Capacity Building Programme
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INTERNET GOVERNANCE RESEARCH PROJECT

IPV6 AND ITS ALLOCATION

(Document for Comment)

Research:
Jean-Philemon Kissangou
Marsha Guthrie
Mwende Njiraini

Supervision:
Andrei Mikheyev
Valentin Katrandzhiev
Vladimir Radunovic

- February 2006 -

INTRODUCTION

The issue of the implementation of Internet Protocol version 6 (IPv6) has been discussed for quite a few years. Increasingly, countries are being told of the many pros of switching from the older Internet Protocol version 4 (IPv4) to IPv6, the primary reason being that IPv4 is simply not suitable for all of the web-enabled devices being used/introduced and that addresses are quickly running out. The argument that the adoption of IPv6 will widen the digital divide is also at the forefront of the debate on this inevitable transition. The greatest technical advantage of adopting IPv6 is the restoration of end-to-end connectivity, enabling end-users to gain full advantage of the Internet.

This research paper seeks to highlight various aspects of the perceived deficiencies of IPv4, provide a more comprehensive view of both sides of the debate for and against IPv6, and propose initiatives, based on a balanced perspective, for the adoption of IPv6, taking into account the constraints of developing countries.

The paper is divided into the following sections:

The introduction of IPv6 can be viewed as a means of bridging the digital divide by enabling global connectivity to end user devices. The first section of the paper therefore provides an introduction to the digital divide, its width, and proposes solutions to bridging the gap between developing and developed countries.

The next section discusses IPv6, compares its features to those of IPv4 and outlines the advantages and disadvantages of this new protocol.

A discussion of the transition to IPv6 follows, with illustrations of how the proposed transition would work, giving examples of countries that have begun the process, the problems encountered with deployment, and a proposed model for developing countries' transition to Ipv6.

Finally, based on the evidence collected in the previous sections, this research paper will analyse various Internet Governance models and determine whether the introduction of IPv6 can bridge the digital divide.

THE DIGITAL DIVIDE AND IPV6

What Is the Digital Divide?

The 21st century has witnessed the emergence of Information and Communications Technologies (ICTs), which have revolutionised the functioning of economy and society. ICT is a broad term used to describe a range of technologies for gathering, storing, retrieving, processing, analysing, and transmitting information.[1] ICTs include such technologies as radio as well as the modern digital technologies like computers, satellites, mobile phones, and the Internet.[2] ICTs have resulted in the formation of what is commonly referred to as the digital, knowledge, or information global economy and society. The main impetus of this revolution has been the demand for Internet services.

However, the benefits of the ICT revolution are distributed highly unevenly. While, in theory, the Internet is open to all, the vast majority of the world's population remains cut off from its developmental benefits. The right to access information is increasingly becoming a basic human right. The United Nations Secretary General's statement at the opening ceremony of the International Telecommunications Union (ITU) Telecom '99 Conference on 9 October 1999 affirms this: "People lack many things: jobs, shelter, food, health care, and drinkable water. Today, being cut off from basic telecommunications services is a hardship almost as acute as these other deprivations, and may indeed reduce the chances of finding remedies to them."[3]

The size and scale of the potential benefits lost through failure to participate in the new "digital society" are great. Unfortunately, many people, particularly in developing countries are deprived access to basic means of communication, mainly due to the fact that communication services have never been offered as a ubiquitous commodity allowing seamless connectivity "anytime, anywhere, by anything, and anyone."

Historically, communication services were provided by monopolies who offered services in limited capacity to a limited set of potential consumers because of the high costs associated with the communication infrastructure. As a consequence, the infrastructure necessary for access to ICT is limited. Additionally, due to the economic gap, disparity in learning processes and experience, developing countries have limited resources and technical know-how needed to acquire and utilise these technologies, which are evolving rapidly and constantly. This "electronic gap" is commonly referred to as the digital divide.

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[1] Smart State Strategy 2005-2015 Glossary. [http://www.smartstate.qld.gov.au/strategy/strategy05-15/glossary.shtm]
[2] www.mountainpartnership.org/glossary.html
[3] Address by Kofi Annan, Secretary General, United Nations at the ITU Telecom Opening Ceremony, 9 October 1999
[http://www.itu.int/telecom-wt99/press_service/information_for_the_press/press_kit/speeches/annan_ceremony.html]

Various Definitions of the Digital Divide

Definitions are key to any discussion and there are numerous definitions of the **digital divide**. It has been defined as a gap between those who, for technical, political, social, or economic reasons, have access to ICT and the capacities to use it, and those who do not. The OECD[4] defines the digital divide as, "the gap between individuals, households, businesses, and geographic areas at different socio-economic levels with regard both to their opportunities to access information and communication technologies and to their use of the Internet for a wide variety of activities."

The divide exists between the north and south, rich and poor countries, rural and urban areas, men and women, skilled and unskilled citizens, and large and small enterprises. The digital divide relates mainly to issues of disparities of access to information along the lines of ethnicity, gender, class, and age; these social groups cannot access needed information due to social, economic, physical, and geographic barriers. "Bridging" the digital divide between the information-rich and the information-poor, the haves and the have-nots of the Information Age, is of increasing concern in the global arena and has become a major challenge for policy-makers at the national, regional, and international level. Statistics show that many countries of the "ICT South," as we shall refer to them, have been increasing connectivity and in some instances have recorded growth substantially greater than their northern counterparts.[5] Of course, the question will be about whether these countries can actually "catch up" with their counterparts, as marginal gains of the more developed countries enable them to maintain their lead and dominance in the area compared to those countries still developing, trying to maintain their modest gains, and improving upon them.

Components of the Digital Divide

ICTs have the potential to assist developing countries in their efforts to "leap frog" entire stages of development.[6] However, despite the potential benefits offered by ICTs, significant barriers to their effective use still exist in both developed and developing countries. The barriers that must be addressed, in order to allow the realisation of the full potential of ICT include a lack of awareness of what these technologies can offer; insufficient telecommunications infrastructure and Internet connectivity; expensive ICT access; absence of adequate legal and regulatory frameworks; shortage of requisite human capacity; failure to develop local language content; and a lack of entrepreneurship and a business culture open to change, transparency, and social equality.

Many people in developing countries have little or no access to ICT because they are poor, illiterate, or have other more pressing concerns, such as food, health care, and security. The digital divide is therefore not a problem in itself, but a symptom of deeper, more important divides: of income, development, and literacy; and thus, the solution should be the use of technology to promote bottom-up development.

[4] http://cs3-hq.oecd.org/scripts/stats/glossary/detail.asp?ID=4719 (accessed on 19 October 2005)
[5] http://stdev.unctad.org/docs/digitaldivide.doc
[6] *Ibid.*

Exclusion in the digital age is not so much *from* information but rather *by* information, leading to what is referred to as the "digital knowledge gap."[7] It has been argued that the digital divide should not be looked at as mere access, but meaningful access to relevant applications, leading to full participation in the social, economic, political, and cultural life in a society.[8]

Developing countries can, therefore, through meaningful access, participate in the Information Age by appropriately utilising technology to enable the extension of essential services, such as health care, education, and agriculture. Indeed, Jeffrey Sachs, author of "End of Poverty," has argued that ICT can help ensure that investment in many areas of development extends much further and can be used to improve the quality of crucial services, such as hospitals, also helping improve the productivity of private businesses, leading to growth. Some argue that promoting the spread not of computers and the Internet, but of mobile phones can "appropriately" bridge the digital divide.[9]

There is ample evidence to suggest that the mobile phone is the technology with the greatest impact on development, raising long-term growth rates, requiring no intervention or funding from the United Nations (UN), as even the world's poorest people have readily embraced mobile phones, because their economic benefits are so apparent *(see article on "Cell Phones Reshaping Africa").*[10] As the mobile networks grow and migrate to next generation networks (3rd Generation (3G)) embedded with an Internet Protocol (IP) stack to enable mobile Internet applications and services, the need for greater addressing space will become unavoidable.[11]

How Wide Is the Digital Divide?

The "electronic gap" between the ICT North and South is constantly changing. According to Abdoulaye Wade, "the developing and developed countries are separated by a band defined as the standard information society, developing countries fall under the lower digital margin while the north/developed countries are at the upper digital margin." Wade refers to this band between the two margins as the digital snake because it grows and changes scale over time, with progress in accessibility to communications.[12]

The diffusion of Internet use in developed countries may be slowing and even stalling, when compared to the explosive growth of Internet access and use during the past decade in less developed countries. With the proliferation of the Internet in developed countries, the digital divide between North America (the United States and Canada) and developed countries elsewhere is thus narrowing, but remains substantial. The

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[7] The term is used in the article *"The Digital Divide Index: A Measure of Social Inequalities in the Adoption of ICT"*(http:// www.csrc.lse.ac.uk/asp/aspecis/20020042.pdf)

[8] http://tcla.gseis.ucla.edu/divide/teachers/goode.html

[9] The Real Digital Divide [http://www.oneworld.net/external/?url=http%3A%2F%2Fwww.economist.com%2Fopinion%2Fdisplaystory.cfm%3Fstory_id%3D3742817]

[10] Africa Goes Cellular [http://www.cnn.com/2005/TECH/ptech/10/17/africa.goes.cellular.ap/index.html]

[11] http://www.nav6tf.org/documents/e-Nations-Internet-for-All.pdf

[12] http://www.unicttaskforce.org/news/digitalsolidarity.html

divide also remains substantial within almost all countries, and is even widening as the number and percentage of Internet users increases. Additionally, people, social groups, and nations on the lower digital margin may be increasingly excluded from knowledge-based societies and economies.[13]

Various methodologies or indices have been developed to evaluate and to measure the digital divide, in order to determine its "width." The Digital Opportunity Index (DOI)[14] is a tool that is used to measure countries' comparative adoption and access to ICT, based on a set of indicators. The DOI takes into account the elements related to the opportunity, infrastructure, and utilisation of ICT. In a recent study, the International Telecommunications Union (ITU) applied these indices to a group of 40 geographically and economically diverse countries. The bottom ten nations are not surprisingly developing ones. Another tool is the Digital Divide Index (DIDIX), developed to benchmark and track national digital divides within European Union (EU) member states.[15] The DIDIX is based on the relative diffusion of computers and the Internet in four disadvantaged socio-demographic groups (compared to national averages), the index is intended as a descriptive metric to compare basic levels of inclusion in EU member states. One of the key dimensions of the DIDIX is Internet usage, which is enabled by IP addresses, thus fair distribution of addresses is identified as a critical measure of the digital divide.

Yet another model was proposed by Corrocher and Ordanini (2002), within a set of countries or geographical areas. Starting from a series of elementary indicators, the methodology groups these indicators into six factors of digitalisation and aggregates the factors into a synthetic index called the synthetic index of digitalisation.[16]

In most African countries, participatory policy formulation processes are still in their infancy, development indicators and measurement of the ICT sector would be particularly useful in governments' decision-making processes in relation to policies, regulations, and investment. The African e-Index[17] research method provides indicators and methodologies to explain the relations between policy and regulatory frameworks and the development of information societies and network economies in developing country contexts. The e-Index seeks to measure what is happening in the ICT sector from the viewpoint of users, consumers, and those marginalised from services and to analyse access, demand, and usage patterns in response to services delivered as a result of operators' responses to policy and regulatory frameworks. The index thus contributes to the theme of diversifying participation in network extension by providing the critical information necessary for creating the enabling policy and

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[13] http://news.com.com/Study+finds+gaps+in+digital+divide+theory/2100-1032_3-5098784.html?tag=nl

[14] International Telecommunication Union, What is the Digital Opportunity Index (DOI)? [http://www.itu.int/osg/spu/statistics/DOI/index.phtml]

[15] Husing, T., Selhofer, H. (2004). DIDIX: A Digital Divide Index for Measuring Inequality in IT Diffusion, IT & Society, 1 (7), 21-38 [http://www.stanford.edu/group/siqss/itandsociety/v01i07/v01i07a02.pdf]

[16] Corrocher, N., Ordanini, A. (2002) Measuring the Digital Divide: A Framework for the Analysis of Cross-Country Differences, Journal of Information Technology 17, 9-19 [http://unpan1.un.org/intradoc/groups/public/documents/APCITY/UNPAN007361.pdf]

[17] Towards and African e-Index: Understanding Supply and Demand by Measuring ICT Access and Usage [http://www.regulateonline.org/content/view/366/31/]

regulatory frameworks for alternative forms of investment as well as network and service innovation.

Apart from comparative measures, there is a need to establish the impact of ICT on the lives of people in order to achieve meaningful social and economic development through ICT utilisation. The Scan-ICT initiative[18] has therefore been created to enhance African capacity to collect and manage key information needed to support the growing investment in ICT, as well as the transition of Africa to an Information Society. The goal of the initiative is to create a pan-African ICT network, connecting all levels of ICT related issues, which will be coordinated and supported by an observatory/research institute. Baseline studies were carried out in six African countries based on indicators developed during planning workshops. The results are available from the UNECA website.[19]

What Is Important for Bridging the Digital Divide?

In a nutshell, the important issues related to bridging the digital divide include access, availability of relevant content, use of tools that increase access to useful technology, and/or information, literacy, and learning.

The digital divide can be bridged through appropriate policies and programmes aimed at strengthening and extending the infrastructure. One such policy that has been implemented with a great measure of success is regulatory reform; the liberalisation of telecommunication markets and rigorous implementation of competition. This has resulted in a narrowing of the digital divide, particularly in Africa, due to the explosive growth of mobile telephony. Today, the continent leads the world in mobile phone growth, as cell phone subscribers outnumber those of fixed lines. This explosion is characterised by the emergence of pan-regional operators who have made unparalleled investments, learning from the mistakes of operators in the developed world.

As mobile and wireless technologies increasingly become the most viable means of bridging the digital divide, regulatory reform may be used to facilitate an open or unlicensed spectrum in access technologies, such as Wireless Fidelity (WiFi), and unproven technologies such as, Ultra-WideBand (UWB), High Altitude Platforms (HAPs), which confer economic advantages to users. The popularity of mobile communications and the introduction of high-speed 2.5 and 3G services create demand for innovative end-user terminals that require Internet addresses for seamless connectivity, a key characteristic of IPv6, necessary for active participation in the Information Society.

Joe Diamond, Executive Director of MASSCAP, the umbrella group of Community Action Agencies (CAAs) in Massachusetts, asserts that the digital divide can be bridged in a lot of ways through information technology's ubiquity, but the next step is to make sure that "people are being helped to get and keep good jobs; that they are being helped to become self-sufficient". With reference to Diamond's assertion, other

[18] Africa Information Society Initiative [http://www.uneca.org/aisi/scanict.htm]
[19] Economic Commission for Africa. (2003) SCAN-ICT: Indicators of Information and Communications Technologies [http://www.uneca.org/aisi/docs/ScanICT.pdf]

policies that may effectively bridge the digital divide, include policies that improve the ICT skills of individuals and workers. Improved access to ICT in public and educational institutions would help develop computer/Internet literacy and build the related skills base.

Policies relating to the management of key Internet technical resources, such as the administrative process of requesting and receiving public IP addresses have the potential to reverse this trend in the IPv6 era, develop public Internet resources, create new Internet users (provide access) and/or Internet uses (provide content and other online services). Tom Vest, however, argues that it takes more than IP address allocation to create strategic value for the user, it also takes equipment, engineering staff, a physical medium through which the new Internet resource can be delivered to end users, and a strategy for putting all of these pieces together, so that they are worth more than the sum of their parts.[20] Vest, however, agrees that IP addresses enable the creation of globally visible Internet resources and enhance public Internet production.

The introduction of IPv6, argue its proponents, presents an opportunity for bridging the digital divide by providing developing countries with immediate access to not only the Internet but also to many next-generation applications currently under development.[21] The new protocol promises a level playing field for IP application development and deployment, where IP addresses are readily available to all, facilitated by management policies that take into consideration the public interest and needs of developing countries. IPv6 presents numerous benefits, including larger address space for end-to-end global connectivity and Internet scalability, as well as improved security and mobility capabilities. But, is this really the case? The capabilities of IPv6 will be discussed below.

What is the Internet Protocol and IPv4?

The Internet Protocol (IP) is a network-layer protocol that contains addressing information and some control information to enable packet routing through a network. An IP address is a numeric identifier that includes information about how to reach a network location via the Internet routing system. Every device directly connected to the Internet must have a unique IP address.

The Open System Interconnection (OSI) reference model is a conceptual model composed of seven layers (Figure 1), each specifying a particular network function that describes how information from a software application in one computer moves through a network medium to a software application in another computer. In 1984, the International Organisation for Standardisation (ISO) developed the OSI reference model, which is now considered the primary architectural model for inter-computer communications.

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[20] Vest, T. (2005) IP Address Allocation vs. Internet Production I: Understanding the Relationship, and the Differences [http://www.circleid.com/posts/ip_address_allocation_vs_internet_production_i_understanding_the_relationsh/]

[21] International Telecommunications Union. Internet for Everyone: IPv6 2005 Roadmap Recommendations [http://www.itu.int/ITU-T/special-projects/ ip-policy/final/Attach09.doc]

7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data Link
1	Physical

Figure 1: The OSI Reference Model Contains Seven Independent Layers

Along with the Transmission Control Protocol (TCP), IP represents the heart of the Internet protocols. IP is the primary network-layer protocol in the TCP/IP Protocol Suite.[22] However, the TCP/IP and OSI protocol suites do not match precisely, the top three layers of the OSI model (Application, Presentation, and Session) are considered as a single Application Layer in the TCP/IP suite.[23] IP is a data-oriented protocol used by source and destination hosts for communicating data across a packet-switched inter-network. Data in an IP inter-network are sent as packets or datagrams utilising best effort services. Each packet contains both the sender's Internet address and the receiver's address. As delivery and routing is based on best effort, the packets can arrive in a different order than the order they were sent in, thus the Transmission Control Protocol places them in the right order again.

The network and transport layers have two primary responsibilities; providing connectionless delivery of datagrams through a network; and providing fragmentation and reassembly of datagrams to support data links with different maximum-transmission unit (MTU) sizes. On the other hand IP provides connectivity, interoperability, security, and discovery, end-to-end across an Internet network. The IP addressing scheme is key to the process of routing IP datagrams through an inter-network. Each IP address has specific components and follows a basic format. These IP addresses can be subdivided and used to create addresses for sub-networks.

There are two versions of IP in use: IPv4 and IPv6. Each Internet host on a TCP/IP network is assigned a unique logical address (32-bit in IPv4) that is divided into two main parts: the network number and the host number. The network number identifies a network and must be assigned by the Regional Internet Registry (RIR) if the network is to be part of the Internet. An Internet Service Provider (ISP) can obtain blocks of network addresses from the RIR or InterNIC and can itself assign address space as necessary. The host number identifies a host on a network and is assigned by the local network administrator.

All other protocols within the TCP/IP suite, except Address Resolution Protocol (ARP) and Reverse Address Resolution Protocol (RARP), use IP to route packets from host to host. ARP is used by IPv4 nodes to resolve the link-layer address for a

[22] The TCP/IP protocol suite establishes the technical foundation of the Internet. Its core functions are addressing, routing and transport (Taken from "IP/IPv4: Internet Protocol Overview" by http://www.javvin.com/protocolIP.html)
[23] http://en.wikipedia.org/wiki/Internet_protocol_suite

given IP address while RARP does the opposite; it resolves the IP address for a given link-layer address.[24]

Under IPv4, the 32-bit address space was structured to permit a large number of hosts (around 16 million) on each network (approximately 256). Those 32 bits allow 2^32, or just over 4,000 million, IPv4 addresses. Underestimating the number of networks led to a change, so that three important classes of networks could be supported: 128 Class A networks, each accommodating up to 16, 777, 215 hosts (/8 in today's terms), 16, 384 Class B networks, each accommodating up to 65, 535 hosts (/16), and around 4 million Class C networks, each accommodating up to 255 hosts (/24). Class C networks turned out to be too small for many enterprises, creating a heavy demand on Class B addresses, but those were larger than any but the very largest enterprises or networks needed.

Some critics lay the blame for the current impending scarcity of IP addresses on "historical unfairness," where older networks—mostly based in developed economies with competitive telecom/Internet markets—received IP address allocations under relaxed terms. Address conservation was not seen as a priority during this time and many large organisations, most of them in the United States, were assigned /8 address blocks.[25] In the early days of IP address management, it was commonly assumed that the Internet's geography would follow that of the physical world, thus, large address blocks were set aside for entire countries. These IP address allocation and assignment management policies have resulted in the perceived scarcity of the current version of IP addresses, negatively impacting efforts to enhance public Internet production. The policies did not envision the 20th century "e-turmoil," the need for Internet architecture to cope with the evolution of the population and the quick adoption of IP as the application convergence layer in many industry segments outside of its historic IT environment.[26] The IPv4 network model is therefore under relatively severe stress in terms of its address and routing scalability, and there is little possibility that the protocol can be made to scale indefinitely to encompass larger and larger populations of users.[27] Further, the policies lacked necessary considerations to bridge the digital divide, notably, the level of fees charged by RIRs for IP-related services, have negatively impacted efforts by developing countries to enhance public Internet production.

With IPv4 address space availability becoming such a serious issue, various technologies were invented as fixes to the limitations of IPv4, such as Network Address Translation (NAT) and Classless Inter-Domain Routing (CIDR).[28] This has

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[24] IPv6 does not use ARP or RARP anymore as link-layer address resolution is carried out as part of Neighbour Discovery (ND) and uses Internet Control Message Protocol version 6 (ICMPv6) messages. ICMP is widely used in IPv4 for error reporting and control of IP transmission. ICMPv6 is a protocol for IPv6 to achieve functions similar to IPv4 ICMP.

[25] APNIC. 2004, IP Addressing in China [http://www.apnic.net/news/hot-topics/internet-gov/ip-china.html]

[26] http://www.nav6tf.org/documents/e-Nations-Internet-for-All.pdf

[27] http://www.potaroo.net/papers/isoc/2006-01/ipv6revolution.html

[28] For a discussion on the evolution of "CIDR" addressing, see Chapter 9 of Huitema, Christian, *Routing on the Internet*, 2nd Ed. New Jersey: Prentice-Hall, 1999. Other documents on CIDR are Fuller, V., T. Li, J. Yu, and K. Varadhan, "Classless Inter-Domain Routing (CIDR): An Address Assignment and Aggregation Strategy," RFC 1519, September 1993 and Rekhter, Y. and C. Topolcic, ...

provided those countries unable to make the switch to IPv6 some more time to implement it while continuing to use the older Internet Protocol and arguably prevent further widening of the digital divide.

A report on IPv4 published by CISCO at the end of 2005 states that "with no change in policy or demand utilising the nonlinear historical trends, it is projected that the remaining pool of IPv4 addresses will be allocated somewhere between 2009 and 2016. However, with policy continually changing, coupled with persistent demand, the remaining global IPv4 pool may be exhausted by 2008."[29] There are others who concur with this finding and predict that if current consumption trends continue then some other form of address distribution mechanism will be needed before the IANA unallocated address pool exhaustion date of 2012 and the RIR date of 2013.[30] Considering that we are already in 2006, we must move quickly to avert any disruptions to everyday business.

Addresses are not the only problem with IPv4. The security of data exchanged over networks, the mobility management and quality of service are among additional weaknesses of IPv4. IPv4 is on the verge of depletion and the process of planning for an IPv6 deployment requires more urgency, starting with staff training, enhancement of management tools, updating of routers and operating systems and deployment of IPv6-enabled versions of applications. Indeed, the depletion of IPv4 constitutes a real threat to the continuation of Internet access, due to a limitation of IP addresses.

..."Exchanging Routing Information Across Provider Boundaries in the CIDR Environment," RFC 1520, September 1993

[29] Hain, Tony. A Pragmatic Report on IPv4 Address Space Consumption, The Internet Journal, Vol. 8, Number 3 [http://www.cisco.com/web/about/ac123/ac147/archived_issues/ipj_8-3/ipv4.html]

[30] IPv4 Address Report. http://bgp.potaroo.net/ipv4/

IPV6

As the debate on the introduction of IPv6 continues, one can find numerous positive and negative comments about the protocol. For example, by European Commissioner *Erkki Liiknem* at the IPv6 Global Service Launch, held in Brussels in January 2004 where he stated that, "IPv6 is part of the next generation of Internet technology. It will improve the performance of the Internet and it will enable the Internet to be integrated into a wide range of devices and services in our homes, business, and while on the move. Some of these are demonstrated at this event – from household appliances to the IPv6-enabled vehicles."[31]

The Internet Engineering Task Force (IETF) developed IPv6, also referred to as the Internet Protocol Next Generation (IPng), in 1993, in response to a series of perceived problems, primarily regarding exhaustion of the current, IPv4 address space. IPv6 has a larger address field, (IPv4 uses 32-bit numbers for its addresses, four octets of 8-bit blocks providing a maximum of 4 billion addresses, while IPv6 uses 128-bit sequences), but does not tackle the larger issues of overloaded address and packet switching semantics, address routing scaling.[32] This does not mean that IPv6 is not a suitable replacement for IPv4 as it has many advantages over IPv4. These are outlined below.

IPv6 Positives

The capabilities of IPv6 in terms of the astronomical number of addresses and its end-to-end mode will allow a greater number of electronic devices to connect to the Internet and thus help in bridging the digital divide.

The introduction of IPv6, alongside unrestricted access to broadband, is of great importance, offering citizens wider access to an advanced Information Society. IPv6 and broadband deliver improvements in economic growth, competitiveness, and productivity through the provision of a whole new generation of services and applications, including 3G. As 3G mandates the use of IPv6, requiring the restoration of end-to-end connectivity, with the phenomenal uptake of mobile communications, particularly in the developing world, the introduction of IPv6 offers the possibility for greater digital inclusion.

From a technical perspective, the ITU, in an article titled "*Internet for everyone: IPv6 2005 Roadmap Recommendations*," highlights the following benefits of IPv6:[33]

1) Larger address space for end-to-end global connectivity and Internet scalability; this is the key advantage of IPv6.
2) Simplified IPv6 data packet header for routing efficiency and performance.
3) Support for routing and route aggregation, making Internet backbone routing more streamlined and efficient (the IPv4 Internet backbone contains data

[31] Report on the Global IPv6 Service Launch Event, January 2004 [http://www.ec.ipv6tf.org/PublicDocuments/ipv6-global-service-launch-03.pdf]
[32] http://www.potaroo.net/papers/isoc/2006-01/ipv6revolution.html
[33] http://www.itu.int/ITU-T/special-projects/ip-policy/final/Attach09.doc

routing information for over 130,000 networks; with IPv6 this number could be dramatically reduced).

4) Serverless ("stateless") IP auto-configuration, easier network renumbering, and much improved plug and play support.

5) Security with mandatory implementation of IP Security (IPSec) support for all fully IPv6-compliant devices (IPSec implementation is not mandated in IPv4). Note that *use* of IPSec is not mandatory, but its presence for implementation allows the user to have the option of secure communications.

6) Improved support for mobile IP and mobile (and *ad hoc*) computing devices.

7) Enhanced multicast networking support.

8) These benefits can be mapped to opportunities for improved business models and potential new application and system markets.

In his January 2006 article, "*IPv6 - Evolution or Revolution*," Geoff Huston[34] argues that the ubiquitous adoption of IPv6 will herald the development of simpler networks, simpler applications, larger populations of connected devices, more efficient services, and a broader diversity of service models. IPv6 is capable of embracing a device-dense world enabled by its ability to provide unique global addresses to each connected endpoint. IPv6 has the potential to dramatically reduce the per-address through the elimination of various forms of dynamic address translation technologies, eliminate the scarcity premium factor in IPv4 address mechanisms, reduce the application complexity, and broaden the diversity of application models. Additionally, IPv6 allows for many forms of peer-to-peer networking models as well as supporting communication transaction security models that rely on end-to-end coherence.

Possible applications and services that this new technology promises to usher in are limited only by one's imagination, and many applications are currently under development. If you consider that every device in the world is individually addressable, then this opens up limitless possibilities. Based on the evidence, IPv6, if embraced and when implemented, should aid in bridging the digital divide. Of course, the issue of the cost of this transition still remains.

Transition to IPv6

The IP protocol version 4 (IPv4) is now overloaded and technically limited. IPv6 was adopted at the end of the 1990s to meet new needs that arose due to the tremendous growth of the Internet and the emergence of new services.

The rapid emergence of IPv6 as a new protocol led to the critical problem of transition from IPv4 to IPv6. Due to the huge size and coverage of the Internet, it is impossible to expect a fast, centrally coordinated transition. There is no fixed deadline expected for the integration of IPv6 but it is expected that the new protocol will slowly replace IPv4, until IPv6 becomes the dominant protocol on the Internet. This transition, which those involved hope will be one without many obstacles, shows that IPv4 may still coexist with IPv6 for several years. The coexistence and interoperability of IPv4 and IPv6 will be required. Some studies foresee that this transition period will last until

[34] http://www.potaroo.net/papers/isoc/2006-01/ipv6revolution.html

2030-2040, at which time, IPv4 networks should have totally disappeared.[35] However, it is important to note that many do not foresee IPv4 lasting for more than a few years from now.[36] Some observers have also raised issues that could stall the implementation of IPv6, including concerns about security systems, transition costs, estimated at between $25-$75 billion,[37] as well as control and distribution of addresses.

As long as IPv4 remains operational, the issues of mixed-protocol approaches and the models by which conversion may occur are important. Juha Lehtovirta, in an article titled "*Transition from IPv4 to IPv6*,"[38] notes that the greatest constraint in the transition to IPv6 is general resistance or disfavour. Lehtovirta states that the transition may never be complete unless the transition techniques prove to be acceptable to most Internet users. He notes that due to the varied sizes of IPv4 networks deployed by organisations, where small user organisations can switch over to IPv6 in a single step, while larger organisations must formulate their own staged transition plan, a distributed approach is necessary to synchronise the transition process at different sites.

In addition, to facilitate coexistence and internetworking, a strict requirement for simultaneous support for both IPv4 and IPv6 on all new systems should be implemented. A feasible address-mapping scheme should be deployed to take advantage of the IPv6 large address space. Finally, smart management tools need to be developed to separate IPv4 and IPv6 characteristics on multiple levels.

The transition from the current IP version to the new one is a complex process in as much as it implies a diversity of technical, economic, and political aspects. However, the technical transition is the most prominent and several transition mechanisms have been proposed. Work on transition strategies, tools, and mechanisms has been a part of the basic IPv6 design effort carried out by the IETF. The IETF IP Transition Working Group has evaluated two transition mechanisms, namely 6-over-4 or dual IP layer and IPv6 in IPv4 tunnelling, allowing a mixture of IPv4 and IPv6 nodes on the Internet network.

The technical transition is based on different mechanisms. The 6-over-4 (dual-stack network) mechanism provides complete support for both IPv4 and IPv6 in hosts and routers. This mechanism uses dynamic header translation between IPv4 and IPv6 packets. However, the difficulties faced in the practical use of this mechanism led IETF to abandon this alternative.

The technique called IPv6-in-IPv4 encapsulation or IPv6-over-IPv4 tunnelling consists of creating a sort of virtual tunnel, which encapsulates IPv6 packets within IPv4 headers to carry them over IPv4 routing infrastructures. Connectivity between IPv6-enabled (IPv6-only node) end-user sites is called IPv6 routing domains. For such connectivity, all ISPs crossed by IPv6 packages did not implement native IPv6 transport services, therefore the IETF proposed a specific mechanism: the "6 to 4"

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[35] http://www.isoc.org/briefings/006/

[36] Huston, G. (2006), IPv6 – Evolution or Revolution [http://www.potaroo.net/papers/isoc/2006-01/ipv6revolution.html]

[37] *Ibid.*

[38] Lehtovirta, J. Transition from IPv4 to IPv6 [http://www.tascomm.fi/~jlv/ngtrans/]

transition mechanism. This mechanism involves the connection of IPv6 domains via IPv4 clouds without using a tunnel. In fact, for each end-user site that carries an IPv4 tunnel endpoint address, the "6 to 4" mechanism manually configures the tunnel by specifying a unique routing prefix. Another mechanism, called Intra-Site Automatic Tunnel Addressing Protocol (ISATAP), is used for intranets, which do not have IPv6 routers.

The various methods implemented in the transition to IPv6 can encourage developing countries to become more involved in the process and learn from existing processes and possibly improve upon them. Many countries or areas in the world have already independently implemented transition plans. Large-scale deployment networks and vendor implementations have been widely promoted. The IP research community has been supported by government initiatives. For example the Japanese initiative in 2000 was very crucial to the Asian region. Japan has become one of the countries at the forefront of the transition, assuming political leadership in the design of the roadmap to IPv6. It views IPv6 as one of the ways in which its economy can be rejuvenated. South Korea followed in 2001 by announcing plans to roll out IPv6. China and Japan have decided jointly in their 7th Japan-China regular bilateral consultation[39] to promote Sino-Japanese cooperation in information and communication fields, including IPv6 as a subject of bilateral cooperation. These transition dynamics also exist in other countries of the region, including India, where the government has led the initiative for the migration to IPv6 by setting up the interagency IPv6 implementation Group (IPIG) and a pilot project as an IPv6 test bed. The Asian countries defined and have started to implement action plans intended to increase the penetration of IPv6 systems with the support of national initiatives coming from public authorities and large industrial actors. These national initiatives have had an obvious effect on the market.

Throughout the rest of the Americas and the Caribbean, initiatives for the transition to IPv6 are beginning to accelerate. In the United States, the Federal Government has mandated the move to IPv6. The Federal Government hopes to have a complete transition of its informatics systems to IPv6 by 2008. The Department of Defence (DoD) has assumed responsibility for the preparation of an action plan in order to renew all the network infrastructures dependent on the DoD. In October 2005, the Latin American and Caribbean Internet Addresses Registry (LACNIC) Board ratified the proposal of the Global Policy of IPv6 Allocation IANA – RIR. This proposal consists of a guideline, which enables the completion of all of the steps established in the LACNIC Policy Development Process.

In Europe, the European Commission (EC) initiated an IPv6 Task Force to design an "IPv6 Roadmap 2005." The EC funded a joint programme between two major Internet projects, 6NET[40] and Euro6IX,[41] to foster IPv6 deployment in Europe. A presentation of the European IPv6 taskforce phase 2[42] in 2002 notes that a concerted effort to consolidate and integrate European efforts is a must. This would include the development of a skills base, sustained European research, accelerated efforts on standards and specifications, awareness creation, and ensuring deployment.

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[39] http://www.soumu.go.jp/joho_tsusin/eng/Releases/NewsLetter/Vol12/Vol12_18.pdf
[40] www.6net.org
[41] www.euro6ix.org/main/index.php
[42] http://www.ec.ipv6tf.org/PublicDocuments/IPv6TF_second_phase_welcome.pdf

Africa has also moved towards the management of the policies of transition to IPv6. Indeed, initial allocation and sub-allocation policies are already made up under the management of the African Internet Numbers Registry (AfriNIC). Clear criteria have been established to qualify for an initial allocation of IPv6 address space. Generally speaking, any Local Internet Registry that wants to qualify, must show a detailed plan to provide IPv6 connectivity to organisations in the AfriNIC region and, in addition, must show a reasonable plan for making /48 IPv6 assignments to end sites in the AfriNIC region within twelve months.

For the purposes of determining the regional uptake of IPv6 it would be useful to compare the number of IPv6 prefixes that have been assigned to top-level providers of the regional registries. Europe has the largest number of prefixes assigned, followed by Asia, and then the Americas. According to the statistics, by 9 January 2006 APNIC had 1384 IPv6 prefix numbers allocated, while RIPE NCC had 679, APNIC 420, ARIN 236, and LACNIC 49.[43]

At the international level, any transition from IPv4 to IPv6, ICANN notes, should ensure that allocation policies for IP addresses provide equitable access to resources, while noting that there may be different interpretations of the criteria for defining "equitable." The system of address allocation has been modified several times in order to ensure that all applicants can obtain enough address space, and it has also corrected, where possible, some of the initial large allocations, thus freeing IPv4 space for the use of others. ICANN, together with the RIR community, has adopted procedures for the review of global Internet number resource policies. On the other hand, each RIR has set up a policy for the distribution of the IPv6 numbers. An example is provided by APNIC. This RIR has adopted an open policy process to meet the needs of IP address distribution in a constantly evolving global system. APNIC and other RIRs have ensured that IP address assignment occurs in an open, transparent, and bottom-up system, meaning that no single economy or region is advantaged or disadvantaged.

The problem of the cost of transition is also important. A 1999 CNET news article[44] stated that the costs of implementing IPv6 might outweigh the benefits and that those pushing for the adoption of the protocol face tremendous obstacles, because of the expenses that businesses would incur in making the change. According to this news article, IPv6 requires businesses to make massive, costly, and complicated infrastructure changes to their networks. We, however disagree with this point of view. It is obvious that the deployment of IPv6 has a cost that can be particularly expensive for developing countries, which still have other needs to satisfy that are of far greater importance. However, the possibility that equipment used in the current protocol can continue to be used with the adoption of the new protocol during the early years of the transition will aid those that are not in a position to afford an immediate and complete transition. The actual and future IPv6 services can benefit developing countries by improving their communication, education, health, and cultural services, to name a few.

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[43] http://www.ripe.net/rs/ipv6/stats/index.html
[44] news.cnet.com/news/0-1005-200-345715.html

Despite the continued transition to IPv6 by countries and organisations, the developing countries seem to be lagging behind. What then is the source of the problem with the transition to IPv6? Adiel Akplogan of AfriNIC indicates that some of the problems relating to the IPv6[45] include lack of applications, lack of a commercial approach, feverishness to change what works, and a lack of information in certain areas. Additionally, in developing countries, existing infrastructures will certainly have an important complexity due to IPv4 limits. However, the use of IPv6 technology will help developing countries to manage the development of network infrastructures more effectively. The migration of services to IPv6 will encourage developing countries to open their Internet services to new user communities and encourage current and future network deployment by facilitating the increased use of more devices, requiring this protocol and seamless communication via its use.

The steps below show the possible phases of an action plan for the transition to IPv6:

1. Consciousness-raising campaign
2. Training
3. IPv6 connectivity
4. Addressing plan
5. Evaluation of material and software migration
6. Planning of deployment
7. Routing configuration
8. Migration of applicative services
9. Migration of hosts
10. Metrology and control
11. Exploitation
12. General evaluation

The IPv4 protocol is now limited in comparison with IPv6. In order not to remain on the fringe of development opportunities of this protocol, developing countries must set up the processes of transition in order to move from IPv4 to IPv6. This transition should be progressive, because IPv4 and IPv6 may still coexist for several years. The migration of IPv6 services will encourage the growth of the Internet in developing countries and any related businesses. As such, national and regional initiatives from governments, the private sector, and consumers are necessary to facilitate the successful transition to IPv6.

[45] www.afrinic.net/training/materials/Introduction_IPv6.pdf

The Two IP Protocols and the Digital Divide

Services	IPv4		IPv6		Impact of IPv6 on the Digital Divide
	Solution	**Limits**	**Solution**	**Benefits**	
Security	IPSec	- In the form of additional layer; - Cannot support peer-to-peer security; - Cannot be used adequately through NAT today; - The relatively small size of the IPv4 network offers the possibility to look for, at lower cost, the stations by scanning the four billion addresses available.[46]	Native IPSec	- End-to-end security can be deployed. - Because of the large number of IPv6 addresses, the network is very difficult to scan in order to attack it. One IPv6 subnet is longer to explore than the sum of the IPv4 network in its entirety. - IPv6 protocol may result in security problems in the future. With IPv6 connectivity an attacker can reach all internal IPv6 enabled nodes even	- Widespread destructive worms, such as Slammer or Blaster, no longer pose a threat in the IPv6 environment, encouraging connectivity initiatives. - A smurf attack that uses IP broadcast addresses consumes the available bandwidth on a network. With IPv6 this type of attack consumes bandwidth only on the local subnet. - Attacks by spammers, consumers of bandwidth, are made more difficult because spammers are unable to explore the network, researching attack accomplices. Developing countries can use this available bandwidth for their needs.

[46] X-Force Threat Insight Quarterly (2005), Security Implications and Considerations of Internet Protocol (IPv6) [http://documents.iss.net/ThreatIQ/ISS_XFTIQ_Q305.pdf]
[47] *Ibid.*

				if they reside in a private IPv4 address space.[47]	
Mobility	IPv4 NAT-Transversal Protocol	- Mobility must be added as a new feature.	MIPv6	-Mobility is built into the IPv6 node, thus one can use mobility as needed. - Supports a new paradigm for node discovery through neighbour discovery.	- As it is difficult and costly to build fixed-line infrastructure and net access, mobile technology is one solution to enable access in a flexible way and thus give access even while one moves. - With IPv6, 3G devices (less expensive compared to fixed line equipment) allow users to find or share information, such as medical information, meteorology, or market prices.
Wireless Network	MIPv4		MIPv6	- Designed to handle the forecast computer population security issue.	- Installing wireless networks to homes, schools, hospitals, and community centres will provide free or low-cost broadband Internet access, reducing the cost barrier to inner-city poverty and rural isolation in developing countries, which have problems with developing telecommunications infrastructures. - Easier deployment of wireless network and use of wireless devices.

Quality of Service (QoS)		Impossible to distinguish packets in a flow.	- QoS supports IPv6 with the addition of two header fields (traffic class and low label). - IPv6 enables broadband power lines.	- VoIP with minimum delay. - High-quality video distribution. - QoS in IPv6 allows ISPs to better route traffic by avoiding the points of congestion in networks, thereby making more efficient use of the available bandwidth.	- QoS for large scale networks will allow the use of telephony (by VoIP) and broadcasting even in small communities. - Competition between ISPs will lead to lower costs and better services for its customers.
Auto-configuration	DHCP4	- Required to configure a server. - Enormous consumption of CPU resources.	DHCP6	- Supports stateless node discovery (RFC2462). - Supports prefix delegation to customers and provider networks. - It is used with stateless DHCPv6, so there are no addresses or other entities with lifetimes.	“Plug and play” devices on the Internet will allow the easier use of equipment and devices on a wider scale.

IP addresses number	NAT & CIDR	- Shortage of address space. - NAT threat to end-to-end.	- 128-bit address space.	- Solves the IP address exhaustion problem. - IPv6 enables home networks.	- Available address space for enabling a million new IP nodes and devices included in PDAs, cellular phones, automobiles. and various home appliances. - Alleviating the digital divide, enabling more people and entire countries to access information and knowledge, which in turn will allow them to benefit from the global economy, and create new knowledge and services.
End-to-end	IPv4	- Inadequacy of IP addresses to allocate actual and future hosts and devices which need peer-to-peer connectivity. - NAT, which solves the IP address shortage problem, on the other hand breaks the end-to-end principle.	IPv6	- Easily allows secure peer-to-peer connectivity to all Internet hosts and devices that need it.	- Developing countries can open their Internet services to new communities of users.

Table 1

Management of IP Addresses: The Current Situation

RFC 1881,[48] published in December 1995, provides an indication of IPv6 address allocation and management. The RFC stipulates that the IPv6 address space must be managed for the good of the Internet community. The RFC states that good management constitutes a small element of central authority over the delegation and allocation of the address space. The Internet Assigned Numbers Authority (IANA) is this recognised central authority, with the responsibility for the management of the IPv6 address space. IANA, however, relies on the advice of the Internet Architecture Board (IAB) and the Internet Engineering Steering Group (IESG).

IPv6 addresses are hierarchically (*Figure 2*) managed to maintain good order. IANA delegates to RIRs the task of making specific address allocations to network service providers and other sub-regional registries. Individuals and organisations may also seek allocations directly from the RIRs. The ideal hierarchical structure is that IANA allocates blocks of Internet resources (IP address space, Autonomous System (AS) numbers, and reverse delegation) to RIRs, which then allocate these resources within their respective regions to Local Internet Registries (LIRs), which assign them to end users.

The development and execution of address allocation principles are organised at a regional level by the five currently established RIRs: APNIC, serving the Asia-Pacific region; ARIN, serving Northern America; LACNIC, serving Latin America and the Caribbean; RIPE NCC, serving Europe, Central Asia and the Middle East; and AfriNIC, serving Africa. All RIRs operate as independent and neutral non-profit organisations and their operations are based on an industry self-regulatory model in which open and transparent, bottom-up processes are used to consider the inputs of all stakeholders in the formulation of address management policies. RIRs manage, distribute, and register public Internet number resources for their users, namely ISPs and network providers, throughout their respective regions.

The three regional registries – RIPE, APNIC, and ARIN – share a common IPv6 address allocation policy. While this policy is subject to change, it currently offers a top-level provider (ISP) up to 35 bits of network address space (i.e. the equivalent of more than the whole current IPv4 address space for a single IPv6 provider), and a site receives 16 bits of network address space, which should be ample for the vast majority of organisations. AfriNIC's IPv6 management policy goal is prudent management of the public resource, taking into consideration the long-term interests of the Internet. AfriNIC[49] policy encourages aggregation, to avoid fragmentation of address ranges, conservation, the support of address space requests with appropriate documentation and the avoidance of stockpiling of unused addresses, fairness and equity in the treatment of all existing and potential members of the Internet community relating to the use of public addresses, and finally the minimisation of overhead associated with obtaining address space.

[48] http://www.faqs.org/rfcs/rfc1881.html
[49] http://www.afrinic.net/docs/policies/afpol-v6200407-000.htm

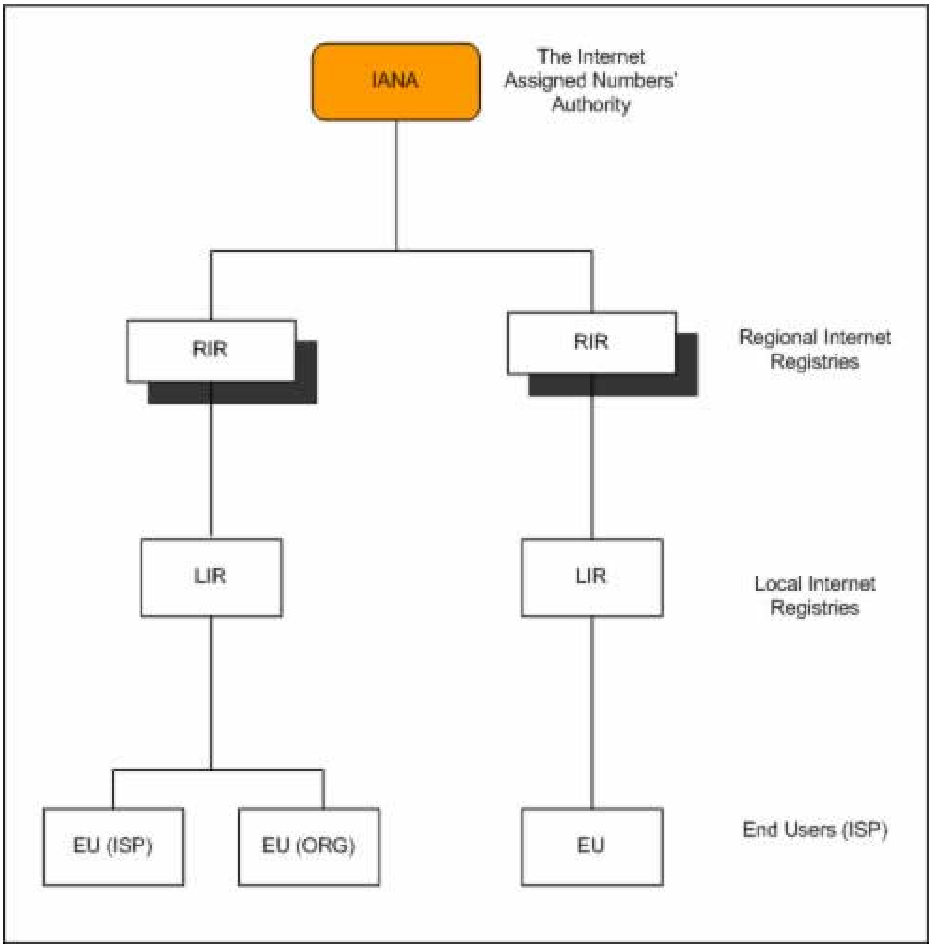

Figure 2: Hierarchical management structure of IPv6[50]

Management of IP Addresses in the IPv6 Era: Future Governance Models

> *"Today, just as in the 1920s with the advent of radio broadcasting, there is passioned debate as to the role of governments in the Internet as a new communication medium… international cooperation is required in managing the Internet...Resolution 102 of the Marrakesh Plenipotentiary Conference…stresses that international cooperation is required in managing the Internet, which is a valid subject of international interest, and it points out that allocation of Internet domain names and addresses should not favour any country or region to the detriment of others."*[51]

The above statement summarises the intentions of various Internet Governance initiatives, the most prominent being the ITU initiated forum, the World Summit on the Information Society (WSIS). The main subject of debate is the controversial issue of how Internet resources, which constitute the basic material infrastructure of the global Information Society, should be managed.

[50] http://www.afrinic.net/docs/policies/afpol-v6200407-000.htm
[51] www.itu.int/osg/spu/statistics/ DOI/linkeddocs/itu_news_sept_05.pdf (ps. 11-12)

To address these public policy issues, WSIS was launched to facilitate proper and equitable Internet resource allocation, streamline existing regulations and policy procedures, develop workable models, and facilitate the participation of developing countries. However, an inherent predicament relating to the establishment of these policies is the challenged credibility of existing Internet Governance models and organisations currently managing these resources, including the Internet Corporation of Assigned Names and Numbers (ICANN). Despite the fact that these organisations have a broad based bottom-up policy development process, doubts have arisen on the contribution of these policies to bridging the digital divide.

In this turbid Internet Governance environment, it is necessary to look closely at how IPv6's addresses will be allocated, which policies should be adopted for their allowance, and "who will do what" at the international, governmental, or local level. The question of how the registries should allocate IPv6 address space to those who request it remains an ongoing controversy. Some points seem clear: even in the IPv6 era, allocations will continue to be made to the regional registries and then further allocated to ISPs and organisations, as they are today with IPv4. The regional registries themselves will develop detailed allocation rules. Several schemes have been proposed for how Internet resources, in particular IP numbers, should be managed in this era of Internet Governance and its most triumphant time of IPv6.

The debates on the question were very impassioned during the first phase of the summit. A paper written by Wolfgang Kleinwächter, titled *Beyond ICANN vs. ITU: Will WSIS Open New Territory for Internet Governance?,* effectively summarises how Internet Governance has ended up being such a complex question. Kleinwächter notes that some governments, mainly the United States and the European Union, supported by the private sector, have argued that the private Internet Corporation for Assigned Names and Numbers (ICANN), with its narrowly defined technical mandate, should continue to be the central organisation in this field. Other governments, led by China and members of the "G20 Group," which includes Brazil, South Africa, and India, based their arguments on a broader definition. Their understanding of "Internet Governance" included not only domain names and root servers but also other Internet related issues like spam and illegal content. These countries wanted to move the whole Internet management system under the umbrella of an intergovernmental organisation of the United Nations, notably the ITU, which hosted the first phase of the summit. The civil society fraternity, while critical of ICANN, did not support an "intergovernmental solution" but argued in favour of a "decentralised mechanism" with different organisations having different core responsibilities.

On 21 October 2004, the Director of ITU TSB Houlin Zhao published a memorandum, "*ITU and Internet Governance*."[52] This ITU memorandum proposed a new IPv6 address space distribution process, based on national distribution, which would compete with the existing RIRs. Key highlights of the memorandum include the allocation of the IPv6 address block to the ITU-T, the standardisation section of the ITU, which would then allocate a contiguous address block to each nation, sufficient to meet the needs of its national population. Under the memorandum, each

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[52] Xhao, H. 2004. ITU and Internet Governance (draft input to the 7th meeting of the ITU Council Working Group on WSIS, December 12-14, 2004 [http://www.itu.int/ITU-T/tsb-director/itut-wsis/files/zhao-netgov01.doc]

nation would establish a national registry framework to manage its national address block and would establish policies for address management appropriate to its individual national situation. Effectively, the national address registries would operate in competition with the established RIR system.

The ITU proposal is founded on the premise that transforming IP addresses to a national resource will ensure that IPv6 distribution would somehow avoid the problems that are allegedly experienced with IPv4 distribution, including geographic imbalances and an excessive possession of the address space by early adopters. The ITU argues that assigning addresses to countries will provide choice introduced by competition between the country registration agency and the regional registration and safeguard sovereignty connected to the registration of addresses.

The ITU proposes a new, independent and unproven process for IPv6 address space distribution, a process based solely on national authorities. Naturally, many diverse voices have been raised against this ITU memorandum. In response, the Numbering Resource Organisation (NRO)[53] stated that the memorandum ignores any consideration of the technical impacts of its proposal on the global Internet (specifically on address space routability) and postpones a solution to this problem for the future. Further, NRO notes that the IPv6 address space distribution proposal in the ITU memorandum overlooks the success of the RIRs in including public and private sector considerations in open regional policy development processes. It also disregards the widely accepted and long-held views that IP addresses are endpoint network identifiers that intrinsically have no national attributes, and that allocation principles regarding their distribution must be guided primarily by technical considerations relating to the viability of the operation of the Internet. The NRO states that the ITU memorandum proposes a uniform model of Internet address distribution, which ignores the technical impacts on the global Internet, the diversity of requirements of the global Internet community, and the body of experience already gained in the operation of the global IP address distribution function.

In a paper published in April 2005 titled, "*The Geography of Internet Addressing*,"[54] the Director General of APNIC, *Paul Wilson*, also notes that the ITU proposal, where countries should receive and manage separate IPv6 allocations, carries a certain risk. The paper also notes that apart from imposing a potential cost and obligation on every country to establish an agency to manage this resource, the proposal creates certain technical risks, which have global implications due to the introduction of numerous IP address policy regimes. Excessive consumption and subdivision of address space under the proposed policy could result in very large numbers of additional address prefixes within the IPv6 routing tables, which would need to be carried by every ISP on the Internet. Carriage of such routes would impose performance and cost impacts that many ISPs could not afford, while address space, which is dropped from routing tables, may become effectively unreachable by some or all of the Internet, thus generating an obvious impact by selectively isolating network users from each other. APNIC also argues that a much larger size of IPv6 address space may result in an explosion in routing table sizes, particularly if allocation mechanisms are introduced, which conflict with today's measures for the control of table sizes.

[53] http://www.nro.net/documents/nro17.html
[54] http://www.apnic.net/news/hot-topics/internet-gov/internet-geography.pdf

On the other hand, Geoff Huston of APNIC,[55] in addressing the ITU's proposal for introducing competition into the allocation of IP addresses through the proposed establishment of national IPv6 address registries, states that the proposal leads to the creation of policy confusion in addressing, it does not align to regional or global business models and that the implementation of the proposal would result in an irrevocable set of actions that would threaten the future viability of the adoption of the IPv6 global network. The proposal creates competition regimes based on policy dilution and creates impetus for rapid consumption through address hoarding that would lead to premature exhaustion of the entire address pool, even one as large as the IPv6 address space. The proposal has no visible relationship to known routing capabilities. The removal of that constraint through the progressive dilution of address distribution policies as they relate to aggregation capability would potentially place unconstrained growth strains on the routing system. The proposal eliminates the common interest in one network and compromises any hope of enhancing routing integrity and security, creating further shake-up in perceptions of the stability and viability of IPv6.

In another rejoinder to the ITU proposal, Brian Candler hopes that the ITU's take-over of IPv6 address allocation and management on a country-by-country basis will not happen, because the driver behind address allocation should be technical. Candler argues that IPv6 allocation is related primarily to routability, not geography[56] and the proposal is a threat to the longevity of IPv6. It is clear that the RIRs have the technical and management resources required to manage IPv6 allocations. If the ITU proposal is adopted it would disrupt the stable and proven mechanisms for IP address space distribution on which the success of the Internet has been founded and on which the global Internet community relies for future operational stability and continued growth.

Apart from the ITU proposal, other schemes for the future of Internet Governance have been proposed. These include a reform of ICANN as detailed in a concept paper by the Internet Governance Project titled "*About ICANN: A Proposal for Structural Reform.*"[57] The main criticisms of the existing Internet technical resource governance model include the unilateral oversight by the United States, the lack of defined roles for national governments, the exercise of governmental powers without corresponding mechanisms for accountability, and a lack of legitimacy. The paper proposes structural reforms for ICANN including: limits on power and internationalised oversight through a legally binding international agreement. The agreement would narrowly define ICANN's powers and would replace US government supervision with internationalised supervision, leading to the abolition of ICANN's Government Advisory Committee. Additionally the paper proposes the introduction of democratisation in ICANN through the reinstatement and the strengthening of the At-Large membership of ICANN. Finally, the paper proposes the introduction of competition through a coordinated sharing of responsibilities between ICANN and the ITU in a way that would offer country code Top Level Domain (ccTLD) managers and IP address users a choice of alternative governance arrangements.

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[55] http://www.apnic.net/news/hot-topics/internet-gov/docs/address-policy-issues.html
[56] http://www.apnic.net/news/hot-topics/internet-gov/internet-geography.pdf
[57] http://dcc.syr.edu/miscarticles/IGP-ICANNReform.pdf

The paper also proposes peer-to-peer oversight, enabling ICANN to share control and authority with a peer entity, most likely the ITU, over the Internet name and address spaces. This would effectively terminate ICANN's monopoly over the name space. With such an approach, the ITU could assume management responsibility for part of the IPv6 address space. Given that ICANN has created new RIRs, such as LACNIC for the Latin American region and AfriNIC for the African region, there is no reason why, the paper argues, in the case of the IPv6 address space, the ITU could not also be made into an address registry. The IPv6 protocol presents plenty of unoccupied address blocks to assign to the ITU, allowing it to establish its own policies and practices. Since the ITU operates on the basis of a completely different, inter-governmental governance model, states/countries and not Internet service providers would acquire their addresses from the ITU. ISPs would thus continue with the existing governance model (of RIRs), which are more closely tied to ICANN. The ITU could then delegate IPv6 address space on the basis of national jurisdictions, in line with its traditional sovereignty-based model. By accepting this role, the ITU would be accepting the continued existence of ICANN.

The "*ICANN Strategic Planning Issues Paper"* of September 2005[58] identifies factors that would have a significant impact on ICANN over the next three to five years. These factors include: international domain names and other developments for facilitating multi-language communication, the introduction of new generic Top Level Domains (gTLDs), IPv6, Domain Name System Security Extensions (DNSSEC), Electronic Number Mapping (ENUM), Internet security (both from a user and a governmental perspective), actions by governments, WSIS, Working Group on Internet Governance (WGIG), the increasing importance of participation by the global community in the policy development of the DNS, and the future of the MOU or other contractual agreements with the US Department of Commerce.

The ICANN paper identifies internationalisation as an important aspect of its strategic planning, particularly due to the continued rise of the Internet as a truly global means of communication. It is proposed that ICANN should encourage participation of all relevant parties in the ICANN process and demonstrate its truly global representative nature in order to maintain its legitimacy. This may be achieved through outreach to include all countries under the ICANN umbrella and assistance to the development of Internet communities in developing countries. Apart from internationalisation, other issues identified include stable budget and financing structures to facilitate greater accountability, operational improvements, improving the security and stability of the Internet, particularly with regard to multiple complicated technical changes to Internet operations or protocols, including the implementation of IPv6, Internationalised Domain Names (IDN), and DNSSEC. In this regard, the paper identifies the need for ICANN to educate the community on the impact of these changes on Internet operations.

In light of the transition to IPv6, the "*Report of the Working Group on Internet Governance*"[59] notes that some countries feel that allocation policies for IP addresses should ensure balanced access to resources on a geographical basis. The report proposes the formation of an Internet Governance forum to facilitate dialogue and

[58] http://www.icann.org/strategic-plan/strategic-planning-issues-paper-04oct05.pdf
[59] http://www.wgig.org/docs/WGIGREPORT.pdf

allow the participation of all stakeholders from developing and developed countries on an equal footing. The WGIG proposes four alternative governance models,[60] which provide a possible middle ground between the opposing sides. These include the creation of a UN body known as the Global Internet Council, that draws its members from governments and "other stakeholders" and takes over the US oversight role of ICANN; secondly it proposes no change to existing structures, apart from strengthening ICANN's Governmental Advisory Committee to become a forum for official debate on Net issues; thirdly the formation of an International Internet Council (IIC), which would take over the US government's role but not be an explicit part of the UN. This would relegate ICANN to a narrow technical role. Finally, the WGIG proposes the creation of three new bodies; the World Internet Corporation for Assigned Names and Numbers (WICANN) to take over from ICANN and look after the Internet's addressing system, with closer ties to the UN and taking over the US government's role; the Global Internet Governance Forum (GIGF), to be a debating chamber for governments, businesses, and the public, and finally the Internet Policy Council (GIPC), to coordinate work on "Internet-related" public policy issues.

[60] http://www.theregister.co.uk/2005/07/15/un_wgig_report/

ARRANGEMENTS FOR IPV6 MANAGEMENT: ANALYSES AND PROSPECTS

Internet Governance is the cornerstone on which the Information Society will be built. However, the Internet Governance debate has raised many contradictions, which constitute real dilemmas, such as open source vs. patents, copyright vs. fair use, root servers vs. the AnyCast scheme etc. One of the Internet Governance-related trade-offs is the debate on the ICANN vs. ITU management of IP addresses.

It is obvious that IPv6 constitutes one of the answers to the need for new TCP/IP standards and the constraints related to the unequal distribution of the numerical addresses. Thus, the current debate must move in the direction of true international management of the resources. However, the governance of the Internet, in relation to these aspects, could benefit from the introduction of new resources generated by IPv6, particularly with regard to management.

The current policies allow for the hierarchical management of the IPv6 address space. At the highest level, IANA delegates IP address space to RIRs, as described in RFC 1881. RIRs in turn allocate Top-Level Aggregation Identifiers (TLAs) to organisations, which in turn allocate address space to ISPs and end users. In this structure, ISPs serve as Next Level Aggregation (NLA) registries for their customers.

In its memorandum, the ITU does not seem to recommend the dismantling of the current structure. The ITU proposes an additional option, which is justified by reasons to democratise and internationalise the IP address allocation/assignment operations for the participation of other countries, particularly developing ones. One can already say that the "war for IPv6 address management" is less complicated than the DNS one, which is more radical and complex.

The main reproach of the ITU's proposal is that of a technical nature. In reference to NRO comments, the ITU proposal appears to provide a great danger of an explosion in routing table sizes.[61] In fact, the fear expressed by NRO is based on the reality that the proposed management of IP addresses is carried out by different entities (national entities not RIRs), and will lead to a lack of control of block addresses and the clogging of routing tables.

A solution to this problem can be found in the installation of a meta-structure of management of the IPv6 addresses. This simply involves the delegation of IP addresses by IANA to both ICANN and the ITU, serving RIRs and member states of the ITU. Both organisations would agree on mechanisms for the regulation and management of these resources, particularly with regard to the technical problems in routing mentioned above.

An international forum and a widened and reinforced ICANN might be a reasonable alternative solution, with defined roles for ITU, making the future of Internet Governance evolutionary rather than revolutionary. It is therefore not surprising to note that the major outcome of the WSIS phase 2 was the emergence of ICANN from the summit unchanged, in its institutional structures, most notably in its mechanisms

[61] http://www.nro.net/documents/nro17.html

for political oversight, but significantly different in the sense of gaining greater legitimacy.[62] Another important WSIS outcome was the launch of the Internet Governance Forum (IGF), a multistakeholder forum, but with no concrete power.

Despite the development of various governance models, the World Information Technology and Services Alliance (WITSA) argues that the debate over how the Internet should be governed, has overshadowed discussion about what the industry should do instead to bridge the digital divide. Harris Miller, the president of WITSA, states that it is necessary to re-focus efforts on the building blocks that bring ICT benefits to developing economies. These include basic IT education, the development and deployment of ICT infrastructure, application services, such as e-government, e-health, and e-learning, as well as a stronger emphasis on intellectual property protection. Additionally, governments and private sectors in developing countries need to help nurture a culture of entrepreneurship, innovation, and intelligent risk. On the other hand, he argues that developed countries need to eliminate barriers to trade by offering full market access and instilling technology-neutral practices.[63]

[62] http://www.ip3.gatech.edu/images/Significance_of_WSIS-II_Tunis-05.pdf
[63] http://www.zdnetindia.com/biztech/enterprise/news/stories/128369.html

CONCLUSION

The past decade has established the information evolution as something meaningful and necessary. IPv6 is an integral part of the Internet evolution.

Today, development proponents defend the idea that ICTs may have a direct impact on development. Indeed, ICTs can help countries develop and extend essential services, including health, education, and agriculture. The digital divide is, therefore, a real obstacle to the development of nations.

The growth of the Internet brings about new markets and business opportunities, in which IP protocols have an important role to play. The Internet Protocol version 4 imposes significant constraints on the adoption and growth of the Internet. Indeed, IPv4's limited address space threatens the very growth of the Internet. Therefore, the necessity and the importance of upgrading this protocol to IPv6 is paramount. The main benefit of IPv6 is its larger address space, which enables the continuity of Internet growth and enhanced potential for services and business models.

Generally speaking, IPv6 offers a second chance to gain a technological edge in information technologies and enable global e-nation building. The existing constraints leading to the adoption of IPv6 in relation to bridging the digital divide are paramount for developing countries. This research has analysed the necessity to set up strategies for transition to IPv6 and has identified concrete actions necessary at the international, the regional, and the national level, for the better and possible equitable management of Internet resources in future Internet Governance models.

Developing countries must, therefore, through meaningful access, take part in the Information Age by using ICTs in an appropriate manner. Developing countries may leverage policy formulation processes that are still in their infancy, to take advantage of new Internet Governance models. The measurement of the "width of the digital divide" using various indices is therefore critical in informing the policy and decision-making process. Additionally, regulatory reform is critical in facilitating access to infrastructure necessary for the provision of access to Internet resources.

IPv6 presents a great opportunity for incorporation into the global information economy through equitable IP address space allocation policies and may help bridge the digital divide by providing developing countries with immediate access to the Internet and many new applications and communication devices. Given that the private sector is currently inclined to largely ignore IPv6 because of its initial deployment costs and perceived long-term returns, the integration of ICANN/IANA and ITU governance models offers developing countries a role in the management of IP numbers.

The solution of IPv6 governance does not lie only in technology, but administering technology through progressive policies and thinking about policy solutions coupled with technical solutions. In fact, the challenge is to sensitise the concerned actors/stakeholders towards the development and implementation of an Internet Governance model that recognises every actor's significance and role.