now support IPv6, including the majority of root servers, generic top level domains (gTLDs) and country code TLDs (ccTLDs) IPv6 deployment is getting its momentum globally and IPv4 addresses exhaustion is approaching rapidly. In fact, Asia Pacific has been the first to announce exhaustion of its IPv4 pool at the end of June 2011, following the central pool exhaustion early February 2011. In Africa, AfriNIC, the African Internet registry, has launched the initiative of establishing an African regional IPv6 taskforce, to primarily oversee IPv6 development and deployment in the region.

IPv4 and IPv6 : the issue

IPv4 uses 32-bit addresses and therefore, the maximum numbers of addresses it offers represent around 4.3 billion. If one subtracts various reservations for loopback, private IP addresses, multicasts, and experimental uses, a roughly over 3.9 billion public IP addresses remain for allocation. As of February 2011, the Internet Assigned Numbers Authority (IANA) had allocated all remaining public IP address ranges to the five global Regional Internet Registries.

By contrast, with a 128-bit address space, IPv6 creates a completely different universe. The total maximum number of available addresses is on the order of $3.4 * 10^{38}$ addresses (340 trillion trillion trillion). The best way to really understand what this means is to ponder the typical IPv6 address allocation from an ISP to a customer for networking use. Customers are usually granted a /64 address, which means a single entity gets 4.3 billion times as many addresses as occur in the entire IPv4 address space.

While the African pool of IPv4 allocation is still important with a supposed depletion by 2013, it is worth noticing that from now on, the global world is moving towards adoption of IPv6. Also, there will be years of dual stack operation and that is the challenge for Africa. Dual stack means coexistence between IPv4 and IPv6, and existing IPv4 users will have to migrate to IPv6 for the following reasons: new functionalities not available in IPv4; reduced costs by using IPv6; and the risks of not gaining connectivity to new services deployed over IPv6 only.

Why switch to IPv6? IPv6 Uncovered!

The future of the Internet lies on Internet Protocol version 6 (IPv6), with its ability to use 128-bit addresses instead of the 32-bit addressing of IPv4. Again, this vastly increases the number of addresses available from about 4 billion to approximately 340 trillion trillion trillion. Beyond an extremely large address space, IPv6 brings numerous other advantages to networks that use this protocol stack. These include the following:

- A redesigned IP header format that moves non-essential and optional elements into so-called extension headers that follow the IPv6 header. The resulting streamlined IPv6 header is more compact, faster and easier to process as it is routed from sender to receiver.
- Efficient, hierarchical addressing and routing: rework of IPv4 into Classless Interdomain Routing (CIDR) taught networking engineers how to organize and orchestrate addressing and routing information. IPv6 incorporates all of this into its base design.
- Multiple auto-addressing and address configuration methods, including DHCPv6 and automated link-local addressing. Local hosts can always automatically configure themselves for local communication quickly and easily;
- Improved security comes from built-in support for IP Security (IPsec) in IPv6. IPv6 incorporates security header extensions for encryption and authentication. This can allow use of virtual private networks (VPNs) with IPsec from end to end. Though IPsec remains optional in IPv6, it is much easier to use.
- Better routing technologies. Support for a Flow Label field in the IPv6 header makes it easier to route and manage IPv6 networks with priority or quality of service regimes on network flows. It also enables the use of sophisticated routing and high-speed packet delivery services through the cloud Multiprotocol Label Switching (MPLS).
- Better Neighbor Discovery protocols for IPv6 replaces the broadcast Address Resolution Protocol, along with ICMPv4 Router Discovery, and ICMPv4 Redirect messages. It uses efficient multicast, anycast, and unicast messages for neighbor discovery and route information.
- No more need for NAT (network address translation) — though IPv6 proxies may be a good idea to maintain anonymity and opacity — because sufficient IPv6 addresses for all conceivable uses eliminate the need for address translation services.

IPv6 adoption globally

Many of the core Internet infrastructure now supports IPv6 including the majority of root servers, generic Top-Level Domains (TLDs) and country code TLDs (ccTLDs). Indeed, technical, business and government sectors have been preparing for Internet Protocol version 6 for a decade. Key service providers and content suppliers such as Facebook, Google and You Tube are deploying IPv6 capabilities on their infrastructure, while numerous governments, through partnerships with the private and civil society, are actively engaged in activities designed to ensure their citizens have Internet access via the new protocol. Indeed, global IPv6 deployment is vital to the continuous growth, stability and resiliency of the Internet.

Drawing from the central global source which is IANA (Internet Assigned Numbers Authority), the five regional Internet registries (RIRs) have allocated the equivalent of more than nine billion /48 IPv6 address blocks to network operators (18 Million in Africa by AfriNIC), which is 600 times the size of the entire IPv4 address pool. In Africa, AfriNIC has launched the initiative of establishing an African Regional IPv6 task force (AF6TF) to primarily oversee IPv6 deployment and development in the region. The AF6TF, in collaboration with African governments, local and regional task forces, service providers, Internet eXchange Points (IXP) and research and education networks aim to share relevant information and know how on IPv6 technology. As a result, governments all over Africa are now developing national road-map for IPv6 deployment through consultation papers, trainings, education and regulation to guarantee that their infrastructure is IPv6 capable. ISPs and mobile operators that support native IPv6 in the Africa region are increasing rapidly, rolling out IPv6 connections to their customers. National IPv6 Task Forces are working together with the African IPv6 Task force to enhance capacity building in the region by creating a common African knowledge and best practices database.

Why have African Higher Education Institutions not adopted IPv6 yet?

While AfriNIC had extended an IPv6 related waiver to African Higher Education Institutions in 2007, the rate of IPv6 deployment in these institutions is still slow and many are still sticking to IPv4 addresses. Many reasons account for this lack of adoption of the new protocol; these are related to lack of native IPv6 Internet access, services available, networking hardware components and infrastructures, and some to necessary changes to important applications and services to enable end-to-end use of IPv6.

Lack of native IPv6 Internet access

IPv4 and IPv6 are not interoperable, and in fact they require different protocol stack software to work properly on networking hardware (including Layer 3 switches, routers and firewalls), as well as on servers and client devices that usually act as the end-points for Internet or private network interactions. ISPs must add IPv6 support to existing IPv4 capabilities (this is usually called a "dual-stack" approach to IPv4 and IPv6), and be able to support both protocols for a yet to be defined period (this will depend on how long the transition will take).

A quick look at recent surveys on ISPs that support (or plan to support) IPv6 breaks down something roughly like this:

- One-third of ISPs already support IPv6;
- Up to 85 percent of all ISPs plan to support IPv6 by the end of 2012, so somewhere around 50 percent are "getting ready" to go with IPv6. In the USA for example, major ISPs such as Sprint, Comcast, AT&T, Time-Warner and Verizon have pilot or partial deployments of IPv6. Most of them offer native, dual-stack services for enterprises and US government customers already (thanks in large part to federal mandates for IPv6 support to supply Internet services to US government agencies and workers).
- The remaining ISPs plan to support IPv6 in 2013 or later.

IPv6 capable networking infrastructure needed

Aside from whether or not external ISP links can accommodate IPv6, internal network infrastructures must also be able to handle IPv6. For companies and organizations that purchase enterprise-class networking gear — including routers, firewalls, Layer 3 switches, and other networking appliances of all kinds (WAN Optimization, spam filters, anti-malware devices, content filters, and so forth) — IPv6 support is more often present than absent.

For networks not already configured for IPv6, some work will be needed to enable IPv6 function on networking gear, then to configure it properly and test it to make sure it's working properly. Routers will need to be IPv6 enabled and to be tested to make sure IPv6 routing protocols are working properly. Layer 3 switches will need to have IPv6 VLANs set up and configured. And finally, firewalls will require turning on IPv6 packet forwarding and rules or filters established for what kinds of IPv6 traffic (and addresses, states, and so forth) to allow or deny. Certain IPv6-based services will also be essential to facilitate proper IPv6 network function, particularly DHCPv6 for assigning and managing IPv6 network addresses, and DNSv6 for resolving IPv6 based name lookups so that clients can use domain names to make Internet service connections.

For campus networks, adding IPv6 support may involve replacing some networking equipment — particularly switches, routers, firewalls and so-called "combo devices" that often integrate all of these functions into a single appliance.

Upgrade and enable key network services for IPv6: DHCP, DNS, E-MAIL and more

To make effective use of IPv6, the network infrastructure must itself be upgraded to provide IPv6 support. At a minimum, this means that some kind of IPv6 addressing scheme must be designed and implemented. Although DHCPv6 isn't required to supply network interfaces with IPv6 addresses, it is enough, like in case of IPv4, for network administrators to understand how to install and use it both easily and readily. This addresses the need for clients to obtain IPv6 addresses that they can then use for IPv6 communications and network access.

Likewise, support for the Domain Name Service (DNS) is as important for IPv6 users as it is for IPv4 users. Network administrators will need to investigate current DNS services to see if they can be enabled, extended or upgraded to add DNSv6 support. For smaller organizations, this often consists of confirming that an ISP (or other providers of DNS services, such as OpenDNS) can deliver DNSv6 services, and then providing the proper IP addresses for primary and secondary DNS servers in the various configuration contexts where such information is needed.

Then there's the application and services universe to consider as well, including email and Web servers. Certainly, as a core information service for organizations, e-mail services will need to be extended to support IPv6. In many cases, current software versions may support IPv6 and, as with other elements we've already explored, IPv6 needs to be enabled, configured and tested for proper operation. In most cases, older SMTP, POP3 or IMAP services need upgrades or replacements to make IPv6 support possible. But the beauty of a dual-stack environment is that both IPv4 and IPv6 can coexist peacefully and harmoniously, and users can employ whichever stack works best for them.

Time to take the IPv6 plunge! Steps for moving African higher education institutions to Ipv6

Deploying IPv6 in higher education campuses and networks equals undertaking specific series of tasks. Inside the network, one would need to research the level of IPv6 support that is present on every device attached to the network. It's a good idea to set up a test lab so that changes and the migration process can be documented independently; this also allows to acquire needed upgrades and replacements, and deploy when a secure working set of equipment, software, and migration scripts or how-tos is available.

In dealing with obtaining IPv6 services from an ISP, campus networks operators may need to contact them and inquire about IPv6 availability (or scheduled dates for turning native IPv6 access on), particularly if this means upgrading CPE software or replacing current CPE devices themselves. For organizations that contract Web, e-mail, DNS, and other hosting services to third parties, network operators will need to find out about their current or planned support for IPv6. This set of information will help to make the needed changes to bring the whole organization into the IPv6 fold.

In Conclusion

We need to understand that change happens if the underlying economics change. Thus, IPv6 adoption is not a mere fact of technical merit, but an overall policy, which integrates the paradigm . As Buffington[1] says "We need to accept that IPv6 is a different network layer protocol than IPv4 and decouple ourselves from the IPv4 paradigm''. Typically, higher education and research networks should seek to play a model role in the overall uptake of IPv6 in a country. This entails provision of IPv6 transport within the network, after a migration to IPv6 and working individually with interested members such as faculties, libraries, etc.

With the IP address space quickly depleting under the current Internet Protocol (IPv4), developing methods and timetables for migration will become critically important to higher education institutions, research agencies and their partners. Indeed, by embracing the next generation Internet Protocol now, research and education networks can better leverage existing phased infrastructure upgrades and software upgrades, and also, it makes it easier for higher education institutions to start exposing their students to the new technology now.

[1] Cort Buffington is the executive Director of KanREN, the research and Education Network of Kansas City.

The simplified addressing and management promised by IPv6 are attractive to institutions, and many more managers will begin to see that IPv4 is quickly becoming obsolete, with the dramatic rise in devices requiring IP addresses. Higher education institutions have a unique leadership role to play, as educational institutions, who should lead the way with new technology as a social responsibility for them.

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Policy Brief

Preparing African Higher Educations Institutions for IPv6 Networking

by Pierre Dandjinou

"So, IPv6. You all know that we are almost out of IPv4 address space. I am a little embarrassed about that because I was the guy who decided that 32-bit was enough for the Internet experiment. My only defense is that that choice was made in 1977, and I thought it was an experiment. The problem is the experiment didn't end, so here we are." —Vint Cerf, LCA 2011 Keynote Speech

Executive summary

The issues related to the depletion of the Internet Protocol (IP) version 4 (IPv4) unique identifiers (IPv4 Addresses) and the deployment of its successor, IPv6 are of paramount importance to all stakeholders including government, technical communities, civil society, private sector and academia. In Africa, many initiatives, mainly spearheaded by AfriNIC, the African Internet Number Registry, are in place and aim at sensitizing, training and accompanying African adoption of the new protocol. Specifically targeted are the African higher education institutions, the networks of which support e-learning, research and innovation. This policy brief elaborates on why IPv6 should be adopted within African higher Education institutions and how the academia and its leaders could fastrack IPv6 migration in the Africa region.

What is IPv6?

The network protocol known as Internet Protocol, or IP, has been available in two different versions since the mid-1990s. Version 4 of the protocol, IPv4, is a 32-bit protocol which only allows a total of 4 billion addresses, while IPv6, which is based on 128 bits offers **340 trillion trillion trillion** of addresses. IPv6 was developed by the Internet Engineering Task Force (IETF) as far back as 1994, and has only begun to register with Internet service providers (ISPs) and major network users with some urgency in the past few years. Currently, many of the core Internet infrastructures