IGF 2016 - Best Practice Forum on IPv6

'Understanding the commercial and economic incentives behind a successful IPv6 deployment'

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1. Introduction & Background

1.1. about the IGF & BPFs

The Internet Governance Forum (IGF) at the United Nations is an open, global forum where different participants from various stakeholder groups – governments, the technical community, civil society, academia, and the private sector – discuss Internet Governance (IG) and policy issues, on equal footing. The Best Practice Forums (BPFs) at the IGF seek to collect, discuss, and disseminate the different “best practices” used by people and organizations around the world for different Internet Governance and policy issues. BPFs provide opportunities to learn from each other by sharing experiences – successes, as well as miscalculations.

IPv6 adoption was selected as a topic for a BPF in 2015 and 2016. While in the first year the BPF focused on best practices to create an environment favorable to IPv6 adoption, in 2016 the BPF explored commercial and economic incentives behind IPv6 deployment.

This introduction briefly recapitulates what IPv6 is and why it should be adopted, before giving a high level overview of the 2015 BPF IPv6 and presenting the scope and goals of the 2016 BPF IPv6.

1.2. Why deploy IPv6?

Note: IPv6 and its deployment are in detail discussed in the BPF 2015 outcome document[1] this section is a summary.

1.2.1. The Internet Protocol version 6 (IPv6)

Generally speaking, devices connect to the Internet via numerical Internet Protocol (IP) addresses. An IP address is a numerical address (e.g., 69.65.11.25) used to identify devices

[1] http://www.intgovforum.org/cms/documents/best-practice-forums/creating-an-enabling-environment-for-the-development-of-local-content/581-igf2015-bpfipv6-finalpdf/file

on the Internet.[2] The Internet's legacy addressing system - Internet Protocol version 4 (IPv4) was created in the 1970s. The pool of IPv4 address numbers contains approximately four billion unique numbers. The growth and expansion of the Internet has virtually exhausted the IPv4 address pool.

A new Internet protocol, IPv6, was developed in 1995. One of the goals of IPv6 was to find a solution to deal with IPv4 address exhaustion. IPv6 addresses are longer in length: An IPv6 address is represented by eight (8) groups of hexadecimal values, separated by colons (:). The IPv6 address size is 128 bits, opposed to 32 bits in an IPv4 address. A bit is a digit in the binary numeral system and the basic unit for storing information.
The preferred IPv6 address representation is: xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx, where each x is a hexadecimal digit representing four (4) bits. "X" ranges from "0-9" or from "a-f."

The IPv6 space is significantly larger in comparison to the IPv4 pool. The practical size of the IPv6 space can be equated roughly to 32 Billion times the size of the current IPv4-based Internet.[3]

The adoption of IPv6 went very slow during the past decade. Today the global user adoption has reached 15%. If growth continues at the same rate like in the past 4 years, we will reach 50% in 2018.

1.2.2. Why Adopt IPv6?

The Internet's sustainable growth depends on IPv6 adoption; the booming mobile market and the Internet of Things (IoT), alone, will require much more IP address space than is available with IPv4.

Anyone running the old protocol needs to adopt the new one in order to support the increasing demand on the global network as more people – and more machines and "things" – come online. IPv4 and IPv6 are two different protocols. IPv6 is not backwards compatible with IPv4. Devices that communicate using only IPv6 cannot communicate with devices that communicate using only IPv4.

Technologies – for example Network Address Translation (NAT) and Carrier Grade Network Address Translation (CGN) that allow different devices to share one IPv4 address – have been developed to extend the life of IPv4. Unused IPv4 address blocks are being traded on so-called secondary or aftermarkets. These efforts should be considered only as temporary solutions and come with their own costs and downsides. They are sometimes relied upon to forestall what is ultimately inevitable for a business, a government, or end users: IPv6 adoption.

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[2] Technically speaking an IP address identifies an interface on a device, not the device itself.
[3] IPv6 theoretically increases the number of unique IP addresses to 2^{128} unique combinations.
The following video visualises the massive amount of IPv6 addresses: https://youtu.be/7LZfbqYSWdY

Until recently, there has been little immediate benefit in deploying IPv6 and, in competitive terms, there was no “early adopter” advantage. However, now that more Internet users are connecting via IPv6, the immediate benefits of deploying the new protocol are gaining visibility, for example:

- Content providers and publishers can see a direct performance benefit if traffic is delivered directly to the end user over IPv6 and no longer has to flow through NAT or CGN devices.
- Network operators will save on the operating and maintenance cost of NAT and CGN infrastructure.
- End users with IPv6-enabled devices can access content from IPv6-ready content providers with improved performance (provided that their ISP offers IPv6 services).

On 7 November 2016, the Internet Architecture Board (IAB) advised that network standards need to fully support IPv6. ‘The IAB expects that the IETF will stop requiring IPv4 compatibility in new or extended protocols’, and that ‘future IETF protocol work will then optimize for and depend on IPv6’. The IAB recommends ‘that all networking standards assume the use of IPv6, and be written so they do not require IPv4’ and ‘that existing standards be reviewed to ensure they will work with IPv6, and use IPv6 examples.’[4]

A good planning can reduce the cost of IPv6 deployment to almost zero. IPv6 awareness at all relevant decision making levels and a good planning are key for a smooth IPv6 deployment. Many of the often mentioned ‘hurdles’ and costs, such as upgrading existing equipment and applications, will be minimal if they happen alongside the existing cycles to maintain or renew equipment. IPv6 should be a requirement for any new IT project or purchase.

1.3. Summary of the 2015 BPF ‘Creating and Enabling Environment for IPv6 Adoption’

The 2015 BPF on ‘Creating an Enabling Environment for IPv6 Adoption’ collected examples of initiatives that promote and support the deployment of IPv6. The different examples are situated in their own contexts. The success in terms of growth of IPv6 use in a certain region or environment will almost always be the result of a combination of initiatives, practices and other factors. Below is a short description of the types of initiatives that are discussed in the 2015 outcome document.

1.3.1. IPv6 task forces, a platform for best practices

Task forces can be organized ad hoc, by the community, or supported by government. They conduct various activities and serve various purposes: raising awareness about IPv6,

[4] IAB Statement in IPv6, 7 November 2016
https://www.iab.org/2016/11/07/iab-statement-on-ipv6/

providing advice on how to deploy IPv6, conducting outreach, developing fully-informed policy recommendations to the government that should result in their country seeing higher IPv6 use.

National IPv6 task forces often collaborate on a regional basis. Regional meetings enable participants to exchange information with members of other task forces who, while from different countries, may operate in similar cultural, economic, and regulatory environments.

1.3.2. Capacity-building

Capacity-building on IPv6, both in terms of technical training for engineers and operators, and raising awareness for non-technical policymakers, law enforcement, and business decision-makers, is fundamental to creating an enabling environment for IPv6 adoption. Many different organizations, for profit and not-for-profit, provide IPv6 training, including the Regional Internet Registries (AFRINIC, APNIC, ARIN, LACNIC and RIPE NCC)[5] and national research and education networks (NRENs).

The 2015 BPF noted that many people who are new to IPv6 wrongly think that they have to do everything at once and that too much new knowledge is needed, while on the contrary it is advised to break a deployment into smaller tasks and evaluate them step- by-step.

While most of the capacity-building focuses on network operators, IPv6 training for law enforcement officials, policymakers, and corporate-level (C-level) business decision- makers (e.g., CEOs, COOs, CFOs, etc.) is also important for creating an enabling environment for IPv6 adoption. It is important to:

- build confidence at the decision-making level that IPv6 is “proven technology” and (perceived) risks are manageable;
- work with decision-makers directly to help them understand the importance of IPv6 deployment, at a level where they can make a meaningful risk assessment for their business;
- ensure that non-technical staff understand the long-term, positive effect of IPv6 deployment on their business goals (for example, enabling growth and the potential for reducing costs); and for product developers and marketing staff, clarify the benefits for organizations that adopt IPv6.

1.3.3. Lessons from the private sector

Discussions relating to best practices in the private sector – for ISPs and content providers in particular – resulted in a set of high-level suggestions. Planning for IPv6 deployment might begin with a review of existing infrastructure and an assessment of vendor IPv6 readiness.

[5] AFRINIC http://www.afrinic.net ; APNIC https://www.apnic.net ; ARIN https://www.arin.net ; LACNIC http://www.lacnic.net ; RIPE NCC https://www.ripe.net)

Employee training is necessary; particularly in the case of technical employees but, depending on the business, for some non-technical personnel as well (e.g. customer service representatives).

As for IPv6 deployment, businesses should consider working from the outside in: deploying IPv6 via dual stack technology for public-facing services first, and then migrating to IPv6 on internal networks, second. To make the transition easier, they should set internal deadlines and engage with customers, keeping them notified, if not engaged, during the deployment process. Other approaches are also possible.

One policy option for encouraging IPv6 adoption that was suggested was for ISPs to use cost incentives, for example raising the price for IPv4, a scarce resource that is becoming costly to maintain, and providing IPv6 to the customer without extra charge. Finally, collaboration with others in deploying IPv6, as happened during the 2012 IPv6 World Launch, has shown to be effective.

1.3.4. Research and education networks and tertiary institutions

Many national research and education networks (NRENs) and tertiary institutions (like universities) have been running IPv6 in production on their networks for more than 10 years. They are important sources of knowledge and expertise on the subject. NRENs conduct valuable research on IPv6 and participate in the work at the IETF to develop RFCs. Universities can help promote IPv6 by supporting student research projects.

1.3.5. Government initiatives

Governments are in a powerful position to create an enabling environment for IPv6 adoption. They can lead by example by requiring the public administration to adopt IPv6. They can require IPv6 in ICT procurement policies which, in turn, obligates businesses tendering for government contracts to provide IPv6-capable products and services. The development of IPv6 profiles can assist public administration in its own procurement processes and evaluation of tenders, and requiring vendors to themselves use IPv6 results in businesses needing to be able to "walk the walk" – not only providing IPv6 services to their clients but running IPv6 themselves.

Submissions to the 2015 BPF on national deployment strategies featured different approaches, from working with the private sector on pilot projects that showcase best practices for the benefit of all, to organizing a national IPv6 launch with IPv6-ready groups, to creating a national IPv6 mandate across the public and private sectors. Governments can help industry by publishing an IPv6 adoption guide that tailors relevant information to different stakeholder groups. Collaboration with industry through government-supported national working groups, study groups, or outsourcing experiments to the private sector has yielded successful results.

1.3.6. IPv6 measurements – tracking success

IPv6 measurements are useful, illustrative tools that IPv6 advocates can use when engaging with policymakers. Measurements can also be used, of course, to gauge the effectiveness of a best practice. Measuring IPv6 usage before and after the implementation of a policy can help reveal that policy's impact.

2. Scope and Goal of the 2016 BPF 'Understanding the commercial and economic incentives beneath a successful IPv6 deployment[6].

2.1. Scope

The 2016 BPF on IPv6 brings together representatives from different stakeholder communities and offer a great opportunity to look at the topic of IPv6 adoption with focus on economic elements and business cases. The BPF does not want to replicate or duplicate work already undertaken by other groups (e.g. the substantive work or technical training done by Internet technical community). Rather, the BPF will take any such work as a starting point and input for the discussion. The BPF should focus on how stakeholders can help each other and exchange best practices.

2.2. Goals for 2016

The 2015 BPF on IPv6 focused on creating capacity building platforms and awareness raising, in the form of national and regional IPv6 taskforces and other initiatives. Building upon the outcome of the 2015 BPF on IPv6, the activities of the 2016 BPF focus on the *economic decisions* and *commercial drivers* behind the decision to adopt IPv6.

2.3. Problem statement

Feedback received from the participants to the 2015 BPF IPv6, especially those with a technical community background, suggests that the decision to adopt IPv6 is not only a technical one, but that other economic factors play an important role.

Most of the networks that make up today's Internet are built and operated on a commercial basis, and must include IPv6 adoption into their business plan, accordingly. The same goes for not-for-profit and public sector network operators, who must take into account the cost versus benefit when deciding to upgrade their networks to the new version of the Internet Protocol. The number of networks that already support IPv6 today proofs that IPv6 adoption is a technically feasible option for businesses. IPv6 adoption is on the rise - not only in the

[6] The 2016 BPF on IPv6 discussed and agreed the Scope and Goals for its activities during its first (23 June 2016) and second (6 June 2016) open Virtual meeting.

global North, but also in a number of states in the southern hemisphere and there appears to be little correlation to GDP and IPv6. There remains some questions such as:

- Why is there such a difference in IPv6 adoption in comparable markets?
- Why is cost often cited as a reason not to adopt, while at the same moment commercial ISPs of all sizes are deploying IPv6?

Some studies explore the “why and when” of IPv6 adoption or model the economic effects of IPv6 versus the prolonged use of IPv4, but in general there is not that much documentation around the commercial aspects of IPv6 deployment, especially not based on specific positive cases of adoption. This is the focus of the 2016 BPF IPv6.

The 2016 BPF invited people to share their commercial experiences with IPv6, with the aim of establishing a better understanding of the commercial and economic incentives that sit behind a successful deployment of IPv6 in commercial as well as public sector networks and Internet services.

3. Facts and Figures - IPv6 deployment

3.1. Introduction

The global Internet keeps on growing and changing. Estimates predict that by 2020 52% of the world population or 4.1 billion people will be using the Internet. The IP traffic is expected to triple between 2016 and 2020. It is predicted that by 2020 there will be 26.3 billion networked devices and connections globally, 5.5 billion global mobile users and 11.6 billion mobile-ready devices and connections.[7]
It becomes increasingly important for the Internet to accommodate scale. IPv6 will enable the Internet to cope with the huge demand for IP addresses in the future.

This chapter makes a status update of the IPv6 deployment. It looks at the IPv6 readiness of the Internet infrastructure and will assess the uptake in IPv6 usage. As a start, section 3.2 is an non-exhaustive overview of indicators, measurements and tools that are being used to monitor progress in IPv6 deployment.

3.2. Monitoring IPv6

Deploying IPv6 means getting the infrastructure ready and starting to use the IPv6 protocol to communicate over the Internet. Both go hand in hand and obviously, the second can’t happen if the first hasn’t been realised.

[7] Cisco VNI,
http://www.cisco.com/c/en/us/solutions/service-provider/visual-networking-index-vni/index.html

Both aspects of the IPv6 deployment are being monitored. Organisations keep track of the readiness of the infrastructure - the core internet infrastructure as well as the user equipment and applications - and of the amount of IPv6 traffic that is sent over the infrastructure by those capable to do so. This section first looks at different ways to assess the IPv6 readiness and then at different ways in which IPv6 traffic is being measured.

3.2.1. Assessing IPv6 readiness

IPv6 ready means that it is possible to communicate over IPv6. This requires that the infrastructure, the machines and applications are capable of handling IPv6. IPv6 readiness starts with the sender's and the receiver's equipment and software, and includes everything in between. A detailed assessment of the progress in IPv6 deployment needs to take the whole chain into account. Only when it is technically possible to have IPv6 traffic, monitoring IPv6 traffic makes sense. What follows are frequently used indicators of IPv6 readiness.

* The allocation of IPv6 address blocks

The public Internet is composed of Autonomous Systems (AS) or individual networks that exchange IP traffic, and each network has an unique Autonomous System Number (ASN). Typical examples of an AS are the network operated by an ISP or by a large organisation.

The first action for a network operator that wants to enable IPv6 on its network - once the operator's the equipment and infrastructure is IPv6 ready - is to get IPv6 address space. Blocks of IPv6 addresses are allocated by the Regional Internet Registries (RIRs) - via Local Internet Registries (LIRs)[8] - to individual networks (ASes). Assuming that an operator will only request IPv6 addresses when his network is capable of handling IPv6, the demand for IPv6 addresses, measured by the number of IPv6 address blocks and the volume of address space that is allocated by the RIRs serves as an indicator for IPv6 readiness of network operators.

The RIRs publish statistics on the allocation of IPv6 blocks for their region. The table below gives an overview of the number of IPv6 allocations by each RIR for the last 10 years.

Allocations	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
RIPE NCC	88	150	413	595	1,012	1,565	1,661	2,057	2,143	2,206
ARIN	62	196	213	357	567	959	545	523	505	602
APNIC	41	61	158	185	637	610	561	505	503	778

[8] Local Internet Registry (LIR) are responsible for the distribution of address space and registration of the address space on a local level. LIRs also ensure that policies and procedures are followed on the local level. Organisations that become LIRs are mainly Internet Service Providers (ISPs) that assign and allocate address space onto their customers, telecom and enterprise organisations, as well as academic institutions.
https://www.ripe.net/manage-ips-and-asns/resource-management/faq/independent-resources/phase-three/what-is-a-local-internet-registry-lir

LACNIC	12	38	43	93	212	447	560	683	1,196	1,061
AFRINIC	14	18	14	13	49	119	76	72	60	86
	217	473	841	1,243	2,477	3,700	3,403	3,840	4,407	4,733

Table – number of discrete IPv6 allocations by RIR per year
Source: Addressing 2015, Geoff Huston, https://labs.apnic.net/?p=758

Network operators can choose between different sizes of IPv6 address blocks with minimum of one /32 address block[9] per allocation by a RIR. The total volume of allocated addresses shows a different dynamic between the regions. The below table shows the volume of allocated IPv6 address space per year in number of /32 blocks. One /32 block represents an address space of 79,228,162,514,264,337,593,543,950,336 IPv6 addresses. Note that one /32 block is larger than the whole IPv4 space. By October 2016, the total volume of IPv6 space given out was 202,660.02 /32 blocks. Although this is more than 202,600 times the IPv4 Internet space, it only represents 0.038% of the available IPv6 space.[10]

IPv6 Addresses (/32s)	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
RIPE NCC	6,550	1,468	964	1,052	2,406	3,174	3,892	6,286	8,217	12,031
ARIN	54	148	14,486	236	780	6,344	1,660	12,558	5,241	641
APNIC	3,224	5,236	139	170	1,335	9,486	3,783	4,442	2,644	2,109
LACNIC	12	51	35	87	197	948	4,605	597	1,359	974
AFRINIC	14	13	10	9	36	147	4,196	51	51	4,471
	9,854	6,916	15,634	1,555	4,754	20,099	18,136	23,935	17,513	20,225

Table – IPv6 address allocation volumes by RIR in /32 blocks per year
Source: Addressing 2015, Geoff Huston, https://labs.apnic.net/?p=758

* Routable IPv6 networks

The first part of an IPv6 address, the *prefix,* specifies the network, while the remaining part specifies a particular address in that network. For a network to be reachable over IPv6, this prefix must be visible on the Internet, i.c. a network must announce an IPv6 prefix in the routing table. RIPE NCC is measuring the percentage of IPv6 enabled networks that announce an IPv6 prefix. The data is published in an online graph, adaptable per country or per groups of countries: http://v6asns.ripe.net/v/6.

[9] The size of a block of addresses is specified by writing a slash (/) followed by a number in decimal which value indicates the length of the network prefix in bits. For example, an address block with 48 bits in the prefix is indicated by /48 and contains 2^(128 − 48) = 2^(80) addresses. The smaller the value of the network prefix, the larger the block: a /21 block is 8 times larger than a /24 block.
[10] http://www.bgpexpert.com/addrspace-ipv6.php accessed on 8 Nov 2016

* IPv6 RIPEness

IPv6 RIPEness is a tool developed by the RIPE NCC to monitor and assess the IPv6 readiness amongst the RIPE NCC members (LIRs). By marking specific milestones in the deployment process, such as requesting an IPv6 allocation and making the prefix visible on the Internet, the organisation itself as well as other stakeholders can see the high-level progress in IPv6 deployment based on comparable criteria.
https://ipv6ripeness.ripe.net

* End user IPv6 readiness

APNIC Labs has designed a test system that reports on end-user capability based on daily tests of random internet users.[11] The APNIC measurements are publicly available. The webpage gives a global overview and statistics on a regional and country by country level:
http://stats.labs.apnic.net/ipv6/

Note: *The BPF IPv6 agreed to use the APNIC Labs deployment measurements to compare the state of IPv6 between countries.*

* Deployment ratios

Efforts have been made to develop IPv6 deployment matrices, to define overall IPv6 deployment levels and allow for comparing between countries and regions. Cisco calculates an *overall IPv6 deployment ratio* based on three other matrices; IPv6-enabled transit AS, IPv6 content and IPv6 users.
http://6lab.cisco.com/stats/information.php#content

3.2.2. Measuring IPv6 traffic

* Global operators and content providers

Global content providers, service providers and operators that have enabled IPv6 for their networks and services monitor and report on the IPv6 traffic. *Google* tracks on an ongoing basis the percentage of users that access Google over IPv6. Statistics are published per country: https://www.google.com/intl/en/ipv6/statistics.html

* IPv6 Domain name system

Each Top Level Domain (TLD), like .com, .org or .de, has its own authoritative nameservers which contain the information on their zone. To support IPv6, these nameservers should have an IP address themselves and native IPv6 connectivity so that they can be reached over IPv6; have AAAA records for their IPv6 address (glue records) in the root zone; and be able to return AAAA (IPv6) address records. Daily statistics on these three requirements are generated by Mike Leber:
http://bgp.he.net/ipv6-progress-report.cgi

[11] How APNIC developed the test is explained at http://labs.apnic.net/?p=83

Domain name registries can count the number of domain names in their zone that have an IPv6 address (AAAA-record) and can track the number of DNS queries they receive over IPv6. CZ.NIC, for example, shows these statistics for the .cz domain names on its website: https://stats.nic.cz/stats/ipv6_domains/?rd=2016-09-30&dr=1y&tp=i-1m&ss=0&ds=normal&da=chart

* Internet Exchange Points (IXPs)

Internet Exchange Points (IXPs) enable the interconnection and exchange of IP-traffic between Autonomous Systems (networks). IXPs can monitor the amount traffic over IPv6 that passes through the IXP. The Amsterdam Internet Exchange (AMS-IX) , for example, has real time IPv6 traffic statistics on its website:
https://ams-ix.net/technical/statistics/sflow-stats/ipv6-traffic

3.2.3. Places to monitor IPv6 Adoption

Below is and non-exhaustive list of websites and portals monitoring IPv6 deployment.

Akamai: https://www.akamai.com/us/en/our-thinking/state-of-the-internet-report/State-of-the-internet-ipv6-adoption-visualization.jsp
Cisco: http://6lab.cisco.com
Eric Vyncke: https://www.vyncke.org/countv6/stats.php

3.3. IPv6 deployment status 2016

3.3.1. Global uptake: historic evolution

The past ten years saw a yearly increase of the number of IPv6 allocations by the RIRs. For every year however, the number of IPv6 allocations is much smaller than the number of IPv4 allocations. However, allocated IPv6 blocks are on average much larger and as result that the total volume of allocated IPv6 addresses per year is much higher.[12]

Allocations	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
IPv6	217	473	841	1,243	2,477	3,700	3,403	3,840	4,407	4,733
IPv4	5,646	6,312	6,969	6,701	7,758	10,061	8,619	7,110	10,853	11,732

Table – Number of individual Address Allocations by the RIRs per year for the period 2005 - 2015
Source: Addressing 2015, Geoff Huston, https://labs.apnic.net/?p=758

Addresses	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015

[12] There's a double effect; IPv6 is allocated in larger blocks of which the size is a matter of choice for the requesting party and special policies came into force to allocate the last /8 IPv4 blocks by APNIC, APNIC and RIPE NCC.

IPv6 (/32s)	9,854	6,916	15,634	1,555	4,754	20,009	18,136	23,935	17,513	20,225
IPv4 (/32s)(M)	168.1	203.9	203.3	189.4	248.8	201.0	114.9	65.1	63.9	64.7

Table – Volume of Address Allocations by the RIRs per year for the period 2005 - 2015
Source: Addressing 2015, Geoff Huston, https://labs.apnic.net/?p=758

3.3.2. Global uptake: IPv6 slowly entering mainstream in 2016?

The global IPv6 deployment is on the rise and in many ways 2016 has been a remarkable year that shows how IPv6 is slowly entering mainstream usage. There are different indications for this, and sind mid 2016 a rapid growth in IPv6 supported content could be observed.[13]

Some observations:

Google
Five years ago, in January 2011 only 0.2% of the users reached Google over IPv6. This was still less than 3% by the end of 2014.
At the beginning of 2016 the percentage of users that accessed Google using IPv6 flirted for the first time in history with the 10% threshold. By June 2016 Google already measured more than 12% users accessing the search engine over IPv6, by October 2016 it reached 15% and the trend continued.
Source: https://www.google.com/intl/en/ipv6/statistics.html

Akamai
Akamai, one of the world's leading content delivery networks (CDN) service providers, saw IPv6 increasingly entering the mainstream in 2016 and reported on major movements in deploying IPv6 by many of the top networks and content providers in the world. Of Akamai's top five network providers by traffic volume, all but one have IPv6 adoption over 20%. Of the top 25 networks by volume, 14 have IPv6 adoption over 10%, and around a third of the top 100 networks by volume have started rolling out IPv6.
Source:
https://blogs.akamai.com/2016/06/four-years-since-world-ipv6-launch-entering-the-mainstream.html

Cloudflare
In November 2016 Cloudflare, announced that almost every site using Cloudflare (more than 4 million in total) was using IPv6. Cloudflare reported significant IPv6 traffic globally where networks had enabled IPv6 to the consumer.
Source: https://blog.cloudflare.com/98-percent-ipv6/

RIPE NCC

[13] https://mobile.twitter.com/bajpaivaibhav/status/798558510086836224

During the first half of 2016 RIPE NCC counted for the first time ever more than 25% of networks (Autonomous Systems AS) within its service region that announced one or more IPv6 prefixes. This was only 5% in 2009 and 15% at the beginning of 2012.
Source: https://labs.ripe.net/statistics/?tags=ipv6

ARIN
By September 2016, one year after full IPv4 depletion for the North American region (24 September 2015), more than half of the networks in the ARIN membership had registered IPv6 addresses. ARIN reported that it continued issuing IPv6 address blocks to 60-100 additional organisations per month.
Source: http://teamarin.net/2016/09/26/life-after-ipv4-depletion/

Facebook
On 17 August 2016 for the first time ever more people used IPv6 to access Facebook than IPv4 from the 4 major USA mobile networks.
Source: https://www.facebook.com/ps/posts/10157221242360858

AT&T
AT&T began planning for the transition to IPv6 in 2006. As of September 30, 2016, approximately 60% of the wireline traffic and nearly 15% of the wireless traffic originating from AT&T Autonomous System Numbers (ASNs) was using IPv6.
Source: https://www.ntia.doc.gov/files/ntia/publications/att_10_3.pdf

IPv6 in DNS
In October 2016 a blogpost compared the use of IPv6 in the world of web objects to that of the infrastructure of the DNS, and concluded that the DNS had seen significant progress in the adoption of IPv6, and slightly more than one third of all users was capable of resolving names using IPv6, as compared with a 7% measurement of users capable of using IPv6 in fetching objects over the web. This lead to the conclusion that the DNS was well on the path of transition and perhaps further than other elements of the Internet's infrastructure.
Source: https://blog.apnic.net/2016/10/20/ipv6-and-the-dns/

3.3.3. Regional trends

This section gives an overview of the current state of IPv6 deployment in the world per geographical region and lists the top 50 countries by IPv6 deployment. The next chapter, will exhibit experiences from countries with a high deployment per region and per sector. It is good practice to only compare data over time and between regions that is based on the same or very similar methodology. The BPF agreed to use the APNIC Labs statistics for this section.

According to the APNIC Labs measurements for mid November 2016, the global IPv6 capability was close to 8%. The Americas (18% IPv6 capable) and Europe (12% IPv6 capable) scored above the global average. IPv6 capability in the other regions lays below

the global average. The country-by-country comparison in this section will show that there are huge differences within the regions and that a few countries are boosting the regional score, for example the IPv6 capability in the USA is almost as high as twice the regional score for the Americas and in only one other country, Peru, the IPv6 capability is (slightly) higher than the average.

IPv6 deployment per region.

	IPv6 Capable	IPv6 Preferred
World	7.50%	6.75%
Americas	18.16%	16.82%
Europe	11.52%	11.04%
Oceania	6.83%	6.35%
Asia	3.83%	3.05%
Africa	0.13%	0.12%

Source: APNIC Labs, 21/11/2016, http://stats.labs.apnic.net/ipv6/

Of the top-50 countries ranked by IPv6 capability 17 showed a double digit deployment rate in October 2016. Of these 17 countries, 10 are European, 3 Latin American, 2 from the Asia Pacific region and 2 from North America North America.

Only one country, Belgium (56% IPv6 capable), scored higher than 50% on IPv6 capability in October 2016 and with 46% Belgium also leads the ranking in terms of IPv6 use ratio. On some distance, Belgium is followed by the US (34% IPv6 capable - 31% IPv6 use ratio) and Switzerland (31% IPv6 capable - 27% IPv6 use ratio).

Ecuador, Peru and Brazil are leading in Latin America, with between 10% and 20% IPv6 capability and use ratio. From the Caribbean, Trinidad and Tobago is flirting with the 10%.

Japan (16% IPv6 capable - 14% use ratio) and Malaysia (15% capable - 15% use ratio) show the highest IPv6 deployment in Asia Pacific. All other countries from the region have deployment rates lower than 10%.

Saudi Arabia (5% IPv6 capable - 4% use ratio) is leading in the Middle East .

Early October 2016, no African country scored higher than 1% on IPv6 capability. On 28 September, however, an important provider in Zimbabwe[14] turned on IPv6 with as result that one month later Zimbabwe is leading on the continent with 2.75% IPv6 capable, and 5.28 % IPv6 use ratio.

Top 50 countries IPv6 deployment per region.

[14] https://afnog.org/pipermail/afnog/2016-September/002869.html

Global ranking IPv6 Capable	CC	Country	IPv6 Capable	IPv6 Preferred	IPv6 Use ratio
Europe					
1	BE	Belgium, Western Europe, Europe	**55.64%**	50.17%	45,89%
3	CH	Switzerland, Western Europe, Europe	**30.78%**	29.27%	26.61%
4	GR	Greece, Southern Europe, Europe	**27.51%**	26.90%	23.00%
5	DE	Germany, Western Europe, Europe	**27.05%**	25.30%	25.20%
6	LU	Luxembourg, Western Europe, Europe	**23.23%**	21.82%	19.41%
7	PT	Portugal, Southern Europe, Europe	**23.19%**	22,39%	19.28%
8	GB	United Kingdom, Northern Europe, Europe	**20.68%**	19.70%	22.16%
11	EE	Estonia, Northern Europe, Europe	**17.17%**	16.74%	15.29%
15	FR	France, Western Europe, Europe	**13.87%**	13.22%	11.51%
16	FI	Finland, Northern Europe, Europe	**12.63%**	11.08%	10.68%
19	CZ	Czech Republic, Eastern Europe, Europe	9.41%	8.41%	8.37%
20	NO	Norway, Northern Europe, Europe	9.23%	8.33%	7.33%
21	IE	Ireland, Northern Europe, Europe	8.40%	8.07%	8.20%
23	NL	Netherlands, Western Europe, Europe	7.37%	6.82%	6.75%
25	RO	Romania, Eastern Europe, Europe	6.48%	6.23%	5.73%
26	AT	Austria, Western Europe, Europe	5.62%	5.30%	6.59%
30	HU	Hungary, Eastern Europe, Europe	4.72%	4.59%	4.85%
31	SE	Sweden, Northern Europe, Europe	4.65%	4.23%	3.41%
32	AX	Aland Islands, Northern Europe, Europe	3.79%	3.75%	5.92%
33	BA	Bosnia and Herzegovina, Southern Europe, Europe	2.89%	2.85%	2.53%
36	PL	Poland, Eastern Europe, Europe	2.06%	2.00%	1.70%
38	RU	Russian Federation, Eastern Europe, Europe	1.84%	1.79%	2.22%
41	SI	Slovenia, Southern Europe, Europe	1.61%	1.59%	1.64%
47	DK	Denmark, Northern Europe, Europe	0.93%	0.86%	0.94%
48	IT	Italy, Southern Europe, Europe	0.83%	0.80%	1.40%
49	BG	Bulgaria, Eastern Europe, Europe	0.73%	0.72%	0.74%
50	LV	Latvia, Northern Europe, Europe	0.64%	0.64%	0.06%
North America					
2	US	United States of America, Northern America, Americas	**33.76%**	31.08%	33.10%
14	CA	Canada, Northern America, Americas	**14.04%**	13.09%	15.41%
Latin America & Caribbean					
9	EC	Ecuador, South America, Americas	**19.18%**	18.35%	18.91%
10	PE	Peru, South America, Americas	**18.69%**	17.99%	17.85%
17	BR	Brazil, South America, Americas	**10.24%**	9.62%	11.02%
18	TT	Trinidad and Tobago, Caribbean, Americas	9.95%	9.62%	11.06%
28	BO	Bolivia, South America, Americas	5.27%	4.65%	5.02%

Asia Pacific					
12	JP	Japan, Eastern Asia, Asia	**15.81%**	14.00%	13.78%
13	MY	Malaysia, South-Eastern Asia, Asia	**14.53%**	13.26%	14.00%
22	AU	Australia, Australia and New Zealand, Oceania	7.68%	7.13%	7.25%
24	SG	Singapore, South-Eastern Asia, Asia	7.00%	6.07%	4.33%
27	IN	India, Southern Asia, Asia	5.54%	3.74%	7.54%
34	NZ	New Zealand, Australia and New Zealand, Oceania	2.74%	2.59%	2.40%
37	LK	Sri Lanka, Southern Asia, Asia	2.01%	1.91%	1.73%
39	TW	Taiwan, Eastern Asia, Asia	1.65%	1.32%	2.37%
40	HK	Hong Kong Special Administrative Region of China, Eastern Asia, Asia	1.62%	0.19%	1.16%
42	TH	Thailand, South-Eastern Asia, Asia	1.32%	1.25%	1.81%
43	KR	Republic of Korea, Eastern Asia, Asia	1.21%	0.39%	1.29%
46	VN	Vietnam, South-Eastern Asia, Asia	0.93%	0.82%	2.50%
49	CN	China, Eastern Asia, Asia	0.35%	0.19%	0.68%
Middle East					
29	SA	Saudi Arabia, Western Asia, Asia	4.73%	4.40%	4.20%
35	TR	Turkey, Western Asia, Asia	2.13%	0.01%	0.40%
44	IL	Israel, Western Asia, Asia	1.14%	0.98%	2.94%
Africa					
**	ZW	Zimbabwe, Western Africa, Africa	2.75 %	2.68 %	5,28%
45	LR	Liberia, Western Africa, Africa	0.95%	0.82%	2.26%
(-58-)	SD	Sudan, Northern Africa, Africa	0.19%	0.18%	0.14%
(-62-)	BW	Botswana, Southern Africa, Africa	0.12%	0.07%	0.01%

** ZW, Zimbabwe, data for 7/11/2016,

Source: APNIC Labs, 07/10/2016, http://stats.labs.apnic.net/ipv6/ , http://labs.apnic.net/dists/v6dcc.html

3.3.4. IPv6 deployment versus Economic performance

The previous section shows that in general the higher adoption rates can be found in more developed regions and an overall low IPv6 deployment in developing nations of the global south. However there are also huge differences within the regions and between countries with a similar development level.

There are outliers, for example Peru and Ecuador in South America, and large differences between the national deployment rates within the European Union. These differences in IPv6 deployment don't line up with the size or strength of economy of the 'IPv6 leaders'.

It seems unlikely that there is a correlation between a country's economic performance (based on indicators such as the GDP) and the level of IPv6 deployment. Comparable markets behave differently and even in the same region and markets, comparable operators that use similar technology and equipment will make different choices to IPv6 deployment.[15]

[15] 'Can You Make IPv6 Work Commercially?', Marco Hogewoning, — 07 July 2016
https://labs.ripe.net/Members/marco_hogewoning/can-you-make-ipv6-work-commercially

A presentation at RIPE 73 meeting in Oct 2016 provides some data of Ipv6 deployment in comparison to GDP: *Are We There Yet? IPv6 as Related to GDP per Capita* https://ripe73.ripe.net/presentations/101-IPv6-GDP-ripe73.pdf .

This observation suggests that economic performance is not the main clarification of the more successful IPv6 deployment in some countries. It seems however that IPv6 deployment in some countries mainly depends on individual decisions by one or more large ISP or operators to deploy IPv6 on their network, for example in Europe and the United States, or are the result of collaboration by industry players and/or encouragement by the government to key decision makers in some Asia Pacific countries. These suggestions seem to be confirmed by the observation that in the Spring of 2015 94% of IPv6 users in the world, confined to just 5 of the world's 30 largest ISPs[16] or the results in for example Japan.

4. Understanding the commercial and economic incentives

The BPF collected case studies from companies and organisations that finished the transition or are implementing IPv6 for their networks and services. The case studies have been collected via an online survey, online research and direct contributions to the BPF. This section will list general observations and summarise main experiences and lessons learned per sector or type of industry, followed by a description of the case studies within their regional context.

4.1. General Observations

4.1.1. Motivation to deploy IPv6

The imminent shortage of IPv4 addresses is the obvious and most cited motivation behind the decision to deploy IPv6. IPv6 is deployed to be ready for the future and it is recognised that IPv6 is the long term solution for the future.

Avoiding costs and more precisely avoiding the high cost of the alternative solutions to get around IPv4 exhaustion and extend the life of IPv4 is the second frequently cited motivation to deploy IPv6.[17]

ITAC Forum 2016, 'Getting the ball rolling: IPv6 Adoption since 2008'
https://youtu.be/xAI8nWM6ESc

[16] Geoff Huston 'May 2015 Update on measuring IPv6'
http://www.potaroo.net/presentations/2015-05-14-ipv6-stats.pdf
The same article noted that 'These 30 ISPs together serviced 42% of the entire internet population, and if 'these 30 providers were to achieve an average 50% IPv6 uptake in their customer base, then the total IPv6 capability level across the entire Internet would be 20% today, rather than 3.6%'

[17] One of the case studies submitted to the NTIA RFC describes the issue of IPv4 exhaustion and address sharing through Network Address Translators (whether NAT44 or NAT64 types of carrier-grade NAT) as it bring a host of concerns.

- Some applications, such as peer-to-peer, work poorly or not at all.
- Companies may appear to be blocking P2P, in violation of Net Neutrality principles, but actually have no recourse for managing their networks.

The benefits and the higher quality of service with the IPv6 protocol, is a third argument behind decisions to deploy IPv6. Sometimes the request to deploy IPv6 or to provide new services over IPv6 came from one or more important clients.[18]

Deploying early, and creating a momentum for others to follow and start deploying IPv6 has been the motivation for early adopters, among which are several universities and NRENs.

In some areas government and regulatory guidelines or requirements and set timelines to deploy IPv6, for example for ISPs, have been an external motivational factor. There are examples of sector organisations that have been promoting IPv6 deployment and providing information or support to their members, for example the Brazilian Federation of Banks.

4.1.2. Economic and Business Incentives

The long term sustainability of the business or service is a commonly mentioned reason for deploying IPv6. The transition to IPv6 is inevitable and, in the words of one respondent to the BPF survey, “if you don’t do IPv6 now, you will run into a brick wall at some point”.

Being competitive, able to offer IPv6 services as a local ISP and showing to the customer that ‘we know what we’re doing’ is regularly mentioned as a reason to deploy IPv6.

Deploying IPv6 to save costs comes back in several case studies. Some calculated the cost of continuing to buy IPv4 addresses to the cost of enabling IPv6 and dual stack technology and concluded that IPv4 is not a good decision to support future customer growth. Other case studies pointed out that a scenario without IPv6 requires to build a more complex, and therefore more expensive solution. Some decided to deploy IPv6 when deploying a new service, to avoid additional costs in the future.

There are examples service providers that were obliged to deploy IPv6 because one or more customers started to require IPv6.

- Address sharing means fate sharing: if an IPv4 address is blocked by a web site, either because one user did something malicious, or because the web site thought that one user was maliciously generating the traffic of multiple users, then all users sharing that address will be affected.
- Similarly, if a translator runs out of ports assigned to a user, some applications may fail or degrade.
- The architecture of address translators may not provide the same performance as native IP traffic, with either higher latency or lower throughput experienced by consumers.

[18] For example, with IPv6 managing a real e2e-network will be easier as no middleware is needed. The quality of service for the users is not affected by CGNAT and other techniques to deal with the lack of available IPv4 addresses. New services like VoLTE, IoT and M2M communication would be extremely hard to deploy in full scale without IPv6.

Providing a high quality of service is another reason mentioned in the case studies. The service provider wants to assure that all users can access content from any kind of device and network.

4.1.3 Decision Making

Based on the received case studies it can be concluded that in general, the decision to deploy IPv6 is made at an executive level.

There have been several cases where IPv6 deployment was first promoted by one, or a few employees, usually at the technical level, before the initiative was pushed up to the decision making level. At the executive level, the engineers or the technical department then had to convince their company to adopt IPv6. Such a scenario seems to be common case in Europe.

In other cases the decision to deploy IPv6 was triggered by an external factor. The external reason can be an executive who learned about the need to deploy IPv6 at an industry conference, the competitors that deploy IPv6, or a government initiative to promote or require IPv6 deployment. In such cases it is the executive level that requests the technical department to adopt IPv6. This scenario is common in Asian countries where governments took on a leading role in the promotion of IPv6

4.1.4 External Factors

Many case studies don't make reference of an external factor that stimulated of obliged them to deploy IPv6. In Asia, however, one can observe a trend where governments play a leading or encouraging role, for example in Japan or Korea, or define requirements (for ISPs) to deploy IPv6 by certain deadlines, as is the case in Malaysia. Case studies from Brazil mentioned the stimulating role from NIC.BR and initiatives in the banking sector. As mentioned in last year's BPF document, governments in Europe and North America[19] lead by example, for example by defining internal deadlines for IPv6 deployment for government networks and e-gov services and by requiring IPv6 readiness in public procurement.

One of the replies to the NTIA's RFC on IPv6 deployment described how governments can play a leading role by bringing industry leaders, government agencies, and civil society together to discuss the transition and accelerate deployment.[20] An example of soft leadership by the Japanese government was shared at AprIGF 2016 (https://aprigf2016.files.wordpress.com/2016/08/tatsuya_akagawa160728_mic_ipv6_aprigf_r04.pdf).

[19] For example:
https://www.whitehouse.gov/sites/default/files/omb/assets/egov_docs/transition-to-ipv6.pdf
[20] See Lee Howard: …. + add link to submission

4.1.5. Long term cost savings

Several case studies mentioned that adopting IPv6 at an early stage and doing it step by step reduces the cost the transition. Planning early allows to align the deployment of IPv6 with regular refresh cycles and other IT initiatives. For an ISP or large network, the planning and preparation can take up several months and the implementation process can then be spread over several years, fitted in other planned or necessary work. The longer well-prepared process has as advantage that the IPv6 enabled machines or programs can replace the existing hard- or software when it comes at the end of its lifecycle. This is much more cost efficient than buying the equipment or develop/buy the software and afterwards, when IPv6 has become inevitable, spend resources on upgrades.

Other case studies mentioned a policy that requires all new services and applications to have to support IPv6, even if the network does not yet allow IPv6 communication, to avoid the costs of adapting or redeveloping in the future.

Solutions such as Carrier-Grade NAT (CGN) and the need to continue to buy IPv4 addresses on an IPv4 Transit market as long as the transition to IPv6 hasn't been completed, can be an important financial burden, in particular for ISPs. There exist different models to assess these costs. Lee Howard calculated that for an ISP in the USA 'CGN costs $1.5 million over five years for every 10,000 users, or $30 per user per year'[21]. LACNIC developed an economic model to compare the costs of various transition alternatives. The model allows ISPs to assess the cost for their company of three alternative interim solutions: deploying dual-stack with CGNAT, deploying CGNAT44 and purchasing IPv4 addresses to support the growth of their customers without address sharing. The model is available as an easy to use module on the LACNIC website: http://stats.labs.lacnic.net/PROYECTOCAF/modelo/ .[22]

4.2. Sectoral Observations

4.2.1. ISPs

ISPs play an important role in the deployment of IPv6. This is the case in developing and developed countries. ISPs exist in different sizes, operating large scale and smaller networks. There are several examples of ISPs in the case studies from across different regions with different levels of economic development. One general observation for ISPs providing Internet access to home users is that their mainstream customers don't care

[21] 'The Cost of Carrier-Grade NAT', Lee Howard, https://conference.apnic.net/data/36/cost-of-cgn_1377486548.pdf

[22] The methodology behind the model is described in chapter 6 of the LACNIC/CAF study 'IPv6 Deployment for Social and Economic Development in Latin America and the Caribbean', December 2015, http://portalipv6.lacnic.net/wp-content/caf-lacnic/CAF-LACNIC-IPv6-Deployment-Social-Economic-Development-in-LAC.pdf

whether they have IPv4 or IPv6, as long as they are provided with stable good internet access. Therefore, the decision is up to ISPs. Some ISPs, for example in Japan, even choose to deploy IPv6 without their customers being conscious about the change.

The fact that the legacy equipment at the customer's' premises - the CPE or customer-premises equipment - also needs to be IPv6 ready is one of the main challenges indicated by ISPs. Some cases demonstrate that this can be addressed by planning ahead and deploy IPv6 at the time of large scale network upgrades that require legacy CPE to be replaced, and start to provide all new clients with IPv6 capable equipment.

A closer look at the respondents to a recent survey (November 2016) on IPv6 deployment showed that 69% of the ISP employees that replied to the survey responded using IPv4, while almost every response came from a network that has both IPv4 and IPv6 allocations. The researchers concluded from this observation 'that corporate LANs, even in ISP networks have not yet deployed IPv6 in all their subnets.'[23]

A 2015 LACNIC study[24] asked ISPs for reasons why they did not yet deployed IPv6. 'The most commonly mentioned reasons were: 'Current infrastructure presents problems for transitioning to IPv6', and 'Deployment and operational difficulties are expected'.[25] ISPs that already finished or had started IPv6 deployment gave as reasons for the deployment:

1. Declining availability and raising cost of IPv4 addresses;
2. Corporate image;
3. Migrating to IPv6 without further IPv4 growth is the most cost-effective solution;
4. Significant customer base growth;
5. Business opportunity.

The study further observed that 'in many cases deployment began as a result of corporate clients requirements, particularly universities.'[26] And that 58% of the ISPs that already started deploying IPv6 replied that deployment had improved their business results.[27]

A relative small number of ISPs service a large part of the Internet users. Geoff Huston calculated that in May 2015 the 30 largest ISPs serviced 42% of the entire Internet user population. The effect of an IPv6 deployment by one or more of these large providers on the global IPv6 deployment rate is immediately visible.[28] A number of these largest ISPs, however, operate in the developing world, and tend to be late adopters so as to reduce capital risk for their enterprise.[29]

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[23] https://labs.ripe.net/Members/jordipaletm/results-of-the-ipv6-deployment-survey
[24] http://portalipv6.lacnic.net/wp-content/caf-lacnic/CAF-LACNIC-IPv6-Deployment-Social-Economic-Development-in-LAC.pdf
[25] (p.47)
[26] P. 49
[27] p.50
[28] G.Huston calculated that an average 50% IPv6 uptake in the customer's base of the 30 largest ISPs would have increased the global IPv6 capability rate in May 2015 from 3.6% to 20%.
[29] Geoff Huston 'May 2015 Update on measuring IPv6'

4.2.2. IXPs

The IPv6 uptake by Internet Exchange Points (IXPs) is uneven across the different continents. Already in 2011 the European IXP Association (Euro-IX) announced that all of its members were IPv6 ready and enabled[30] and today networks can peer IPv6 traffic at all Euro-IX members.

In developing regions the situation is different. In particular in regions where none of the local networks that peer at the IXP are IPv6 enabled or dual-stack there is not much incentive for starting IXPs to deploy IPv6. Organisations that support the creation of IXPs and the RIRs in developing regions are promoting IPv6 deployment. But it is not because an IXP is capable of handling IPv6, that it will see IPv6 traffic passing through its infrastructure. On the contrary, there is often little or no IPv6 peering activity as member networks often do not yet use IPv6 themselves. UIXP[31], the Uganda Internet eXchange Point, for example has been IPv6 enabled for years (i.e. every member has been assigned an IPv6 address) but saw only recently IPv6 peering after some member networks activated IPv6.[32]

4.2.3. Data centers

There are some commercial deployments observed for long term business preparation. On the other hand, in the short term, data centers still need globally unique IPv4 to be accessible for their customers. Therefore, while some successful cases are observed such as UOL Diveo in Brazil, in general, deployment is still limited. There are cases of data centers providing connectivity in IPv6 but through IPv4 based translation technology such as 6rd.

4.2.4. Cloud Service providers

There have been some recent developments with cloud service providers deploying IPv6 for (parts of) their services. Akamai has made an announcement that IPv6 is on by default for new customers. CloudFlare has enabled IPv6 for their existing customers. AWS and Microsoft Azure gain native IPv6 connectivity:
https://redmondmag.com/blogs/the-schwartz-report/2016/10/azure-gains-ipv6-connectivity.aspx
https://azure.microsoft.com/en-us/updates/ipv6-for-azure-vms/

Lee Howard describes the situation for cloud providers in the United States as follows “Content is moving slowly. Only 16 of the top 50 U.S. web sites are capable of IPv64, essentially unchanged for nearly two years5, and 15% of the top 25000 worldwide. Recent

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http://www.potaroo.net/presentations/2015-05-14-ipv6-stats.pdf

[30] ‘Euro-IX IXPs are IPv6 ready!’, Euro-IX, 7 June 2011
http://www.netnod.se/sites/default/files/Euro-IX_IPv6_press.pdf

[31] https://www.uixp.co.ug/

[32] Information received from the IGF BPF on IXPs, bp_ixps@intgovforum.org mailing list, 20 October 2016.

announcements from Amazon Web Services (AWS)7 and Microsoft Azure 8 are almost as encouraging Akamai's announcement that IPv6 is on by default for new customers, and that CloudFlare has enabled it for their existing customer. A lot more companies need to follow CloudFlare's lead and enable IPv6 for existing web sites."[33]

4.2.5. Content Providers

Several contents providers at global level support IPv6, among them are Google, Yahoo, Facebook, LinkedIn. The number of users accessing content over IPv6 is increasing. For example, users accessing Google websites with IPv6 is increasing by 1% every three month and over 14% in total, in Sept 2016.

On the other hand, the web service availability with IPv6 of the Alexa top one million websites is about 5.8%, while service availability of the Top Alexa 1000 was at 22% in October 2016.[34] There is still room for improvement.

Further, having local content available in IPv6 in each country/economy is another area to be addressed. There are some local content providers observed to have IPv6 availability such as UOL DIVEO in Brazil, Kakao talk in Korea.

4.2.6. Vendors

Vendors of ICT equipment play an important role as their implementation and feature roadmap decisions have an impact on the IPv6 readiness of other actors in the chain. Important progress has been made, but there are definitive areas that need improvement. This is only possible with more wider adoption since primarily the improvements are related to issues typically found with practical experience. For ISPs and network operators, nearly all current routers and access equipment support IPv6. The most recent mobile devices also fully support IPv6. All current computer operating systems (OS) support IPv6, therefore, once IPv6 is turned on by default, users will connect to IPv6 without needing to do any configurations or settings.

There are already devices for consumers, such as cameras, televisions and others on the market that support IPv6. However, most consumer devices that are being used do not support IPv6. The consumer market is still evolving in the direction of IPv6 adoption. There are still issues due to overall lack of understanding and Internet protocol knowledge, but many efforts are being undertaken to help resolve this.

The security features and functionalities for both IPv4 and IPv6 capable devices need consistent enhancements as the Internet keeps evolving. For IPv6 there are some varying protocol nuance which vendors need to understand to create effective mitigation features. Also the interaction between IPv4 and IPv6 co-existing networks need to be taken into

[33] Add link to case study
[34] https://aprigf2016.files.wordpress.com/2016/08/ipv6_measurement20160726-shian-shyong-tseng.pdf
http://www.worldipv6launch.org/measurements/

account. As much as operational training is needed for engineers deploying IPv6 networks, vendors also need training to effectively create and implement security solutions for IPv6 capable devices.

Some areas that need added attention are logging, auditing and filtering capabilities which directly influence devices such as intrusion detection and firewall devices.

"IPv6 requirements for ICT equipment - RIPE-554"
To address the needs of the ICT vendor community and the people responsible for procuring IPv6 capable equipment, the RIPE community developed a procurement document, titled "IPv6 requirements for ICT equipment" and named RIPE-554. The document is used by many global organizations as a guideline during equipment evaluation and in the RFP creation process, to require IPv6 support in equipment and software. RIPE-554 is a list of IPv6 requirements that vendors must meet in order to qualify for consideration for IPv6 capable equipment purchases. RIPE-554 has been translated in numerous languages and widely used around the world. As a result, many vendors have included this set of specifications in their IPv6 implementation roadmaps.

RIPE-554 advises that every tender includes the following text:

> "*All ICT hardware as subject of this tender must support both the IPv4 and IPv6 protocols. Similar performance must be provided for both protocols in input, output and/or throughput data-flow performance, transmission and processing of packets.*
>
> *IPv6 support can be verified and certified by the IPv6 Ready Logo certificate.*
>
> *Any software that communicates via the IP protocol must support both protocol versions (IPv4 and IPv6). The difference must not be noticeable to users."*

After this general requirement the tender should list detailed specifications and requirements for the equipment or software needed. RIPE-554 provides guidelines to specify requirements and lists for different types of hardware and software what standards the tender initiator require. Please see https://www.ripe.net/publications/docs/ripe-554

Note to the tender initiator:
RIPE-554 is intended to be used as a template to include detailed requirements into the RFP. Adding the words "equipment must be compliant with RIPE-554" is not sufficient! To support the authors of the tender, there's a must-read first section, called "how to use this document".

4.2.7. Mobile networks

Expected need to accommodate large numbers of subscribers in coming years. IPv6 provides advantage from scale. Several mobile vendors have recently started deployment in

IPv6. In the US. Out of the cases collected, this is the next area where Japanese government, at the national level has put focus for IPv6 deployment, with a milestone for major mobile phone providers to adopt IPv6 by default in 2017, as a way to accommodate growth in this service sector. SKTelecom in Korea has completed commercial deployment in mobile network in Sep 2014. Apple made it a requirement for all applications in Apple Store to support IPv6 from iOS9. For the handsets, both Android and iPhone support IPv6.

4.2.8. Adoption for non-Internet large scale infrastructure/Large business networks

IPv6 adoption is observed in some applications outside the conventional global Internet connections. Some examples are use in nation wide Smart Meter for electricity supplies, IPv6 multicast services as infrastructure platform for image streaming in nation wide scale by its largest Telecom in Japan with over 19 million subscribers, which they see benefit in IPv6 for large scale multicast service. BMW[35] is IPv6 ready for their website, and they have presented about their idea of IPv6 transition steps as being ready in network infrastructure, then devices and services, and for innovation. There are several banks and financial services firms which have adopted IPv6, such as Banrisul, Banco do Estado do Rio Grande do Sul, Rabobank and Wellsfargo.

4.3 Regional Observations

In section 3.1. we discussed the general trends in IPv6 deployment on a global, regional and national level. Readers who seek data on the IPv6 deployment are referred to that section. This section on regional observations will showcase concrete case studies of companies and organisations that deployed IPv6 and highlight motivational factors and challenges. The case studies have been collected for this BPF via an online survey that was amongst other promoted via the IGF website and BPF-IPv6 mailing list, or were contributed directly to the BPF. In addition the BPF was able to draw from the information collected by the NTIA RFC and online available information, for example case studies presented at other meetings and forums.

4.3.1. Europe

From Europe, we would like to share cases of ISPs in Switzerland and Greece which both have IPv6 deployment rate of over 27% as of Sep 2016 according to APNIC labs IPv6 measurement. In addition, we cover the case of Continental which has deployed IPv6 for their website. There are also cases from Proximus (Belgium), Tele2 (Sweden), PC Extreme.B.V (Netherlands) which are published in the list of case studies.

Disclaimer:
The BPF wants to share a variety of experiences and examples. This section does intent to be exhaustive or representative for a specific country or region!

[35] http://d2zmdbbm9feqrf.cloudfront.net/2016/eur/pdf/CCSIP6-2006.pdf

Switzerland

Swisscom (Telecom operator, Switzerland)
Swisscom is a full-service telecom operator: Service include wireless and wireline services (voice, TV, Internet, networking) for residential, business and wholesale customers in Switzerland. Their IPv6 capable rate is 58%, as of Sep 2016, according to APNIC labs IPv6 measurement.

For Swisscom the main motivation to deploy IPv6 was that IPv6 is the only long term solution to the shortage of IPv4 addresses. By deploying early, they wanted to create momentum for others to deploy IPv6 and use as well. IPv6 is a strategic technical decision to keep the services that are offered today running in the future. The introduction of IPv6 - and in particular of IPv6 only networks - helped to relieve the impending shortage of IPv4 addresses. Deploying IPv6-only networks is possible for wireless networks. Swisscom deployed VoLTE on an IPv6-only APN, and they are planning to migrate the APN for Internet-access to IPv6-only.

Taking an incremental approach in the IPv6 deployment was a factor that contributed the the success of the project. Swisscom started early and progressed with small steps, so that no big “program” was necessary. The two elements that helped the IPv6 deployment to succeed were:

1. Convince the right people that IPv6 must be deployed and that deployment better start early than late;
2. Develop and deploy in small increments that fit normal project budgets
Using 6rd (RFC 5969) helped immensely to start an IPv6 service early that scales to carry all traffic.

IPv6 is a factor that sets Swisscom apart from competitors. Leadership on IPv6 deployment contributes to the image of being a technical leader, which in commercial terms translates into a willingness of customers to pay for quality. So far, Swisscom doesn’t consider IPv6 (yet) to be an enabler for new business, and customers that prefer to stick to IPv4 can still do so. So far, IPv6 is not yet an enabler for new business for Swisscom. Customers can still do with just IPv4.

The Swisscom case study also mentioned that throughput of 1Gb/S of data costs CHF 8,000 over IPv4-CGN (without cost for logging) and CHF 1,650 over IPv6, a simple calculation concludes that the IPv4-CGN solution is four times more expensive.

Greece

Forthnet (ISP, Greece)

Forthnet S.A. is a Greek Internet Service Provider. Forthnet enabled IPv6 on its corporate network in 2011 and its retail internet service is fully IPv6 enabled since 2013. At the time of writing Forthnet was running a pilot project for the business service and expected to have its business Internet service fully IPv6 enabled in Q4 of 2016.

As of September 2016 Forthnet had an IPv6 capable rate of 43%. Their motivation to deploy IPv6 was the imminent lack of IPv4 addresses and the high cost of other solutions

From a comparison of the cost of "buying" IPv4 addresses vs enabling IPv6 and DS-Lite, Forthnet concluded that continuing on the IPv4 path would not support the customer growth envisaged by their business plan. Forthnet started migrating existing customers to DS-Lite, freeing IPv4 addresses for new customer In addition, the was an internal requirement for every new network-related project at Forthnet to take IPv6 into account.

Germany

Continental (Automobile Industry, Germany)
Continental, the globally active German Automotive Group, has enabled IPv6 for their website in Germany, the Asia Pacific, Europe, North America and Latin America. Overall target is to enable the IPv6 protocol and dual-stack on the network infrastructure of Continental to the public Internet. Continental set the requirement that connectivity to external partners via Internet must run over IPv6, and the own network of Continental is being prepared for this situation. Below are the most important steps:

- Public DMZs of Continental is IPv6 enabled incl. lines. (ext. IPv6 clients can connect to IPv6 web service in DMZ)
- Continental public websites are accessible from IPv6-only consumer
- Public-websites-content provided over IPv6 is accessible via Continental Internet-proxies (dual-stack enabled including lines).
- Employees using IPv6 can connect via Conti-Remote Access; Remote Access Gateways are IPv6 enabled incl. Lines.
- Ext. Continental DNS-root is IPv6
- IP-Address-Management tool of Continental is functional to register IPv6
- IPv6-addresses used for public internet access are registered in Continental IP-Address-Management tool
- IPv6 address/subnet routing concept for Corporate Services is documented

The driving factor behind the deployment of IPv6 on the Continental network was the company's which that connectivity to external partners via Internet must run over IPv6. Therefore, the network of Continental needed to be prepared for this situation.

There was no defined business case with a financial benefit. The major driver was to avoid any risks in connectivity for B2B and B2C, for example in case a business partner or consumer can only access via IPv6 or IPv4 CGN.

Evaluation for IPv6 in Continental products/services or IoT/smart factory is ongoing. The main lesson learnt was it requires high effort in training, planning and testing for IT-staff. There was no major invest in hardware, licenses or services for IPv6.

BMW
German car manufacturer BMW presented at the Cisco Live 2016 event in Berlin in February 2016, on it's approach to deploy IPv6:
"BMW Group - An Enterprise Introducing IPv6", Christian Huber, at Cisco Live 2016, Berlin,February 2016
Presentation: http://d2zmdbbm9feqrf.cloudfront.net/2016/eur/pdf/CCSIP6-2006.pdf
Video: https://www.ciscolive.com/online/connect/flowPlayerRedirect.ww
(free registration needed for video)

Estonia

Estonia Telekom (ISP, Estonia)
In 2015 IPv6 in Estonia went from almost not existing to 6% in little than four weeks time. The main reason for this sudden uptake was that Estonian Telekom, the largest Internet provider in the country enabled IPv6 in its networks. One of the leading engineers documented the IPv6 project in a blog post.[36]

Several years of planning preceded the actual IPv6 deployment. It was difficult to build a business case that justified the cost of the IPv6 deployment. Therefore it was decided to wait and combine the transition to IPv6 with a major infrastructure update - the replacement of the broadband network gateway (BNG) platform. To avoid future additional costs it was decided to provide native IPv6 from day zero. In order to minimise the disruption to the services that transition might cause, it was chosen to make the transition in one time and roll out IPv6 connectivity to all end users with last generation CPE.

The transition had to happened without the end users noticing it. While the ISP can decide to deploy IPv6 on its network, it has no control on the the customer's home network on the the other side of the CPE. To avoid causing problems for the user at home it was decided to rely on Happy Eyeballs to have an IPv4 fallback mechanism in case the IPv6 connection malfunctions. More technical detail can be found here (link).

The transition went smoothly as planned and also in the months after the transition there were no problems affecting the customers. Six month after the deployment almost 15% of the customer base were active IPv6 subscribers, and 81% of them had at least one IPv6-enabled device in their LAN.

[36] 'IPv6 deployment in Estonia', Tarko Tikan, June 2015 https://labs.ripe.net/Members/tarko_tikan/ipv6-deployment-in-estonia (accessed 15 Nov 2016)

Next Estonia Telekom intends to deploy IPv6 in its mobile network.

Belgium

Proximus, the incumbent telecom operator and one of the mains ISPs in Belgium, started the implementation of IPv6 more than 10 years ago, with as main motivation to be ready by the time IPv4 exhaustions impacts. The deployment is seen as a 'must do', while the business case is negative, and the cost to replace CPE as an important factor to be taken into consideration. The program board that oversees the IPv6 deployment consists of representatives from different departments.

Even though the Proximus started deploying IPv6 more than 10 years ago, it will take another 5 to 10 years to have all services IPv6 ready.

A recent article[37] on IPv6 in Belgium mentioned that in 2012 the Belgian Regulator, Federal Computer Crime Unit (police) and the ISPs agreed on a code of conduct to limit the use of CGN, concretely to limit the sharing of 1 IPv4 address to a maximum of 16 subscribers. One can assume that this agreement and the fact that it made using CGN/NAT solution more costly, was an motivational factor for the operators to start deploying IPv6, and is probably one of the factors behind the high IPv6 deployment rates in Belgium.

The Belgian regulator is currently working on a report on the IPv6 deployment in the country, which amongst other will assess the effect of the code of conduct[38].

4.3.2. Americas (and the Caribbean)

4.3.2.1. Latin America

Ecuador, Peru and Brazil are the top three countries with high IPv6 deployment rate in the region, according to APNIC labs. Both Ecuador and Peru have IPv6 deployment rate of 18% as of Sep 2016, according to APNIC lab's IPv6 measurement. IPv6 deployment rate in Brazil is approximately 10%, according to APNIC lab's IPv6 measurement. We introduce the cases of ISPs in Ecuador and Peru, and contents providers in Brazil.

Peru

Telefónica del Perú (ISP, Peru)
Within Peru, Telefonica Peru has the highest IPv6 deployment rate of 24% IPv6 capable (APNIC labs stats). Telefónica del Perú has deployed IPv6 native connectivity to more than 2.5 million broadband residential customers (mainly ADSL lines). Thanks to this, Peru has been the leading country in the región until Apr 2016 (later on surpassed only by Ecuador) with around 16% of accesses to Google over IPv6.[39]

[37] http://www.networkworld.com/article/3100968/internet/why-belgium-leads-the-world-in-ipv6-adoption.html
[38] http://economie.fgov.be/nl/binaries/Studie_naar_de_invoering_van_IPv6_in_Belgie_tcm325-264455.pdf
[39] https://www.vyncke.org/ipv6status/compare.php?metric=p&countries=pe,ec,br,bo

Telefónica is a leading provider within the Hispam region. Telefónica del Perú has modern infrastructures and experienced engineers. Therefore Perú was well placed to roll out the new IPv6 technology.

IPv6 is a matter of business continuation and is simplifying comms for new business paradigms such as IoT, Smartcities, Smart Industry, etc. Only those playing with the technology at first hand will be able to identify the business and differentiation opportunities:

- New businesses such as IoT, Smartcities, etc. are all developed with IPv6 in mind.
- IPv6 means costs today that might be lowered by correctly phasing network deployments/updates. Benefits will be more experimented as long as the majority of the traffic becomes IPv6 (as it is already happening in some other countries) or new businesses take benefit of that. For the latter, we expect IoT to play this business role as long as we start to see large IoT deployments, not just reduced testing pilots.

The government in Perú has been pretty active by promoting the leading role of Peru in IPv6 to local corporations and the local administration, for example by organising events.
One of the most important lessons that was shared in the case study was to plan ahead and correctly phase the deployment; this will reduce complexity and save on extraordinary costs.

Brazil

UOL DIVEO (Brazil)
Universo Online (known by the acronym UOL) is a Brazilian company that provides web content, products and internet services. UOL is subsidiary of Grupo Folha. As of January 2015, UOL's website was ranked 73rd on SimilarWeb and 108th on the Alexa Internet globally.[2][3]

In 2012, UOL was ranked by Alexa as the fifth most visited website in Brazil, after the Google portals (Google Brasil, Google EUA, YouTube) and Facebook.[4] According to Ibope Nielsen Online, UOL is Brazil's largest internet portal with more than 50 million unique visitors and 6.7 billion page views every month.[5][6]

UOL started providing IPv6 for its service infrastructure to be able to handle IPv6 end user traffic to UOL websites which increased when the telecommunication companies started to delivery IPv6 to their customers. There was no external factor involved.

The short term motivation was to continue to receive the traffic from users that had migrated from ipv4 to ipv6. UOL has many end users using ipv6. They need to continue to access the products and reached by advertisement traffic.

The mid term motivation was the end of availability of IPv4.

Long term: Customers started to ask for IPv6 as a new requirement. UOL provides both hosting services and contents. Customers of hosting services started to request IPv6 service so that they can set up IPv6 supported websites. UOL also received request to have their website, as contents provider IPv6 ready.

The main takeaway from the UOL is : the market demanded IPv6, so it was necessary to deploy IPv6. Without the IPv6 deployment UOL would had lost clients and revenue in the last 4 years.

Globo (Brazil)
Globo is a contents provider for the largest media group in Brazil. Their motivation for IPv6 deployment is to ensure that the quality of service for their users is not affected by CGNAT and other techniques that will be used to deal with the IPv4 exhaustion. The stimulus to deploy came from NIC.BR.

By deploying IPv6 Globo wanted to assure that all its users can access their content from any kind of device and network. IPv6 will assure that Globo can reach all of its users without the limitations that they have in IPv4.

One of the main takeaways from the Globo case study is that they needed the commitment from the board to implement IPv6 and to get that commitment, the board needed to understand the importance the IPv6 deployment.

America Movil Brasil (Brazil)
The exhaustion of free IPv4 addresses was the main motivation for the IPv6 project. The exhaustion could force the company to suspend new sales, because of a lack of IPv4 Public Address available in the network.

There was a great government incentive for the creation of standards and deadlines for CPE manufacturers. The rules were adapted to avoid new products to be “IPv4 only” under the sentence of sales blocking. That decision helped companies like America Movil that wanted to deploy IPv6 on their network, because IPv6 ready equipment became available on the market.

The biggest challenge was the lack of content and Dual Stack and unavailability of CPE compatible with IPv6, which forced:
- to use CGNAT in many locations;
- to develop an automated process to provide fallback for customers who have applications only capable of IPv4 that do not work with CGNAT (IP cameras for example);
- to set up an audit process to identify unjustified public address requests to prevent any IPv4 public address waste.

Other devices like as IP Cameras, Residencial WiFi Routers, Connected Home devices and

SmartTVs without support IPv6 generated an important financial impact in CGNAT and Legal ID Platform.

After defining the strategy and solution, a program was created inside the Corporate PMO (Project Managing Office) involving several projects and company's areas in 4 fronts:
a) IT Front: New legal identification system / big data; adequation of provisioning systems, CRM, BSS and Field Services; new BI reports.
b) Engineering Front: IPv6 implementation along the whole network; CGNAT implementation on the main cities; log collector systems; team training; adequation of Management, Provisioning and OSS platforms.
c) Customers Front: internal and external communication, training of the call center and field technicians; revision of the customer service processes; monitoring of customer experience KPIs (churn, visits, contact rate, etc).
d) Regulatory and legal Front: coworking with NIC.br, government areas, customer defense entities; revision of contracts and services delivered to the clients.

The project implementation was managed inside the company as a survival strategy and technological evolution. There was no business gains up to now.

Conclusions:
There was no financial gain in the IPv6 deployment.
The costs of CGNAT increased, but delivering only IPv6 was not an option for our customers, because of the resistance coming from the industry (IoT, IP Cameras, WiFi routers, SmartTV, etc) about IPv6 compatibility of their products.
Several cloud systems, APPs, eCommerce and eGov still don't support IPv6, what forces the ISPs to use CGNAT solutions and pay the bill.

The key factor contributing to the success was that a enough time was spent on tests, homologation and planning. In addition, the simulation of the client's environment, the small pilots and the accompaniment of the project's engineers / IP architects in the field visits were very important.

The support from the executive level to maintain the project's original guidelines also contributed to the success.

Banrisul - Banco do Estado do Rio Grande do Sul (Brazil)
Banrisul is a Brazilian bank that deployed IPv6, for the following two main reasons:
1. Allow new clients who already use IPv6 connectivity to have access to the Internet Banking of the Banrisul.
2. Guideline of FEBRABAN - The Brazilian Federation of Banks – (The main entity representing the Brazilian banking industry) to have all financial institutions implement IPv6 before July 2016 for access to Internet Banking services.

The pressure of FEBRABAN made that the company management took a favourable position so that it was possible to mobilize the main areas of the bank (development, security, infrastructure, etc.) and overcome the initial challenges of mobilization and commitment to the project.
The main challenge is to maintain the mobilization and commitment to the project. IPv6 training needs to be emphasised and maybe repeated in some areas.

Takeaways from the Banrisul case study:
The main lesson learned is that training is essential.
The commercial and economic incentives were attracting new customers that are in line with new technologies and require alternatives to access services available on the Internet.
Banrisul didn't measure the financial impact of the IPv6 deployment in the Internet Banking services, yet. However, one was surprised of the amount of IPv6 connections which exceeded all expectations.

The project was of low cost: the internal costs of the teams involved, and the cost of hiring a consultant expert in IPv6.

Included IPv6 training for all teams involved at the beginning of the project a would have made it easier to overcome some challenges, especially in the Development Unit.

As a financial institution, Banrisul must capture the source IPv6 address and store logs for legal purposes. This was a challenge to the Development Unit.

NIC.br and CGI.br stimulating IPv6 deployment (Brazil)
Since 2009, the Brazilian Network Information Center (NIC.br) along with Brazilian Internet Steering Committee (CGI.br) led the deployment of IPv6 in Brazil. Together, they created a project, IPv6.br, to help all Brazilian companies that have services related to Internet to work with IPv6. Three main activities of this project has been made to improve IPv6's deployment.

First of all, free IPv6 training courses. As ISOC has stated in their website, one of the major IPv6 transition costs is staff training. In order to minimize cost and help companies, NIC.br gave more than 150 courses teaching over 6000 network administrators around the country.

Second, collaborating with working groups that seek what is the biggest problem to deploy IPv6 in different areas. For the cases stated in this document two groups are relevant. One group was formed by the Brazilian Government in order to coordinate the work required to adoption of IPv6 in large telecommunications companies (like AMERICA MOVIL BRAZIL), and other was created by FEBRABAN in order to assist banks to migrate to IPv6 (like Banrisul).

Lastly, promoting events related to IPv6, like "World IPv6 day", "Semana IPv6" (local event), "World IPv6 Launch" and "Fórum IPv6" (local event). All these events were important to

increase the recognition of the companies which have deployed IPv6, primarily to content providers like Globo and UOL that have participated in all events.

4.3.2.2. North America

United States

AT&T:[40]

AT&T envisions a future in which literally billions of IP-enabled devices are connected to the network, and IPv6 is a critical enabler of this vision. Accordingly, AT&T began planning for the transition to IPv6 in 2006.As ever more devices connect to the Internet such as computers, smart phones,netbooks, tablets, connected vehicles, smart cities and the Internet of Things (IoT), each of which requires its own unique IP address the legacy system supplying those addresses is rapidly nearing the point of exhaustion.In short, we are running out of IP addresses.Transitioning to IPv6 is a critical step for supporting the continued, sustainable growth of the Internet. Ultimately, IPv6 gives the industry greater room to grow, innovate and support new devices. According to WorldIPv6Launch.org, as of September 30, 2016, approximately 60% of the wireline traffic and nearly 15% of the wireless traffic originating from AT&T Autonomous System Numbers (ASNs) is using IPv6 today.[41]

The single largest factor that contributed to AT&T's decision to migrate towards IPv6 remains overcoming the impending unavailability of IPv4 addresses. Also, the greatest incentive for dual stack of native IPv6 is the cost of implementing other technologies (such as Carrier Grade Network Address Translation (CGN), tunneling (6rd) or other work-arounds).

They describe primary benefit of IPv6 is that :

- It addresses the address exhaust concerns around IPv4.
- Direct connection
    - IPv6 is critical for the deployment of Voice over LTE (VoLTE) services because VoLTE is dependent upon a direct connection to the end user and will not function behind Network Address Translation (NAT) or other technologies that would otherwise be used to extend the life cycle of IPv4 addresses.
    - Because IPv6 enables that direct connection, IPv6 can offer lower latency, which improves call quality.
    - More advanced users also may find it easier to run servers; e.g., host games, support their own email server etc., again because of the absence of NAT.

The fundamental motivation behind an organization's decision to implement IPv6 ultimately boils down to necessity. ISPs or service providers such as AT&T know that, despite current

[40] Submission to the NTIA: https://www.ntia.doc.gov/files/ntia/publications/att_10_3.pdf
[41] http://www.worldipv6launch.org/measurements

workarounds, eventually IPv4 addresses will exhaust, and that supporting the ever-escalating demand for Internet access makes migration to IPv6 inevitable.

6connect (Network Resource Provisioning , US)

6connect provides network resource provisioning and automation[42]. IPv6 is not planning for 6connect, it's a required part of all deployments.Most internal resources in the company are v6 only.

The decision was made a few years ago to treat v4 as legacy and not to turn back. This means in many cases, not only are they single stacked over v6, but even dual stacked hosts have heavy dependency on v6 only services. As the motivation behind the decision to deploy IPv6, first, IPv6 has an attractive factor for 6 connect . It gave the the ability to deploy more infrastructure at a lower cost and a repeatable architecture done once, without ever having to look back and size of pop or resource utilization. The costs are now easily calculated for new deployments and have no unknown cost factors. The vendor selection and partner selection has become far easier with v6 intelligence at the top of the requirements list. Second, they could completely eliminate NAT. They are now able to have a single security policy which applies globally simplifying security policy. Lastly, compared to other current technology, IPv6 turns out to be low hanging fruit. There are far greater challenges in the orchestration automation technology space, so v6 is one of many easy things to tick off the list and keep the company on its toes.The biggest issue is having to educate partners, vendors and customers. The technology itself will always have some issues just like every other protocol or network service out there.

As business case, as a cost factor, they updated their architecture in hardware, software, services, etc, while this technology had an economic impact, the was relatively small, compared to technologies such a virtualization. IPv6 is just another required update to the architecture. 6 connectr sees that , while there are some performance and policy benefits, the true benefit is staying in business. They consider v6 is a _requirement_ to continue to conduct business on the Internet.

As lessons learnt, 6connect believes IPv6 will be only as hard as you make it. Many inefficiencies were removed related to Out Of Band networks and NAT. They are now able to operate with lower network cost and no longer need to check on IP resource utilization per pop. All pop sizes are now the same IP architecture despite serving small, medium or large service areas. To have done better planning, removing dual stack earlier would have saved time and money. IPv4 support turned out to be the larger cost than just moving to single stack IPv6 where possible.

Microsoft[43]

[42] https://www.6connect.com/, https://www.6connect.com/blog/
[43] https://www.ntia.doc.gov/files/ntia/publications/microsoft_10_4.pdf

Microsoft has a long history of supporting IPv6, starting with Windows Vista, Windows Server 2008, and Windows XP Service Pack 3. document assumes IPv4 and IPv6 coexist for some time. Aside from the obvious benefit of a much-larger address space, IPv6 benefits to Microsoft include improved peer-to-peer networking for communications and multiplayer gaming and improved delivery of personalized user experience using IP-based location services.

As a provider of online services, Microsoft's motivations are described above. As a networked organization, Microsoft is looking for internal efficiencies in its "Intranet of Things", including servers, workstations, BYOD, and infrastructure embedded devices such as cameras, sensors, clocks and displays. The demand for low-latency peer-to-peer networking in communications and gaming has greatly increased, mobile operators are attempting to build IPv6-only LTE networks to deal with IPv4 address depletion, and governments are considering support mandates for IPv6 from their vendors and suppliers. IPv4 addresses are increasingly difficult and costly to obtain, and location services which deliver targeted experiences to end users based on IP addresses are hobbled by network address translations. Each of these changes accelerates the need for native IPv6 support at the customer-facing network edge and further vindicates Microsoft's early and ongoing investments of IPv6 in our online services and in Windows clients and servers.

They expect to see minor performance benefits as address translators are removed and implementations are improved. Since some equipment implements IPv4 in hardware, but IPv6 in software, hardware parity over time should improve performance. To date, IPv6 performance in Microsoft has been the same as IPv4 for practical purposes.

As return investment, for Microsoft as a service provider, the anticipated return is a mixture of reduced risk and increased market opportunity. The internal use of globally non-routable addresses creates risk because the addresses can leak into the Internet due to human error and misconfiguration. Moreover, the need to purchase IPv4 addresses on the open market introduces risk due to fluctuating commodity prices.Market opportunities increase when customers mandate IPv6 support and when IPv6 allows faster infrastructure growth for services experiencing rapid customer usage.Microsoft corporate IT efforts are based on a belief that IPv6 support is a cost of business, with returns on investment to be seen only over a very long time frame.

They have not included any discussion about potential power, computational or software maintenance efficiencies which would arise from a purely IPv6 environment, as this BPF

WelsFargo[44]
Wells Fargo & Company is an American international banking and financial services holding company. To WelsFargo, IPv6 provides numerous benefits, including: greater space for

[44] Submission to the NTIA: https://www.ntia.doc.gov/files/ntia/publications/wellsfargo_10_3.pdf

growth; reduced requirement for readdressing duplicate address space in mergers/acquisitions; the ability to support low-functionality end-points that may lack DHCP and static addressing capabilities (IoT, even Android devices); the ability to reduce reliance on NAT (and associated logging complexity); the ability to more universally geo-locate address space (assuming ULA usage is reduced compared to RFC1918); and the simplification of routing tables through improved summarization.

They also observe unexpected benefits of implementing IPv6 include gaining a very detailed knowledge of all the technology used in the organization; Establishing closer working relationships with application and procurement teams; gaining deeper insight into asset/inventory systems and how to establish relationships between elements; opportunity to provide specific, relevant technical training to a wide variety of engineering teams. It also provides a clean-slate for designing from the ground-up..

Risk mitigation of the Internet transitioning to IPv6, or IPv6 being required of the organization without appropriate preparation is the driving motivation for IPv6 implementation.The desire to remain fully connected to the Internet and support all customers as well as employees (i.e. VPN, outbound web proxy, email) is a significant factor driving implementation. Risk mitigation in having to otherwise enable v6 in a rapid, reactive fashion (and possibly root out rogue internal implementations where it was needed but not supported) is another significant factor, as is perception that future mergers and acquisitions will be simpler if IPv6 is the pervasive enterprise communication standard protocol.

4.3.3. Asia Pacific

From South East Asia, we see Malaysia with high IPv6 deployment rate of approximately 14%, according to APNIC lab's meansruement. From East Asia, Japan is observed to have high deployment rate in the region, more of less the same as Malaysia with approximately 15% deployment rate. Deployment rate in Korea is not high overall at this stage (1.15%) but has a few initiatives observed as case studies in area where challenges remain in the region for IPv6 deployment such as case studies from contents provider and mobile network service provider.

Malaysia

Telecom Malaysia

In August 2015, Telecom Malaysia became one of the top-10 IPv6 network operators in the world, according to World IPv6 Launch, measuring over 15% IPv6 deployment.

TM's deployment of IPv6 was driven by two primary factors: the responsibility to drive IPv6 adoption as the nation's leading communication service provider; and to ensure business continuity for all the customers, in view of global IPv4 address exhaustion.

TM took the following economic and business factors into consideration

1) Ability to offer IPv6 services give competitive edge amongst local ISP
2) Graceful migration of unmanaged customer devices / CPE (no force migration).
3) Minimize capex through natural progression of hardware refresh (no drastic network equipment upgrades)

While IPv6 used to be something on the network strategy map years ago, IPv6 deployment is considered as something done and is now a pre-requisite / enabler of other potentials.

In addition, the regulatory body (MCMC) in Malaysia developed strict guidelines that provided the necessary push required for all Malaysian ISPs to move to IPv6. Without the act, ISPs may delay IPv6 adoption due to the lack of commercial demand and the associated costs. (For full story, see: "Championing IPv6 deployment in Malaysia" http://blog.apnic.net/2015/12/01/championing-ipnt-in-malaysia/).

Lessons Learnt:

1. Top-down support & company-wide communication is key to the success of any initiative.
2. Spread the deployment cost – try to slot in during typical network tech refresh
3. IPv6 by default for any new network/service implementation

Japan

Japan: NTT East (IPv6 Multicast):

NTT East is the telecommunications services provider which cover Eastern Japan, with 19 million subscribers as of March 2016. With NTT West which cover the west areas of Japan, they provide nation wide telecommunications services in Japan. They use their platform for their intranet services and adopted IPv6 in their IP based network in 2004. They wanted to provide platform for image streaming as their business strategy at the time and it was technically challenging to provide the PPPoE service in IPv4. They saw benefit in IPv6 to provide multicast service in large scale. They also consider IPv6 from mid-short term business perspective,: It has no risk to impact continuity of the services in the future , such as IPv4 address exhaustion. From a business perspective, adopting IPv6 is working positively for future service continuity

IPv6 Multicast has greatly contributed for providing videos and image based services.There was no degrading of performance nor scalability as initially anticipated as concerning factor of IPv6 adoption.There was no impact on cost. The equipment was both IPv4 and IPv6 capable, therefore there was no additional cost. Based on NTT East's IPv6 Multicast Streaming infrastructure, NTT Plala provides image streaming service to its subscribers for optical fibre service .

Others:

As another aspect of NTT group's service, The largest fiber-to-home infrastructure, deployed by NTT group (http://www.ntt.co.jp/index_e.html), has been deploying the default IPv6 service capability since around 2012. IPv6 promotion council and Task force on IPv4 address exhaustion Japan (http://www.kokatsu.jp/blog/ipv4/en/) has worked with NTT to monitor the progress of this deployment activities. As in summer of 2016, about 20% of

fiber-to-home residential customer houses of NTT group are IPv6 capable without any notification nor configuration by their customers, as shown at http://v6pc.jp/jp/spread/ipv6spread_03.phtml .
This site provides other ISP's (i.e., KDDI and CTC) IPv6 service status, as well.

In the area of mobile, Japan has three major MNO (Mobile Network Operator), which is NTT DoComo, KDDI and SoftBank. In the discussion at MIC (Minister of Information and Communication) in 2015, Japan will progress "IPv6 Mobile Launch" in 2017 (next year), which means all three mobile carriers in Japan will start the full-scale IPv6 service deployment in their commercial mobile networks. Page 8 in http://www.soumu.go.jp/main_content/000388371.pdf .

There are also other application observed in Japan as as smart meter for electricity measurement in nation wide scale. Smart meter system for residential houses in Japan, deployed by major electric utility companies. Especially, TEPCO (http://www.tepco.co.jp/en/index-e.html), that is the largest company in Japan accommodating more than 30 Million residential houses, and Kyushu Electric Power Company (http://www.kyuden.co.jp/en_index.html), that accommodates more than 8 million residential house, has been developing IPv6 single stack smart meter access network. TEPCO mainly uses multi-hop wireless network with 6LOWPAN and Kyushu Electric Power Company mainly uses 4G LTE IPv6 service for the access network.

Korea

SKTelecom (Mobile, Korea):
The motivation behind the decision to deploy IPv6 is to solve the problem of IPv4 exhaustion and to take technology leadership in the market. As an external factor, there was IPv6 government project with KISA (tax reduction for corporate). As business factor, the issue of IPv4 address exhaustion and increase in IoT devices, to deal with the problem of IP needs for exploding devices in IoT environment. Consideration was needed to build up infrastructure for the services which require device to device communications. They carried out as a 3G government project in 2010 and a LTE government project in 2012. They started to commercialize IPv6 service in Mar. 2013 and completed in Sept. 2014. They have launched IPv6 default devices to deal with IP shortage problem for new services. IPv6 traffic was increased through cooperation with Google.

It was relatively easier to deploy IPv6 on the new networks than the existing networks, therefore they decided to deploy IPv6 mainly on the networks for mobile services. As effect they observe in busines through IPv6 deployment, SKT (ISP) secured potential sales increase and a cooperative business relationship with Kakao (CSP) in the process of IPv6 commercialization. Further, SKT reduced IPv6 adoption cost by conducting a government project in cooperation with KISA.

Kakao Talk (Contents Provider, Korea)

Kakao Talk[45] provides similar Messenger service to WhatsApp, an similar Portal Web service for news, mail and web surfing to Yahoo.com. They have undertaken IPv6 deployment activity through cooperation with Kisa and ISPs.Their motivation behind the decision to deploy IPv6 is to o provide Mobile centered services. They saw that end user's IPv6 only devices are getting increased and there is a need to give the best support native IPv6 environment. They have considered balance between costs through additional purchase of equipments for IPv6 deployment and development of human resources for IPv6 operation, and service quality improvement by providing Native IPv6 environment. They believe considering cost, it is reasonable to keep IPv4. It took them review IPv6 deployment. Currently, IPv6 is supported in some of services, and their ur goal is provide all the services through Dual Stack, and we have completed IPv6 deployment in about 10% of our services. They observe no benefit in early IPv6 deployment without additional supports. As incentive to deploy IPv6, they see changes in users' environment are needed ro requiring IPv6 deployment on the Apps such as Apple, Google will be efficient. IPv6 deployment will cause additional cost anyway, and they deployed IPv6 stage by stage solving the difficult cases of IPv6 deployment on application and OS with NAT64 and Proxy.

Observations on the IPv6 Deployment in Korea
contributed by Billy MH Cheon, KISA, www.kisa.or.kr

< IPv6 Deployment Status in Korea >
The first IPv6 allocation to Korea was made for the KOrea advanced REsearch Network in 1999. Since then a lot of efforts have been made for IPv6 deployment. Korea has a fairly enough amount of IPv6 addresses, 5,245 /32. However, Korea has kept a quite low profile in terms of actual IPv6 usage regardless its multifaceted efforts. The figures of IPv6 measurement by country from Google was 3.58% as of July 28 and the graph showed the increase in 2014.

In the private sector, SKT deployed IPv6 on the voice and data of commercial LTE networks in Sep. 2014. Followed by this, in Dec. 2015, in collaboration with KISA, major CATV operators such as CJ hellovision, C&M, and HCN also deployed IPv6 on their commercial services. This year, NAVER, one of large local CSP, commenced IPv6 on its commercial service. Now, IPv6 services are being provided for 11 regions with about 6,0000 subscribers in Korea.

From the public sector, the Korean government & KISA set up a national plan to promote IPv6 deployment. The government made all ministries procure IPv6 compatible equipments by law since 2014. And also, they exempted income and corporate tax in IPv6 equipments purchase - 3% for large companies and 7% for SMEs. KISA established 'IPv6 deployment support center' in 2014 and has provided the full range of services such as a helpdesk service, a training as well as a testbed for IPv6 environment. KISA also hosted IPv6 workshops and published guidelines to share technical / managerial know-hows with SMEs.

[45] http://m.daum.net, http://t1.daumcdn.net, http://img.daumcdn.net

< Observations in comparison with IPv6 deployment in Europe >
KISA attended one of the 2016 RIPE meetings and interviewed ISPs and companies on IPv6. We asked what made differences between Korea and some of European countries and followings were highlighted questions and answers.

1. Why Europe is relatively ahead of other region in terms of IPv6 deployment ?
   - There are many Multi national ISPs and they are making a competitive market environment.
   - CGN may cause legal problems.
   - If CTO has a technical back ground companies more easily adopt IPv6.

2. Was there any direct government supports in IPv6 deployment ?
   - Almost none. Even there was, it was not effective.
   - Indirect approach would be more effective. For example, smart city with IPv6
   - voluntary activities in NOG was noted in most of countries with high IPv6 adoption rate.

3. Any benefit from IPv6 deployment ?
   - None from the short term view
   - After complete IPv6 adoption, ISPs may be able to make a profit from selling their IPv4 at good price.

4. Any other specific difficulties in operating IPv6 network ?
   - Same as IPv4 network, not much different from IPv4 network.

5. Additional charging scheme for IPv6 ?
   - No additional fee should be charged.

6. Any highlighted challenges ?
   - Legacy equipments change
   - Too many CPE equipments on leased line

4.3.4. Middle East

In November 2016, Etisalat, one of the first telecommunications service providers in the UAE, announced the rollout of IPv6 for all Etisalat eLife customers across the UAE. eLife is the commercial name used for the company's tv, Internet and telephone solutions for consumers.[46]

[46] http://www.itp.net/610263-etisalat-rolls-out-ipv6-for-home-subscribers?tab=article

4.3.5. Africa

/ information to add on Zimbabwe, Kenya, SudREN - Sudan
Liquid Telecom https://www.internetsociety.org/afpif-2016/day3-presentations-and-livestream /

4.3.6 Global Players

Google
Google support IPv6 in its Google website, youtube, and android (not in all cases).
It also provides Google Public DNS64 service, which administrators of IPv6-only networks can combine this with locally-provided NAT64 using the well-known prefix 64:ff9b::/96 to reach public IPv4-only sites from IPv6-only networks.

LinkedIn (SNS)
Improvement in user experience by adopting IPv6 is observed in LinkedIn, as no large scale TCP timeout in IPv6 compared to IPv4.
Overall,they are happy to report that there is increasing adoption of IPv6 and also better performance when visiting LinkedIn if you are visiting our site through mobile carrier networks.
http://cgi1.apnic.net/conference_data/files/APSr107/APNIC_Keynote_2016_LinkedIn.pdf
https://blog.apnic.net/2016/05/13/linkedin-ipv6-measurements/

Cisco (Vendor)
Cisco states on its website that they are committed architecturally to IPv6 across the board: All of their devices, all of their applications and all of their services.
It also states that if we don't overcome the challenges of IPv4 we will slow down the growth of the Internet and lose momentum as an industry. IPv6 is important to all of us, to everyone around the world. It is crucial to Cisco's ability to tie together everyone and every device.
http://www.cisco.com/c/en/us/solutions/ipv6/overview.html

Microsoft (OS)
See 4.3.2. America, North Ameri, Case Study for “Microsoft”. The list of IPv6 supported microsoft products and other IPv6 related resources are available at: https://technet.microsoft.com/en-us/network/bb530961.aspx

Apple (Vendor, Mobile Phone handsets, App store for mobile)
Apple made a very clear statement about app availability over IPv6 in 2015.
“Starting June 1st 2016, all apps submitted to the App Store must support IPv6-only networking.” My making such a statement, Apple helps mobile providers making the transition to IPv6 easier.
https://developer.apple.com/news/?id=05042016a

Facebook
Facebook uses Identifier Locator Addressing (ILA)feature of IPv6, to accommodate large scale mobility within their infrastructure.This allows them to maintain coherent identifiers, even if the physical location of the device moves.
https://www.nanog.org/sites/default/files/20161018_Lapukhov_Internet-Scale_Virtual_Networking_v1.pdf

Netflix(Contents Provider)[47]
Netflix, the Internet tv streaming service is dual stacked.
When devices support IPv6, the Netflix Client supports IPv6. When supported devices run on dual stacked networks, the Netflix client uses IPv6 as a default, but can fall back to IPv4 if needed.
In August 2016 around 10% of global traffic was IPv6 based, with traffic in Western Europe and the US higher than this global average and IPv6 traffic in Africa almost non-existent.

4.3.7 Non commercial deployment

Universidad de Guadalajara (University, Mexico)
They have shared the case of academic network infrastructure (web server, mail server, Internet connectivity to academic network users). Universidad de Guadalajara UDG is a +265,000 students university with 15 university centers (campus) and +180 high schools; with 95% of it's locations connected to the data network and the Internet. UDG's network is composed of 91 Km of its own fiber optic metropolitan network, leased circuits and microwave radios deployed all over the state of Jalisco; it is considered a nationwide leader in ITC. The implementation of Internet Protocol version 6 (IPv6) in UDG's data network , has been a great effort that started in 2001. Since then the university's ITC staff has promoted IPv6 use within the university and other national entities. This initiative is reflected today in network traffic of the institution reaching 90% of hosts with IPv6 addresses in production.

As the motivation behind the decision to deploy IPv6 in recent years, a change has occurred in the technological paradigm that enables on-demand provisioning, almost in real time, IT resources through virtualization infrastructure of data centers; however, the rigorousness of the networks has become an obstacle to its flexibility and operation. Besides the above, they add depletion Internet addressing, IPv4, as another major limitation in scalability.

The needs of the University of Guadalajara regarding the implementation of Information and Communications Technologies (ICTs) represent a major challenge because of the size of its academic community and territorial dispersion. In this sense, the solutions implemented make a number of featuraes that have led us to search the available ICT innovations. The

[47] Based on Nina Bargisen, Netflix, 30 Aug 2016, at AfPIF, Recording & slides : https://www.internetsociety.org/afpif-2016/day1-presentations-and-livestream

data network of the University of Guadalajara, in the main distribution and dorsal, is not exempt from this situation because it is required to be dynamic and have growth in devices and access points to cover the academic demands.

5. Remaining challenges

5.1. Remaining challenges after implementing IPv6

- Bugs and technical issues
    - This is a common challenge which most of the case studies have shared, and, especially when being an early adopter in a certain service sector
    - This may vary per service sector, for example in area where there are more deployment cases such as and from late adopters, we hear less of such issues
    - Several companies in the US have explicitly stated more need for more vendor support IPv6
      There are several other case studies which expresses that debugging IPv6 supported product was the challenging part of IPv6 deployment
        - Particularly for specific functionality (such as ND inspection OSPFv3 neighbor authentication, VXLAN overlay v6 transport, etc.)
        - Lack of support entirely in some critical product sets
        - Limited or missing v6 support in many operational and security tools and services (including DDOS mitigation services).

  Possible way forward
    - Several US Case Studies request for action from the government (NTIA in the case of US), to require vendors to support IPv6.

- Cost of staff training and human resources for commercial deployment
    - For small/medium ISPs/Data centers - cost of training staff to have sufficient knowledge on running IPv6 network
    - This issue as identified in developing country such as Japan as well. In case of Japan, community body jointly developed hands on seminar program per different industry sector.

  Possible way forward
    - This may be an area where governments or nonprofit industry bodies or jon efforts by the community in the regional/economy can support, depending on what best fits in that environment
- ISP infrastructure is IPv6 ready but CPEs in customer premises do not support IPv6
- As related issue, consumers are allowed to buy their own modems and gateways, and there is no incentive for those retail manufacturers to include IPv6 support: unlike

ISPs, most consumers don't know anything about IP, and therefore IPv6 does not drive sales.

- Some ISPs require customers to apply for IPv6 service, to enable IPv6 (From fear of getting customer complaints by making IPv6 available by default)
- It requires additional costs to or limitation for small businesses
  The absence of economies of scale and scope typically result in higher investment costs for small businesses. While rural carriers often include IPv6 capability in their specifications when seeking to procure new products, rural carriers' purchase patterns and needs are often different from larger carriers. Smaller companies' lack of market power limits their ability to enhance the demand for, or drive specific development of, IPv6-capable hardware and software.

5.2. Challenges for regions where where deployment is not taking off

5.2.1. Deployment Challenges in Developing Countries

In the recent years IPv6 deployment has been paced up in different part of the world especially in Europe and USA. There are significant progresses in Latin America and in part of Asia for example in Japan and Korea.

But still mostly in the developing world IPv6 deployment rate is far behind. As part of the 2016 IPv6 BPF initiative we have also tried to find the deployment challenges in the developing nations. It has been observed from the survey that still there are lacks of motivations, few technical challenges remains and lastly in most of the countries no real initiatives from the governments to promote or encourage IPv6 deployment to fulfill the need of connecting the unconnected.

Most of the service providers (ISPs, Mobile Operators) are aware of the fact that sooner or later they will need to deploy IPv6. Some deployed IPv6 in the transit paths and in their core networks but at the access layer mostly no visible IPv6 deployment and largely depending on Carrier Grade NAT (CGN).

Some ISPs mentioned even they can offer IPv6 to their corporate customers without any challenge but there is not much interest from the customers rather in some cases they are not willing at all as they don't have enough knowledge on IPv6 deployment and IPv6 security.

Regarding IPv6 deployment for the last mile broadband users, some ISPs mentioned that they have technical difficulties in shaping the bandwidth in IPv4 and IPv6 dual stack environment and looking for technical solutions to that to comply with the commercial packages they are offering.

Some acknowledged that not all their engineers are capable enough to manage IPv6, especially IPv6 security.

Another major issue for the ISPs in South Asia is the CPEs. More than 90% of the Wifi access points presently in use are not IPv6 capable. Which is one of the main demotivation factors in deploying IPv6 for the last mile broadband users. Still a large number of cheap CPEs being sold in the market are not IPv6 capable.

Mobile Operators were waiting for more Smart Phone users before deploying IPv6. But recent years use of smart phones growing rapidly, one of the mobile operators in Bangladesh mentioned their smart phone users are now more than 20% and it's growing fast. Now they are considering deploying IPv6 seriously. But any fixed strategy and timeline is yet to be fixed.

In the Content side only a handful content providers are offering contents via IPv6. Lack of awareness seems to be the major factor in this area. No major technical or other challenge found in the survey.

- Convincing decision makers about the need of IPv6
- This is the case even in global corporation such as Microsoft describes as :
  "Advocacy of IPv6 occurs at levels below the decision makers. It is understood that IPv6 will be a hard sell because it is more difficult to quantify the potential benefits than to quantify the likely costs to replace equipment, retrain staff, and implement the physical and configuration changes required to make the transition. This is particularly true when networks are heterogeneous mixtures of operating systems and include embedded devices and sensors which are assigned addresses and remotely managed differently than servers and workstations."
- Rural areas in some developing countries use second hand equipment, hence needs another cycle to upgrade to IPv6 supported equipment

6. Conclusions / next steps

*** the takeaways and next steps will be discussed that the BPF workshop at the IGF meeting in Guadalajara. The conclusions will be added to the BPF document. ***

6.1. Takeaways for policy makers

/placeholder/

6.2. Takeaways for business decision makers

/placeholder/

6.3. Additional questions to be addressed

/placeholder/

Appendix :

Survey replies and case studies

https://docs.google.com/document/d/15HP5OkTPfnWkK4z4Z5qNbyuqNmAAP1o_xlxuZjrkt28/edit?usp=sharing

new case studies BPF 2015

(see link)