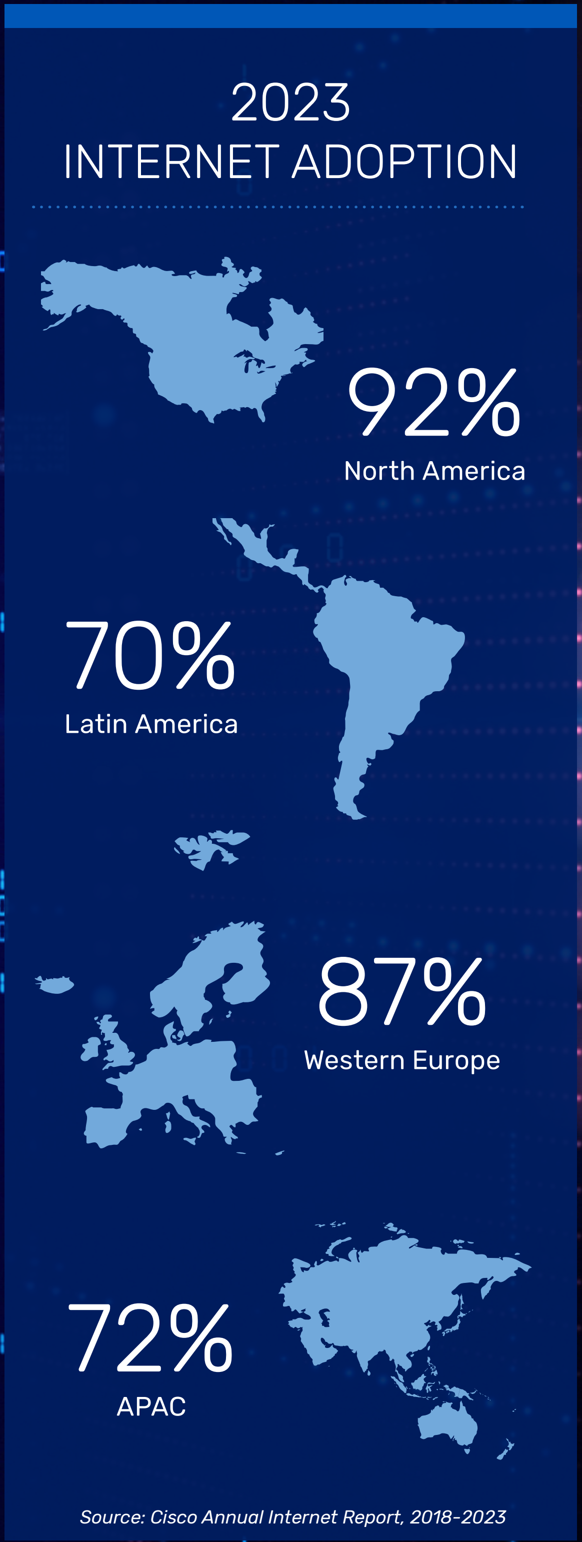
The Pandemic Widens the Gap in Latin America

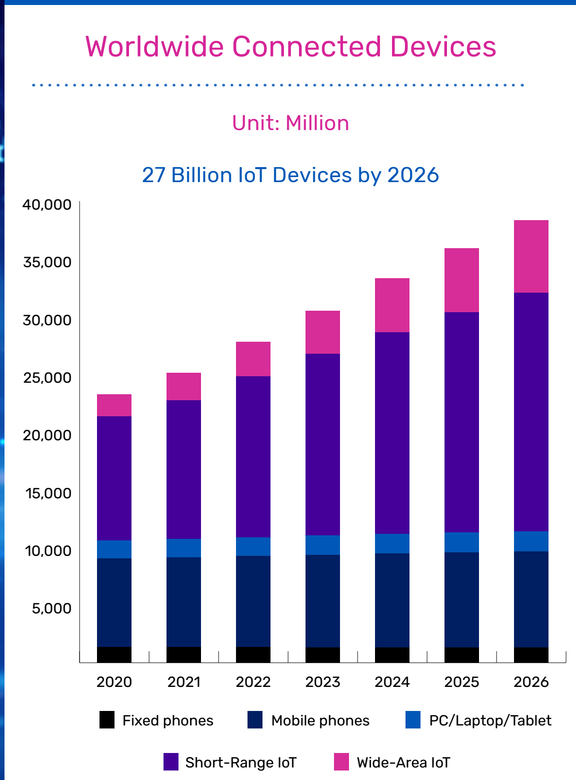
Latin America is quickly becoming one of the most connected regions of the developing world, with nearly 70 percent of its population connected to the internet and fast-growing mobile adoption. However, many groups living in rural, indigenous, and low-income communities lack the same level of access and have been forced to shut down entirely due to the pandemic, losing access to remote healthcare and critical public health information at a time of urgent need.

APAC — Furious Buildout is Needed

In 2020, almost half of the population of Asia-Pacific (1.9B) lacked access to the internet.[3] As the connected populations relied on the internet during the pandemic for services and economic activity, the unconnected populations were cut off. Demand for infrastructure development had been growing steadily. The Asia Development Bank in 2019 estimated that the region's infrastructure development would require an investment of $1.7 trillion annually until 2030. By 2023, the rapid growth in connected populations is expected to reach 72%.

[1] Bloomberg, *"There are far more Americans without broadband access than previously thought"*, February 2020
[2] European Commission: *DESI 2020 Internet Index*
[3] *Data Reportal*, *We are Social, and Hootsuite: DIGITAL 2020: GLOBAL DIGITAL OVERVIEW*





Source: Ericsson (November 2020)

HOW MUCH WILL MY NETWORK GROW?

The first step in any network-related economic analysis is to determine the growth of subscribers, traffic, and devices. This section provides some industry trends to consider.

Subscriber, Traffic, and Device Growth Trends

According to Ericsson, global connections and traffic volume is growing faster than the population (1%) and mobile subscriptions (2%) or internet subscribers (6%). In developed countries such as the U.S., mobile subscriptions are expected to grow at 2% or less for the next five years, but mobile data traffic will grow at 25-28% annually. Worldwide, the number of connected devices will increase by 8.7% annually, driven by IoT.

Average Number of Connections per capita

Region	2018	2023
Global	2.4	3.6
Asia Pacific	2.1	3.1
Central and Eastern Europe	2.5	4.0
Latin America	2.2	3.1
Middle East and Africa	1.1	1.5
North America	8.2	13.4
Western Europe	5.6	9.4

Source: Cisco Annual Internet Report, 2018-2023

Implications to IPv4 Economics

Many regional or rural broadband communications service providers have built their networks on IPv4, simply dedicating a public IP to every subscriber/household served or by using basic NAT. Basic NAT could include a home router/cable modem that can support multiple devices within a household with one public IP and multiple private IP addresses. Therefore, the number of IPv4 addresses required is roughly equivalent to the number of subscribers or households served.

As regional ISPs expand coverage to previously unserved areas, acquire new subscribers through acquisition, or respond to increased demand for upgraded broadband access from existing subscribers, the original allocation of IPv4 addresses may soon be inadequate. For these regional or rural ISPs, the growth rate of subscribers or homes passed may be significantly higher than the national average. Communications service providers will need to consider the long-term growth of their subscriber base when considering any additional purchase of IPv4 address blocks.

HOW MUCH WILL THE NEEDED IPv4 ADDRESSES COST?

The “free” IPv4 addresses from the Regional Internet Registries (RIRs) have now been fully allocated. Today, almost every block has been assigned to some entity. RIPE (the Regional Internet Registry for Europe, the Middle East and parts of Central Asia) made its last 22-block assignment in November 2019.

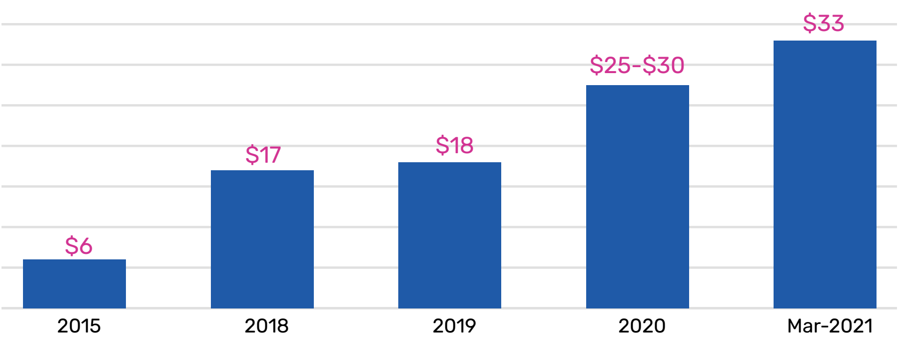
Technically, IP addresses cannot be bought or sold. According to the American Registry of Internet Numbers (ARIN), IPs are not purchased or sold but rather exchanged between two organizations. Organizations in possession of RIR-allocated IPs essentially transfer the rights to use and register IPs to other organizations.

IP addresses can be transferred for a one-time fee or leased for a specified period (e.g., monthly). IP addresses are transferred in blocks, usually through a broker and a bidding process. In addition to the costs for the IP blocks themselves, which vary by size of the block and other supply/demand factors, there are RIR transfer fees which vary by RIR. On the open market, the cost of IPv4 addresses has risen sharply over the last few years and is expected to continue to rise in the coming years as demand exceeds supply.

IP Block	IPv4 #	Aver. Per IP	Average Per Block
/24	256	$26.35	$6,746
/23	512	$26.54	$13,588
/22	1,024	$27.97	$28,641
/21	2,048	$30.09	$61,624
/20	4,096	$27.89	$114,237
/19	8,192	$29.20	$239.206
/18	16,384	$26.83	$439,583

Figure 1. Example Average Transfer Cost [4]

IPv4 Cost Trends



Source: IPv4.global, Hecifed

Today, IPv4 addresses cost up to $33 each.[5] By 2024, using the 23% annual growth rate of the last three years, the IPv4 address could increase to $61.

While it is possible to acquire additional IP addresses each year to align with expected growth, many communications service providers choose to obtain all needed IP addresses at one time for the foreseeable future to ensure quality and continuity of supply and to ease future configuration and deployment efforts.

[4] *Using ARIN 2021 transfers thru March 15, 2021. Source: https://auctions.IPv4.global/prior-sales*
[5] *Highest final price for /21 through RIPE, Source: https://auctions.IPv4.global/prior-sales*

Application	Concurrent Sessions	TCP	UDP
Facebook	17	11	6
YouTube	22	18	4
FB Video	13	11	2
Netflix	30	27	3
Chrome	94	89	5
Instagram	17	16	1
Google Play	8	7	1
WhatsApp	3	2	1
FB Messenger	20	15	5
SnapChat	29	19	10

Figure 2. Average Concurrent Sessions Used for Popular Applications

Calculation of Available IP Ports

65,536	IP Ports
- 1024	Reserved Ports
64,512	Available IP Ports

HOW MANY MAXIMUM CONNECTIONS CAN A SINGLE IPv4 ADDRESS SUPPORT?

Most devices, when connecting to the internet, will make numerous stateful and stateless connections, using hundreds or even thousands of concurrent sessions.

There is a practical limit to how many private IP addresses can be supported by a single public IP address. Defining that limit is an open question with many variables, but nevertheless it is one that communications service providers should evaluate. This section provides background information on key variables related to IPv4 traffic.

Concurrent Sessions

Since clients may use multiple connections and most connections will be TCP, a single subscriber or endpoint device can reasonably consume anywhere between one and many hundreds of concurrent sessions when active.

500 CONCURRENT SESSIONS
Estimated for heavy users, including browsing, social media, email and other applications.

TCP/UDP Limitations

TCP and UDP protocols define a hard limit maximum of 65,536 ports per IP address, but not all ports are available for use:

- **Ports 0 to 1023** are reserved for privileged services and designated as well-known ports and are not available for further allocation.
- **Network hardware such as routers, firewalls and CGNAT devices** routers, firewalls and CGNAT devices will have practical limits on the maximum number of simultaneous connections, as determined either by system resources or hard-coded limits.

The table shows expected number of concurrent sessions that popular applications will use.

HOW MUCH CAN I EXTEND MY IPv4 BLOCKS WITH CGNAT?

CGNAT enables oversubscription of IPv4 addresses — that is, multiple subscribers can "share" the same public IPv4 address. The amount of oversubscription, or the number of IPv4 addresses required to support the subscriber base, is driven by the hard limits or ports as described earlier and by:

- The total number of subscribers to be supported
- The percentage of subscribers that are active at the same time
- The number of IP ports needed for the type of traffic and usage supported

Practical Traffic Profiles for Oversubscription

Five traffic profiles are illustrated in the table here showing the range of oversubscription observed in practice.

- In the example profiles, a mobile operator could support only 21 active subs for every public IP, but a wireline operator could support as many as 64 or more active subscribers for every public IP.
- These profiles serve as a guideline and are based on industry experience and best practices of operator customers.

Representative Traffic Profile	Ports Needed	Oversubscription Level*
Light	250	258:1
Wireline – Low	1,000	64:1
Wireline – Med	1,500	43:1
Wireline – High	2,000	32:1
Mobile	3,000	21:1

Figure 3. Representative Oversubscription Levels Deployed in Service Provider Networks

These profiles are based on best practices of live service provider networks that have deployed CGNAT. Mobile networks typically have a lower oversubscription level due to the number of applications that frequently sync and update on a mobile smartphone.

To fine-tune their CGNAT configurations and determine the best model, operators should analyze their own network traffic.

Another consideration is the number of active subscribers. For example, if about 85% of subscribers are actively using the network at any time, then 15% of the assigned IPv4 addresses are inactive or underutilized. This number can, of course vary by service provider.

! **When using CGNAT, the level of oversubscription, number of active subscribers that can be supported for every IPv4 address, is calculated by dividing the total available IP ports (64,512) by the number of ports needed.**

IP Block	IPv4 #	Sell Price [6]	Net Revenue [7]
/24	256	$26	$5,358
/23	512	$26	$11,015
/22	1,024	$27	$23,201
/21	2,048	$31	$53,665
/20	4,096	$28	$97,185
/19	8,192	$29	$201.633
/18	16,384	$27	$375,713

Figure 4. Example Revenue from the Transfer of Excess IPv4

HOW CAN I LEVERAGE MY EXISTING IPv4 BLOCK?

Turn Costs into Revenue

With the oversubscription achieved through CGNAT, an operator may have more than enough IPv4 addresses to meet any foreseeable growth. If the operator determines that there are unused blocks, these can be sold or transferred through an IPv4 broker or the RIR. Each RIR has its own transfer fees, and the broker will charge commission.

Example revenue from the sale of IPv4 blocks is shown in the table. For example, a /22 block could be transfered for $23,201 or more, depending on the time frame, region, and quality of the IPv4 addresses.

Support Future Growth

With CGNAT, operators can avoid the cost of acquiring additional IPv4 addresses and still sustain growth.

Existing IPv4 address blocks and infrastructure can be leveraged to support future growth, based upon the desired level of oversubscription. The table here shows the number of subscribers that could be supported by IP block size while applying the traffic profiles described previously.

IP Block	Total IPv4 Addresses	Subscribers Supported by Traffic Profile				
		Light (258:1)	Wireline-Low (64:1)	Wireline-Medium (43:1)	Wireline-High (32:1)	Wireless (21:1)
/24	256	66,048	16,384	11,008	8,192	5,376
/23	512	132,906	32,768	22,016	16,384	10,752
/22	1,024	264,192	65,536	44,032	32,768	21,504
/21	2,048	528,384	131,072	88,064	65,536	43,008
/20	4,096	1,056,768	262,144	176,128	131,072	86,016
/19	8,192	2,113,536	524,288	352,256	262,144	172,032
/18	16,384	4,227,072	1,048,576	704,512	524,288	344,064

Figure 5. Representative Examples of Subscribers Supported

[6] *Source: https://auctions.ipv4.global/prior-sales Global average of prior sales from 01/04/2021 - 03/25/2021*
[7] *Subtracts a 15% brokerage fee and a transfer fee of $300*

REPRESENTATIVE CASE STUDY: REGIONAL BROADBAND SERVICE PROVIDER

A US regional service provider delivers advanced broadband internet, digital TV, phone, and security to approximately 55,000 homes and businesses. The company has built its own optical and cable networks as well as grown by acquisition. As the company expanded, it became aware of the steady depletion of its IPv4 addresses. Below is a summary of the costs of acquiring additional IPv4 addresses compared to deploying a CGNAT solution, over five years.

Operator Statistics

Current subscribers	55,000
Annual subscriber growth	5%
Expected subscribers in five years	70,262
Existing IPv4 allocation available	57,000

TCO Analysis

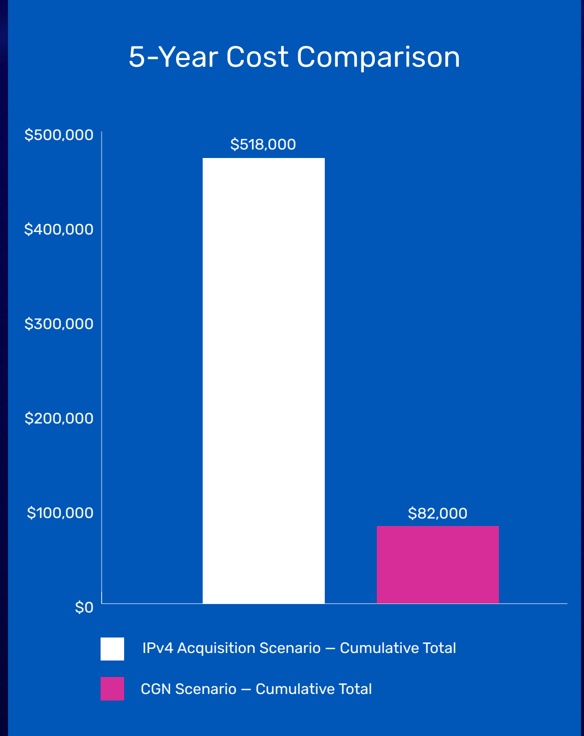
Cost of IPv4 acquisition at $30 each	$ 518,000
Cost of CGNAT solution	$ 82,000
Net savings	$ 436,000

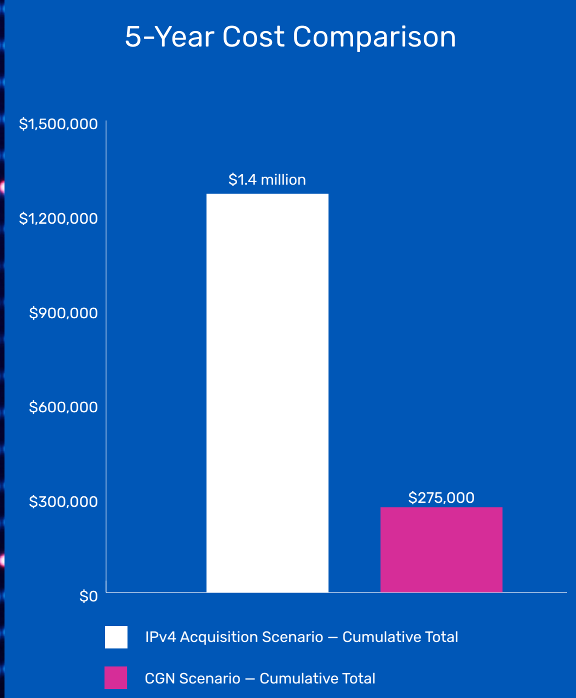
Other benefits

- Company could recover 31 IPv4 addresses for each one used
- 90% of residential fiber-to-the-home customers go through CGNAT device
- Greater than 99.9% customer satisfaction — only five customers requested dedicated public IP addresses

5-Year TCO Savings $436,000

TCO savings are estimates based on actual customer scenarios, best practices, and A10 Networks industry experience.





REPRESENTATIVE CASE STUDY: RURAL WIRELESS INTERNET SERVICE PROVIDER

With Rural Digital Opportunity Fund (RDOF) grants from the U.S. government, this traditional wireline service provider is transitioning to a premier provider of wireless high-speed internet. It is rapidly expanding its subscriber services and buildout to various markets of diverse sizes.

The company is building out its communications infrastructure in communities that are currently underserved by broadband technology. Its pool of IPv4 addresses is already fully used for existing subscribers. The initial buildout will serve 15,000 new wireless customers with substantial growth, approaching 40,000 subscribers, projected over the next five years. With most technical and operations resources assigned to other buildout initiatives, budget and resources were very limited. The operators were heavily dependent upon contract and vendor professional services to complete the many projects and meet the FCC RDOF benchmarks. Below is a summary of the costs of acquiring additional IPv4 addresses compared to deploying a CGNAT solution.

Operator Statistics

Initial subscribers	15,000
Annual subscriber growth rate	20%
Existing IPv4 allocation available	0
Expected subscribers by EOY 5	39,191

TCO Analysis

Cost of IPv4 acquisition at $32 each	$ 1.4 million
Cost of CGNAT solution	$ 275,000
Net savings	$ 1.1 million

Other benefits

- The operator can expand to meet buildout requirements of the FCC RDOF auction without excessive costs for IPv4 addresses.

5-Year TCO Savings $1.1 million

TCO savings are estimates based on actual customer scenarios, best practices, and A10 Networks industry experience.

OVERCOMING COMMON CGNAT CONCERNS

What is NAT444, NAT44 and CGNAT?

NAT444 and NAT44 are models implemented in CGNAT solutions to extend the utility of existing IPv4 addresses. With NAT444, communications service providers give a private IP address to a customer's router (first NAT IPv4-to-IPv4). The translation to a public IP address is done further within their network (second NAT IPv4-to-IPv4). Traditional NAT used today, in contrast, can be referred to as NAT44.

While NAT444 extends the time before migrating to IPv6, it does not allow access to IPv6 content, and IPv6 transition/translation will still ultimately be required in addition to the CGNAT. End-to-end connectivity is very complex, especially for IP telephony or file sharing services.

Many operators have concerns about inserting a CGNAT function into their networks. Below are answers to some of the most common questions.

How do I comply with law enforcement requirements?

Law enforcement agencies generally mandate that network operators provide the details of the location of a particular subscriber—either at the current time or a given moment in the past—and have this information available within a very short timeframe. This can be a very difficult task as it requires the ability to quickly map the subscriber inside address with the public IP address. The standard subscriber translation logging can easily exceed a terabyte of storage a day, depending on the number of subscribers supported.

With advanced logging techniques including log compression or deterministic/fixed NAT, a provider can easily reduce the volume of logs and parse the data.

How do I ensure application integrity?

Communications service providers must ensure that the CGNAT solution deployment is completely transparent to their subscribers and that applications do not suddenly stop working. The CGNAT solution must provide complete support for application-level gateways (ALG) that enable applications to operate properly through address or protocol translation.

What about gamers?

While they usually comprise a small percentage of subscribers, serious gamers will often demand a direct IP connection. The CGNAT solution must allow the ability for direct IPv4 to subscribers as needed.

Should security be a concern?

Service provider networks are big targets for distributed denial of service (DDoS) attacks.

In CGNAT, hackers can target the gateway itself to take down the access of large swaths of subscribers. They can also target an individual subscriber and jump to the NAT gateway they are connected to propagate their attack to other subscribers.

Providers need to have the capability to protect their subscribers from DDoS attacks and ensure that the CGNAT gateway itself is not compromised. A CGNAT and IPv6 migration solution should have the ability to protect itself and the subscribers behind the gateway.

IPv4 — IPv6 MIGRATION CONSIDERATIONS

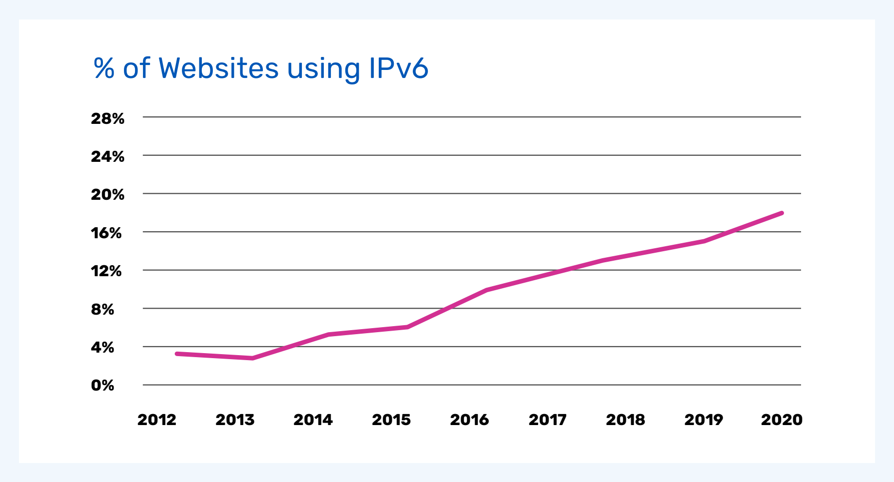
The IT Dilemma

The alternative to IPv4 exhaustion and acquiring more IPv4 addresses is, of course, to use the new standard, IPv6. However, many organizations simply cannot justify the near-term cost and disruption that a data center and network change-out to IPv6 will entail. Switching to IPv6 is costly and time consuming. All connected devices must be inventoried and changed out or reconfigured. There is a risk that a needed device or application will not work and cause service disruption that will take time to troubleshoot and fix. Many times, customer equipment is older and not compatible with IPv6, and the replacement cost too high.

IPv6 conversion also takes a great deal of detail-oriented effort by network administrators for testing and production; in some cases, they must re-architect entire networks. Balanced against the daily operational demands they face, as well as the need to move forward on strategic initiatives like 5G, cloud, virtualization, edge cloud, and others, administrators may need to delay IPv6 conversion in the short term.

Uneven IPv6 Adoption

However eager operators and organizations are to move forward with IPv6, their subscribers, employees, students, and other users still want to access IPv4-only sites. Today, while high-traffic web destinations such as Google, Yahoo, Wikipedia, Facebook, Netflix and YouTube all support IPv6, only 17 percent of websites use IPv6, and globally, only about 30 percent of Google searches use IPv6. That means that almost two-thirds of Google queries are accessing IPv4-only websites. In the U.S., adoption is higher, with about 45% of Google searches using IPv6. However, it should be expected that there will always be some amount of content that will remain IPv4 only.



Connected devices, including cellular IoT devices, are expected to exceed 35 billion by 2025, with most of the new devices likely being IPv6-compatible. As a result, most organizations must manage a growing base of newer IPv6-enabled devices with older IPv4 devices connecting to both IPv4 and IPv6 content. In addition, older applications and devices may not be IPv6 compatible. For example, some rural cable operators have postponed IPv6 due to incompatibility of home cable routers, where the cost to change out those devices is too high and the process too disruptive to subscribers.

IPv4 and IPv6 will Co-exist for Years

Globally, IPv6 adoption will not be achieved overnight. To provide a complete IPv6 service, each link in the chain must be running IPv6, from the end user to the carrier to the content provider. Realistically, not all three of these links in the IPv6 chain will transition to IPv6 at the same time. IPv6 will likely never reach 100% adoption. Therefore, most organizations, including communications service providers of all technologies and sizes, will need to support both IPv4 and IPv6 for some amount of traffic and subscribers for a long time.

A10 NETWORKS — YOUR PARTNER THROUGHOUT THE IPv4 TO IPv6 LIFECYCLE

A10 Networks Thunder® CGN, the most advanced carrier-grade networking solution, provides high-performance CGNAT with protocol conversion that allows communications service providers and enterprises to extend IPv4 investment while simultaneously transitioning to IPv6 standards.

A10 Networks Thunder CFW provides a unique combination of multiple security functions in a single product—a highly scalable, high-performance firewall, IPsec VPN, secure web gateway, and carrier-grade NAT with integrated DDoS protection. Thunder CFW provides address translations between IPv4 and IPv6 as well as an advanced Gi-LAN firewall.

A10 Networks Thunder CFW and CGN Solutions Provide:

- High performance in all form factors, including container, virtual, bare metal and physical
- CGNAT (NAT44/444) to address IPv4 exhaustion
- IPv4/IPv6 migration through techniques including:
    - NAT64, DNS64
    - DS-Lite
    - 464XLAT
    - Lw4o6, MAP-T, MAP-E
    - 6rd
- Advanced features for logging and compliance to help providers meet requirements for compliance and auditability. Application-level gateways (ALG) support network growth and a seamless user experience. Built-in security strengthens defense against cyberthreats including DDoS.

What is the best solution for me?

A10 has the technology expertise to help you decide the best solution for your network needs and business growth. Our evaluation can help you determine the most cost effective approach for IPv4 preservation and IPv6 migration. With over 270 service provider customers globally, including Tier 1 and regional operators in North America, South Korea, and Latin America, Middle East, Europe and Asia, we have proven industry technology that reduces business risk and assures a seamless network build.

Contact us today for more information and your customized cost analysis.

IPv4 Preservation

Thunder CGN

Thunder CGN offers industry-leading carrier-grade NAT that scales networks to overcome IPv4 exhaustion, supports network growth, and delivers a seamless user experience.

Learn More

A WISE, CONFIDENT APPROACH

Across the globe, demand for broadband services is surging. As the COVID-19 pandemic shifted broad swaths of modern life online, average broadband network usage soared. Robust broadband connectivity paves the way for new opportunities for both communications service providers and underserved communities and customers, facilitating the introduction of new services such rich content experiences, new forms of collaboration, distance learning, telehealth, IoT, precision agriculture, and more.

Service providers will need to address upfront the challenges posed by IPv4 exhaustion and its impact on the cost of new subscriber IP addresses, and to implement CGNAT wisely — addressing the immediate challenge of IPv4 exhaustion while making plans for an eventual transition to IPv6.

Service providers can approach CGNAT deployment with confidence — a proven and complete carrier-grade networking (CGN) solution will provide both CGNAT and IPv4-IPv6 migration techniques, ensure a seamless subscriber experience and the ability to grow. while reducing costs that can be applied towards bridging the digital divide.

ABOUT A10 NETWORKS

A10 Networks (NYSE: ATEN) provides secure application services for on-premises, multi-cloud and edge-cloud environments at hyperscale. Our mission is to enable service providers and enterprises to deliver business-critical applications that are secure, available and efficient for multi-cloud transformation and 5G readiness. We deliver better business outcomes that support investment protection, new business models and help future-proof infrastructures, empowering our customers to provide the most secure and available digital experience. Founded in 2004, A10 Networks is based in San Jose, Calif. and serves customers globally.

For more information, visit A10networks.com and follow us @A10Networks.

Learn More

About A10 Networks

Contact Us

A10networks.com/contact

Part Number: A10-EB-14143-EN-01 APRIL 2021