THE REPUBLIC OF UGANDA

MINISTRY OF INFORMATION AND COMMUNICATIONS TECHNOLOGY

TRANSITION FROM INTERNET PROTOCOL VERSION 4 (IPv4) TO INTERNET PROTOCOL VERSION 6 (IPv6) POLICY

(DRAFT)

DECEMBER 2010

Table of Contents

ABBREVIATIONS

AfriNIC	African Network Information Center
ccTLD	Country Code Top Level Domain
CIDR	Classless Inter Domain Routing
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name System
EC	European Commission
ICT	Information and Communications Technology
IP	Internet Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
ISP	Internet Service Provider
ITU	International Telecommunications Union
LIR	Local Internet Registry
MDA	Ministries, Departments and Agencies
MTU	Maximum Transmission Unit
NAT	Network Address Translation
NBI	National Backbone Infrastructure
NGO	Non Governmental Organisation
TCP	Transmission Control Protocol
QoS	Quality of Service
VOD	Video On Demand
VoIP	Voice over Internet Protocol

EXECUTIVE SUMMARY

INTRODCUTION

1.1 Background

The rapid success of the Internet, leading to accelerated consumption of IP addresses, has led to the anxiety about shortage of IPv4 addresses in the coming years worldwide. Internet protocol (IP) addresses are the unique numerical identifiers used to identify each device on the Internet, so that data is transmitted to the correct destination.

In addition to the Internet, all other communication networks are also slowly migrating from circuit switched technology to Internet Protocol (IP) based technologies and Uganda is no exception. Newer types of consumer devices and applications are being manufactured which will be IP-enabled.

The current technology is Internet Protocol version 4 (IPv4) based having a 32-bit addressing space of only 4 billion devices. Internet Protocol version 4 (IPv4), on which the Internet has been running for more than 20 years now is reaching its design limits mainly with the depletion of number resources associated with it, known as Internet Protocol (IP) addresses. This is essentially due to the rapid growth of the Internet during the past few years. Although IPv4 has proven to be robust, easily implemented and interoperable, the initial design did not anticipate the exponential growth of the Internet.

Several efforts like Network Address Translation (NAT), , Classless Inter Domain Routing (CIDR) have been taken on as a strategy for reducing the use of public IPv4 addresses. Currently, the final IPv4 free address blocks have already been allocated to Regional Internet Registries. In fact, many experts estimate global depletion as early as August, 2012. There is a wide recognition that this addressing space is insufficient for the future networks. Therefore IPv6 has been developed with 128 bits of address space in order to cater for the addressing requirements of future networks and devices.

With the growth of Internet usage as a result of the arrival of the submarine cables and anticipated completion of the National Backbone Infrastructure (NBI), Uganda is expected to have a substantial increment in the use and consumption of IP services since they will be cheaper. This implies that network operators in the country are likely to face a shortage of IPv4 addressing space in the near future if timely action is not taken to transition from IPv4 to IPv6. It is expected that rapid growth of broadband and wireless technologies in the telecom sector, as well as the existence of a conducive policy environment that promotes widespread uptake and use of the Internet, especially among the young population, and the need for IP addressing by the increasing number of IP enabled end user devices will push the demand for IP addresses in Uganda. It is thus imperative for the Government of Uganda to put emphasis on making the country IPv6 ready to meet the rising demand for IP addresses in future.

Uganda has shown significant improvement in ICT but still lags behind in Internet access with a total consumption of 3,640Mbps and 460,000 active mobile broadband subscribers (UCC March 2010 report). IPv6 Deployment is vital to Bridging the Digital Divide. Internet access over Mobile/Wireless technology is growing at a fast rate; Internet access using mobile networks is cheaper, and offers a higher speed of deployment than fixed networks. This "Digital Divide" may be reduced by extending mobile networks since there is relatively greater availability of mobile/wireless networks in the country. Emergence of mobiles as a platform for wireless Internet access will put more pressure on the IP address space. This will require a larger IP address space to enable wireless networking & mobility. IPv6 is emerging as the preferred platform and is a core component of the wireless Internet architecture (3G & Beyond 3G), the protocol provides for the availability & extensibility of IP addresses in large-scale sensor networks, IP Security, Mobile IP and IP-based Multimedia.

The African Network Information Center (AfriNIC), the body responsible for distributing IP address numbers to African Internet users, has established a resource center for

IPv6 on its website, created an IPv6 Virtual lab and continuously organizes trainings in its numerous member states. This is in a bid to facilitate a smooth transition from IPv4 to IPv6. The International Telecommunications Union (ITU) has published a new online resource for IPv6 related information. The aim is to raise awareness of IPv6 deployment, as well as providing information related to training events and IPv6 related news. An IPv4 exhaustion counter estimates the number of days as to when all IPv4 free addresses will be used. The International Telecommunications Union (ITU) is carrying out training in several IPv6 courses. The Tunis Agenda for the information society (2005), paragraph 68, recognizes that all governments should have an equal role and responsibility for international Internet governance and for ensuring the stability, security and continuity of the Internet. We also recognize the need for development of public policy by governments in consultation with all stakeholders. These activities by ITU and AfriNIC are aimed at creating awareness among African countries.

As we transition towards full IPv6 networks, it is important to note that there is no IPv4 turn off date. IPv4 IPs will remain in use together with IPv6 for a long time to come. Simple, clear and practical coexistence technologies must and will be in use for a long while to come.

1.6 Justification

IPv4 has been the foundation of the Internet and many enterprise networks since the early 1980's. Two studies [SOLENSKY] [RFC1752] in the early 1990's projected that IPv4 address space would be exhausted around 2010. Those studies launched the work that created IPv6.

The demand for IP addresses has increased exponentially mainly due to the increased usage of the Internet. We now have mobile phones, TV sets, refrigerators, cars, robots, cameras connected and controlled through the Internet. Soon, human beings may also be connected to the Internet and all this depends on the availability of IP addresses.

IPv6 will solve the impending problems of global IPv4 address space exhaustion and enable many new features needed to cost reduce existing networks. (Further, it will enable new networking applications (e.g. sensor networks [ARCHROCK], smart buildings and smart grids [OECDSG]) and mobility applications for 3G and post-3G networks).

IPv6 is of particular importance to Internet users in developing countries as it offers great opportunities and opens a new era for the global Internet community. The Ugandan government critically considers IPv6 deployment as a potential enabling factor for the ICT industry to further develop and prosper.

Specifically, the following justify the transition;

a) IPv4 address exhaustion with the increasing number of devices that are IP enabled.

b) Limitation of deploying end-to-end IP security over an IPv4 network

c) The new (user) service opportunities and customer benefits that will result from adopting IPv6.

d) The operational benefits, including network efficiency.

e) Cost effectiveness i.e. potential reduction of future operating costs.

f) Minimizing industry-wide disruption during the transition say company A changing from service provider A to service provider B. (e.g. Commercial risk, loss of market confidence.

1.6 Benefits

Feature	IPv6	IPv4
Unconstrained address abundance	340 trillion trillion trillion addresses	4.2 billion addresses - less than a single IP address per person on the planet.
Easier management of networks	IPv6 networks provide auto configuration capabilities. They are simpler, faster and more manageable, especially for large installations.	Networks must be configured manually or with DHCP. IPv4 has had many overlays to handle Internet growth, which demand increasing maintenance efforts.
End-to-end connectivity integrity	Direct addressing is possible due to vast address space - the need for network address translation devices is effectively eliminated.	Widespread use of NAT devices means that a single NAT address can mask thousands of non-routable addresses, making end-to-end integrity unachievable.
Platform for innovation and collaboration	Given the numbers of addresses, scalability and flexibility of IPv6, its potential for triggering innovation and assisting collaboration is unbounded.	IPv4 was designed as a transport and communications medium, and increasingly any work on IPv4 is to find ways around the constraints.
Integrated interoperability and mobility	IPv6 provides interoperability and mobility capabilities which are already widely embedded in network devices.	Relatively constrained network topologies restrict mobility and interoperability capabilities in the IPv4 Internet.

Improved security features	IPSEC is built into the IPv6 protocol, usable with a suitable key infrastructure.	Security is dependent on applications - IPv4 was not designed with security in mind.

EXPERIENCE FROM OTHER COUNTRIES AND LESSONS FOR UGANDA

2.1 International Scenario

The current status of deployment of IPv6 in different parts of the world is very encouraging and gives an idea of what the future holds for the Internet in the coming years. Many countries around the globe like Japan, Korea, China, European Union and USA have set up national IPv6 networks to enable the network operators and software developers to get a hands-on feel of this technology. Some of the important ones are described below;

a) Europe

The European Commission (EC) initiated an IPv6 Task Force in April 2001 to design an "IPv6 Roadmap 2005" and delivered its recommendations in January 2002, which were endorsed by the EC. A phase II IPv6 Deployment Task Force was enacted in Sep, 2002 with a dual mandate of initiating country/regional IPv6 Task Forces across the European states and seeking global cooperation around the world.

For its part, the European Commission (EC) funded a joint program between two major Internet projects—6NET and Euro6IX—to foster IPv6 deployment in Europe. The Commission committed the financial support to enable the partners to conduct interoperability testing, interconnect both networks, and deploy advanced network services, including support to some 40 IPv6 research projects on the continent.

The EC IPv6 Task Force and the Japanese IPv6 Promotion council forged a strategic alliance to foster IPv6 deployment worldwide.

b) Japan

Japan took political leadership in the design of a roadmap for IPv6 in the fall of 2000 in a policy speech by Prime Minister. The Japanese government mandated the incorporation of IPv6 and set a deadline of 2005 to upgrade existing systems in every business and public sector. Japan sees IPv6 as one of the ways of helping them leverage the Internet to rejuvenate the Japanese economy. The IPv6 Promotion Council was created to address, in a comprehensive way, all issues related to the deployment and rollout of IPv6. In 2002–2003, the Japanese government created a tax credit program that exempted the purchase of IPv6-capable routers from corporate and property taxes. Under the framework of the Japanese government's e-Japan initiative, the Ministry of Public Management, Home Affairs, Post and Telecommunications have sponsored an "IPv6 promotion council," which, among other things, has established and promoted an IPv6 Ready Logo program and allocated the equivalent of $70 million for IPv6 research and development

c) South Korea:

In 2001, the South Korean Ministry of Information and Communication announced its intention to implement IPv6 within the country. In September 2003, the Ministry adopted an IPv6 Promotion Plan with commitment for funding IPv6 routers, digital home services, applications, and other activities.

Korea Telecom, which is a major purchaser of Hexago's gateways, recently began an IPv6 trial, and the government has helped fund pilot programs offered by ISPs and municipalities. The government of South Korea plans to achieve complete IPv6 Transition in Public Sector and 10M IPv6 users by 2010; total IPv6 Transition in Backbone network by 2010 and in access network by 2013 for ISPs.

d) China:

In December 2003, the Chinese government issued licenses and allocated a budget for the construction of the China Next Generation Internet (CGNI). The goal is to have that network fully operational by the end of 2005. China and Japan have declared jointly in the 7th Japan-China regular bilateral consultation toward further promotion of Japan-China cooperation that IPv6 is an important matter in the area of info-communications field.

e) Kenya:

Kenya's IPv6 taskforce was formed by the Permanent Secretary, Ministry of Information and Communications (MoIC) on the 13th of August 2008 as a multi stakeholder partnership. Its main mandate is to develop strategies for the eventual nation-wide deployment of IPv6. The taskforce is chaired by Kenya's Ministry of Information and Communications (MoIC) with the Kenya's dot ke country code top level domain (ccTLD) manager (KENIC) as its secretariat. The other members of the taskforce are drawn from various public, private sector, academia and civil society (PPP).

The specific objectives of the taskforce are:

i. Developing a strategy for IPv6 awareness in the areas of technology, policy and business;

ii. Developing an IPv6 capacity building strategy;

iii. Identifying suitable transition mechanisms;

iv. Identifying and driving projects in IPv6 product development among others.

Milestones;

v. Equipment for an IPv6 test bed was acquired;

vi. Members of the taskforce have undergone hands on training in IPv6;

vii. They have been able to configure the equipment to IPv6 and testing has started;

viii. Some service providers are already using IPv6 – core Network.

f) **Egypt:**

In 2004, MCIT launched the Egypt IPv6 Task Force (E-IPv6). E-IPv6 is a non-profit-activity created by a group of experts representing the government, industry as well as universities and research institutes, and aiming to raise awareness among the ICT community in Egypt as regards the IPv6 activities worldwide, and more importantly to develop a smooth transition plan to IPv6 as far as national infrastructure and services are concerned. The task force started with twenty three members and has been expanded to more than fifty members representing twenty organizations. The task force's objectives include raising the awareness on the impacts of IPv6, identifying suitable transition scenarios, as well as coordinating industry and research and development efforts to facilitate the transition into IPv6 .

The Ministry of ICT and NTRA have setup a lab to conduct research on IPv6 for commonly used applications in the country such as VoIP and telemedicine. Reports from these studies have been presented at AfriNIC meetings.

Many test labs with native IPv6 have been built & connected together by using IPv6 over IPv4 Tunnels. Connectivity of IPv6 test labs via dedicated leased lines. (Native IPv6 connectivity) is still underway.

g) Senegal:

Senegal has setup a local IPv6 task-force lead by significant involvement from government to support local awareness and encourage network operators to implement IPv6. Senegal is drafting a national policy to enforce that all imported network

equipment is either IPv6 compatible or that the vendor can prove that there is a clear upgrade road-map to support IPv6.

The leaders of the Internet Society Senegal are establishing the IPv6 Forum Senegal to extend to its national Internet community and Africa at large a strong voice and representation in the new Internet world to enable equal access to knowledge and education on New Generation Internet technologies and create momentum in deploying IPv6 for the global good.

2.2 Lessons for Uganda

Countries internationally face a similar situation; organizations would prefer to receive more concrete and immediate evidence of the benefits of IPv6 transition before making the move, while application developers are waiting for the trend of IPv6 adoption to be firmed before committing resources to develop major applications. Recognizing the longer-term benefits of IPv6 deployment, many countries have thus taken positions on IPv6 transition through Government-led initiatives to catalyze the movement of IPv6 transition. Once the IPv6 transition becomes a trend, both organizations and application developers are more inclined to commit the necessary resources to join the transition.

2.3 Requirements for smooth transition

a) Minimizing the resistance

The general attitude of large organizations to IPv6 is assumed to be disfavor. The viewpoints of the IETF and industry are different, which may lead to significant resistance in adopting the new technology. Industry sees the world from the business point of view. Computing is a tool for doing business; the techniques used are never a primary factor. Where Internet engineering people concentrate on the shining state-of-the-art technology and new capabilities of IPv6, a large corporate user is concerned

about the flexibility of the transition, compatibility with old systems and predictable cost of transition. The resistance to IPv6 may be minimized by organizing sensitization IPv6 seminars/workshops. The focus of these seminars is on explaining the deployment and transition issues. These could also undertake to explain the value that IPv6 brings to such issues as multicast, multihoming, mobility and global routability.

b) Stepwise transition

We are already aware of the fact that the transition cycle will take years and there is no way to synchronize the process on different sites. A distributed approach is necessary. Presumably only the smallest user organizations are able to switch over to IPv6 in a single step. All others must be able to make their own staged gradual transition plan, and proceed in it with as few inter-dependencies as possible. Both Ipv4 and Ipv6 protocols can be run simultaneously on the same network equipment. It should even be realized that some old, small-scale systems may never be capable of running IPv6. They will maintain the old protocol suite in the network to the end of the old hardware usage time.

c) Technical training

Organize IPv6 hands-on workshops. At these workshops, participants will start from scratch and build an IPv6 network, including routers, hosts, DNS tools and various transition tools, ending up with a functional IPv6 network fully interconnected to the global Internet.

3.0 SITUATIONAL ANALYSIS

3.1 Government experience

Currently, there is no centrally coordinated Government effort to purchase and distribute IP addresses to MDAs. The generally observed practice is that most institutions will acquire their addressing as follows:

i) At the acquisition of email and/or Internet services from an ISP;
ii) Directly from an assigning agency.

This arrangement is haphazard and uncoordinated. Going forward, it would be prudent to have a Local Internet Registry (LIR) setup under the MoICT whose role would be to acquire, distribute and manage the IP resource within the different government bodies. Creation of the said LIR will go a long way to alleviate renumbering problems that arise whenever a Government body changes ISPs. This LIR should also spearhead the government IPv6 technical drive.

3.2 ISP experience

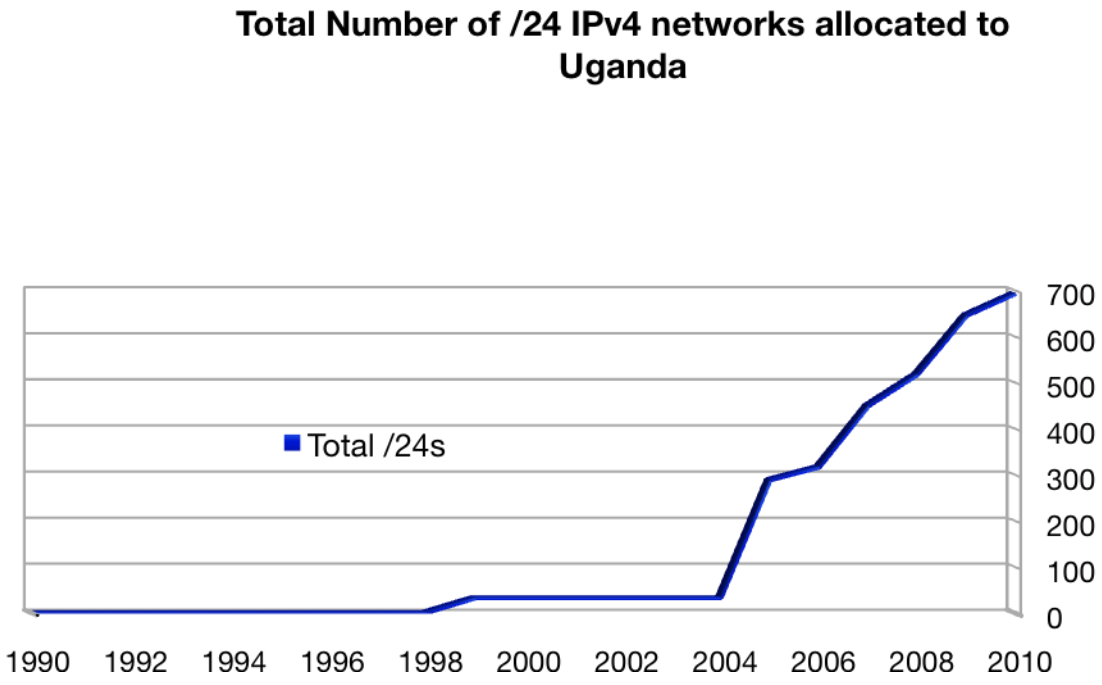
Every ISP should register and become a member of AfriNIC which is the regional body responsible for the numbers resource over Africa. Once registered, a yearly fee corresponding to the size of space that the ISP has requested for is levied.

It is important to note that IP addresses are a free shared public resource, allocated by IANA internationally and AfriNIC for the African region. Effective management of this resource is vital to maintain the ongoing health of the Internet which is why an annual membership fee is levied to the members. Obtaining IP addresses from AfriNIC, gives an organization the right to continue using these addresses provided they are used in

accordance with the allocation and assignment policies set by the IANA and AfriNIC community.

A full list of recommended steps and guidelines of how to acquire IP resource from AfriNIC is listed at http://www.afrinic.net/ISP_LIR_Guidelines.htm

Presently, according to records from the AfriNIC database, Uganda has almost 180,000 Public IPv4 addresses allocated to it. Assuming a population of 32Million Ugandans, that is distribution of about 178 people per IP address. With the exception of a few parastatals like the Bank of Uganda, the bulk of these IPs belongs to the various Internet Service Providers in the Country. The graph that follows shows the rate at which these addresses in groups of /24 networks have been allocated to entities in Uganda.



3.3 Uganda IXP

The Uganda Internet Exchange Point, launched in 2003, is a common interconnection point for all data service providers in Uganda that helps keep local Internet traffic local. It is a critical infrastructure that will be important in the transition to IPv6.

3.3 Legal and Regulatory framework

1) Cyber Security Bills

The following bills are in place to enhance cyber security; the Electronic Transactions, Electronic Signatures, and Computer Misuse bills. The purpose of these laws is to guide and regulate the ICT sector so as to create a level ground and conducive environment for doing business using electronic means.

Electronic Transactions Bill - The Bill creates a light handed regulatory regime for electronic transactions. It facilitates the development of e-commerce in Uganda by broadly removing existing legal impediments that may prevent a person from transacting electronically because of a lacuna in the traditional laws. It makes provision for functional equivalence, thus paper transactions and electronic transactions are treated equally before the law. It further, establishes rules that validate and recognize contracts formed through electronic means; sets default rules for contract formation and governance of electronic contract performance and defines the characteristics of a valid electronic writing and an original document. The bill also supports the admission of computer evidence in courts and arbitration proceedings.

The Electronic Signatures Bill - The Bill makes provision for the use of electronic signatures in order to ensure that transactions are carried out in a secure environment. The bill establishes a Key Public Infrastructure that recognises authenticity and security

of documents; recognises the different signatures creating technologies and provides effective administrative structures e.g. establishment of Certification Authorities.

The Computer Misuse Bill - The Bill takes cognisance of the fact that all computer operations are susceptible to computer crimes that were not recognized by the previous legal system. It creates several computer misuse offences e.g. unauthorised modification of computer material lays down mechanisms for investigation and prosecution of the offences.

2) NITA-U Act

The National Information Technology Authority Uganda's mandate is to coordinate, promote and monitor IT development within the context of national social and economic development.

NITA-U's main functions include;

i) Providing first-level technical support and advice for critical Government IT systems including managing the utilization of the resources and infrastructure for centralized datacenter facilities for large systems through the provision of the specialized technical skills;
ii) Identifying and advising Government on all matters of IT development, utilization and deployment. The specific expertise shall include, but not limited to, areas of Networking, systems development, IT security, training and support;
iii) Setting, monitoring and regulating standards for IT planning, acquisition, implementation, delivery, support, organization, risk management, data protection, security, and contingency planning;

3) Uganda Communications Act

The Uganda Communications Act, Cap 106 Laws of Uganda was enacted to develop a modern communications sector and infrastructure by a number of avenues including:

a) Enhancing national coverage of communications services and products,
b) Expanding the existing variety of communications services available in Uganda to include modern and innovative services;
c) Introducing, encouraging and enabling competition in the sector through regulation and licensing competitive operators to achieve rapid network expansion, standardization as well as operation of competitively priced, quality services;

In this vain, Uganda Communications Commission (UCC) was established to implement these objectives along with a number of other functions that include facilitating the entry into markets of new and modern systems and services. However, while Cap 106 Laws of Uganda enacted in 1997 does mandate UCC on management of the other essential or critical resources for telecommunications services (i.e. spectrum and numbering), it does not explicitly pronounce itself on IP addresses. UCC's function under Section 4(bb) of the Act (to carry on any other functions that are related or connected to the foregoing) on the other hand can be deemed sufficient mandate to cover UCC's interest and activities in this area.

Additionally, Cap 106 Laws of Uganda does require that any person wishing to establish a telecommunications station, or provide telecommunications services, or construct, maintain or operate telecommunications apparatus has to obtain a license issued under the Act.

POLICY STATEMENT, OBJECTIVES AND STRATEGIES

4.1 Policy Statement

The IPv4 to IPv6 transition policy aims at providing policy guidelines, mechanisms and incentives to Ugandans for the rapid adoption of IPv6 through an orderly and smooth process to ensure Internet stability and a promote a sustainable socio-economic environment through the exhaustive use of the IP.

4.2 Policy Objectives

The major objective of this policy is to smoothly implement an IPv6 operational network at a national level to prepare for a smooth transition to IPv6 in Uganda.

The policy focuses on the following specific objectives:

a) To ensure that there are enough IPv6 addresses for every IP device;
b) To establish policies for IPv6 address assignment and registration for the Government of Uganda LIR in accordance with the regional policies adopted by the AfriNIC community.
c) Equip a pool of technical people with technical capacity to manage IPv6 networks and applications;
d) Create a Local Internet Registry (LIR) and obtain a block of IPv6 addresses for government usage.
e) Develop an IPv4 to IPv6 transition strategy;
f) Implement a network interruption free transition from IPv4 to IPv6;
g) Carry out IPv6 seminars and IPv6 training sessions to the public sector, private sector and the general public;
h) Promote use of IPv6 applications like web sites, Mailing lists, Skills Centre Newsletter.

4.3 Strategies

a) Facilitate the efforts of stakeholders regarding the adoption and the deployment of IPv6, for instance through awareness-raising campaigns;

b) Undertaking detailed study for transition from IPv4 to IPv6 environments based on the experience gained through the networks within the country;

c) Involve Internet Service Providers to get connected to IPv6 based network and initiate the services within one year;

d) To facilitate, among other things by enabling IPv6, an integrated part of research & educational networks;

e) Making all major ISPs and major universities / research laboratories/organizations in Uganda IPv6 aware: Implement a show case for awareness creation among all stakeholders: users, ISPs, industries, research institutes policy makers and politicians.

4.3.1 Government taking the Lead

a) Government will put in place a strategy to promote nation-wide IPv6 transition via the inclusion of IPv6 elements in the National Backbone Infrastructure (NBI), the Government Procurement policy and enforcing the importation of IPv6 compliance equipments;

b) Promote training and awareness of Government Officials at proper levels (benefits of regional training – ITU, CITEL, CTU, ICANN, ISOC, RIRs, etc.);

c) Government will work hand in hand with the equipment vendors and Service Providers to sensitize and create awareness and

d) Government will facilitate and create an enabling environment for gradual transition to IPv6.

IMPLEMENTATION OF IPv6

5.1 Approach to Transition for IPv6

For a long while to come, both IPv4 and IPv6 will have to coexist. In light of this, IPv6 characteristics are explicitly designed to simplify the transition and interoperability. For example, IPv6 addresses can be automatically derived from IPv4 addresses, IPv6 tunnels can be built on IPv4 networks, and at least in the initial phase, all IPv6 nodes will follow the *dual stack* approach. To coexist with an IPv4 infrastructure and to provide an eventual transition to an IPv6-only infrastructure, generally the following mechanisms are used:

- Dual IP layer stack
- IPv6 over IPv4 tunneling
- DNS infrastructure
- Native IPv6

These are described briefly as following:

Dual IP Layer

The dual IP Layer is an implementation of the TCP/IP suite of protocols that includes both an IPv4 Internet layer and an IPv6 Internet layer. This is the mechanism used by IPv6/IPv4 nodes so that communication with both IPv4 and IPv6 nodes can occur. A dual IP layer contains a single implementation of Host-to-Host layer protocols such as TCP and UDP. All upper layer protocols in a dual IP layer implementation can communicate over IPv4, IPv6, or IPv6 tunneled in IPv4.

IPv6 over IPv4 Tunneling

IPv6 over IPv4 tunneling is the encapsulation of IPv6 packets with an IPv4 header so that IPv6 packets can be sent over an IPv4 infrastructure. Within the IPv4 header:

• The IPv4 Protocol field is set to 41 to indicate an encapsulated IPv6 packet.

• The Source and Destination fields are set to IPv4 addresses of the tunnel endpoints.

The tunnel endpoints are either manually configured as part of the tunnel interface or are automatically derived from the sending interface, the next-hop address of the matching route, or the source and destination IPv6 addresses are in the IPv6 header.

For IPv6 over IPv4 tunneling, the IPv6 path Maximum Transmission Unit (MTU) for the destination is typically 20 less than the IPv4 path MTU for the destination. However, if the IPv4 path MTU is not stored for each tunnel, there are instances where the IPv4 packet will need to be fragmented at an intermediate IPv4 router. In this case, IPv6 over IPv4 tunneled packet must be sent with the Don't Fragment flag in the IPv4 header set to 0.

Native IPv6

Native IPv6 is an implementation where IPv6 will be the sole running Internet layer. This will be achieved after full transition of all necessary hardware, software and services. This scenario is still a couple of years away.

DNS Infrastructure

A Domain Name System (DNS) infrastructure is needed for successful coexistence of IPv6 and IPv4 because of the prevalent use of names (rather than addresses) to refer to network resources. Upgrading the DNS infrastructure consists of populating the DNS servers with records to support IPv6 name-to-address and address-to-name resolutions. After the addresses are obtained using a DNS name query, the sending node must select which addresses are to be used for communication.

a) It takes time to audit existing systems, bring vendors on board , plan IPv6 networks – starting early – reduces the cost of transition;

b) A mandatory IPv6 transition would be difficult to implement. Indeed, no country has mandated an immediate IPv6 transition with a cut-off for IPv4. Instead of regulatory intervention, the preferred option internationally has been for the Government to take the lead in encouraging IPv6 transition. Initiatives are generally tailored according to two consistent themes: (a) Government catalyzes IPv6 transition through its procurement process; and (b) Government provides initiatives for industry to formulate its own transition plans through education or research initiatives. This approach will help to assure the different stakeholders of the benefits of IPv6 by show-casing how IPv6 transition could be implemented;

c) The biggest hurdle that will be faced in deploying and using IPv6 is that the technical personnel lack the knowledge and experience needed for efficient deployment and user support.

5.2 Challenges of Implementing IPv6

1) Cost

The potential costs associated with deploying IPv6 can be grouped broadly into capital expenditure as well as operational expenditure. The capital expenditure is to cover things like replacement of hardware that is not IPv6 compatible. The other capital expenditure will be in upgrading the software that runs both IPv6 capable equipment as well as that bills or provisions clients. This will mostly show up as licensing fees where applicable. Operational expenditure related to IPv6 will cover costs in training Network staff to use the new addressing scheme as well as the actual man hours required to configure and deploy the new addresses.

Most end-users will not incur significant capex costs given that most operating systems in circulation today have had support for IPv6 inbuilt for years. The only capex cost

they are likely to meet are in upgrading or replacing the gateway devices or wireless routers that connect their network to their upstream providers.

Expenditure and support activities will vary greatly across and within stakeholder groups depending on their existing infrastructure and IPv6-related needs. By and large, ISPs offering service to a large group of customers will likely incur the most transition costs, while independent users will bear little, if any, costs. Factors influencing these costs include

a) The type of Internet use or type of service being offered by each ISP;

b) The transition mechanism(s) that the organization intends to implement (*e.g.*, tunneling, dual-stack, translation, or a combination);

c) The organization-specific infrastructure comprised of servers, routers, firewalls, billing systems, and standard and customized network-enabled software applications;

d) The level of security required during the transition;

e) The timing of the transition.

f) Some organizations are likely to move slowly on the transition to IPv6 because they might look at themselves not as impacted by the scarcity of IPv4 addresses.

2) Maintaining interoperability, continuity and security during transition

Organizations will need to maintain network interoperability and continuity as they transition away from today's IPv4-only environment. During the initial phases of transition, agencies are likely to move to an environment to accommodate native IPv6 and encapsulated IPv6, in a largely IPv4 network leading to a ubiquitous dual-stack environment. As applications transition and the use of IPv4 diminishes, organizations will operate in an environment largely as an IPv6 network. Hardware and software interoperability will be essential as organizations move forward with their IPv6 plans and interconnect their networks across dual environments. Since maintaining

interoperability and security for these types of evolving environments is the highest priority, the transition period should ideally be kept minimized.

3) Technical Expertise

Presently, Uganda lacks the critical mass of Network Engineers with viable IPv6 hands on experience. This is an issue that will have to be addressed by all stakeholders before the transition can begin in earnest.

5.3 Institutional Framework

5.3.1 Ministry of ICT

The Ministry of ICT was established in June 2006 with a mandate of;

i) Providing strategic and technical leadership, overall coordination, support and advocacy on all matters of policy, laws, regulations and strategy for the ICT sector.

ii) Ensuring sustainable, efficient and effective development; harnessing the utilization of ICT in all spheres of life to enable the country achieve its national development goals.

5.3.2 UCC

Towards the implementation of IPv6 in Uganda, Uganda Communications Commission shall encourage the integration of IPv6 through the creation of a favourable, stable and harmonised regulatory environment. This shall including the following:

(a) Exploration of possible incentive schemes to licensees to encourage the adoption of IPv6.

(b) Continued efforts to promote wide spread use of Internet and deployments towards realizing universal access but additionally with IPv6 capability

(c) Engaging licensees in discussions with respect to the adoption of IPv6.

5.3.3 NITA-U

As the responsible agencies tasked to be first level technical support and government reference to all issues concerning Information Technology, the National Information Technology Authority- Uganda (NITA-U) shall incorporate planning for the transitions from IPv4 to IPv6 in its work The Authority shall also be responsible for;.

(a) Obtain IPv6 addresses on behalf of governments.

(b) Training of IT Personnel in Government in areas of Transition from IPv4 to IPv6

(c) Advice and setting standards for all network equipment to be procured by MDAs to insure that they are IPv6 Compliant.

(d) They will also ensure that they effectively sensitize the MDAs about the necessity and benefits of Migrating to IPv6.

5.3.5 Service Providers

The service providers are to ensure that the services they provide don't get any interruptions, these providers range from Telecoms to ISP and other Infrastructure service provision. From the findings of the IPv6 Task team some of the Telecoms and ISPs are progressively preparing for the transition, e.g. Orange, Warid and Infocom are all preparing their networks for the transition. It would be prudent for the regulators UCC and NITA-U to ensure that the service providers are well prepared for the transition.

5.3.6 Academia

Since ICT Institutions are some of the biggest consumers of Internet services and also train future network engineers, they can play a big role in the transition from IPv4 to IPv6 as outlined below:

a) Increased support towards IPv6 in public networks and services;

b) The establishment and launch of educational programmes on IPv6;

c) The adoption of IPv6 through awareness raising campaigns;

d) Establish appropriate training facilities;

e) The continued stimulation of the Internet take-up across the country;

f) Engage in IPv6 research;

g) An active contribution towards the promotion of IPv6 standards work;

h) The integration of IPv6 in all strategic plans concerning the use of new Internet services.

i) By embracing the next generation Internet protocol now, ICT institutions can better leverage existing phase infrastructure upgrades and software upgrades.

j) Also as educational institutions, it is in their interest to start exposing their students to the new technology.

k) Also to some educational institutions, leading the way with new technology is a social responsibility for them.

MONITORING AND EVALUATION

The outputs of this transition policy will require consistent monitoring and evaluation of the outcome indicators. The Government and all the other relevant stakeholders will carry out monitoring and evaluation at different levels.

A monitoring and evaluation framework shall be developed to ensure midterm review of the policy. The policy shall receive a periodic review of one (2) years to ensure that there is a smooth transition.

ANNEXES *(Omitted on this online version)*

ANNEX1: COMPOSITION OF IPv6 TRANSITION TASK FORCE

ANNEX2: STATUS OF WORLDWIDE IPv4 TO IPv6 TRANSITION

ANNEX3: COST IMPLICATIONS FOR TRANSITION FROM IPv4 TO IPv6 GOVERNMENT

ANNEX4: RESPONSIBILITY MATRIX