



PUBLIC IP ADDRESS ALLOCATION AND ASSIGNMENT IN AFRICA

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Abstract

The exponential growth of the Internet has led to the rigorous but necessary implementation of the Classless InterDomain Routing Address (CIDR) strategy as an interim solution to the scaling problems. The CIDR strategy has been in implementation since 1994 and without it, the Internet would probably not be globally reachable today. The eventual exhaustion of the IPv4 address space and the growth of Internet routing tables have imposed some new constraints in the allocation, the assignment and the use of public IPv4 addresses particularly to countries and regions that are still trying to bridge the Information Technology (IT) gap. Public IPv4 addresses are being stockpiled by supranational Registries who use these addresses as a means to further expand their IP networks in the African region through the provision of Internet services. The current structure of Regional Internet Registries (RIRs) responsible for the management and allocation of the public IPv4 address space for specific regions does not adequately address problems faced by the African Region. The very low Internet penetration in Africa provides an opportunity for the creation of an African IP Address Space and a Regional Registry.

Introduction

In 1972 when Robert Kahn first introduced the concept of an open network while working with the Defense Advanced Research Projects Agency (DARPA), very few could predict that this concept will grow to become one of the most successful and influential technologies of this century. Sometime in 1973, the decision by Vinton Cerf and Robert Kahn to have a 32 bit address space was considered more than adequate for the foreseeable future. The 32-bit IPv4 address space meant there could be a maximum of 4,294,967,296 hosts connected to the Internet with the current version of the Internet Protocol (Internet Protocol version 4 - IPv4).

The value of the Internet (as a global network and a major information resource) is expected to increase as more hosts become connected and more services are made available. Hence, the management of public IP addresses will always be a very important factor in the future of the Internet. Today, each computer on the Internet requires a 32-bit public IPv4 address. Some of the bits are reserved for the network

part of the address and the remaining form the host part.

The absence of a Regional Internet Registry for the African region together with the implementation of interim measures to address the Internet scaling problems will affect future large scale deployment of this technology especially in Africa. The poor underlying telecommunication infrastructure, its low penetration and high cost of available bandwidth are problems currently faced by most countries in Africa. This situation is expected to change in a few years because of projects like Africa One, OXYGEN, the Telecom Africa project which all have as their main objective, the building of high capacity regional fiber networks for both voice and data transmission. At the completion of these projects, it is expected that there will be a significant increase in the Internet penetration in the African region.

Classful IP Addresses and Past Allocation Strategies

The total number of available public IPv4

addresses has been divided into three primary network address classes (separated on octet boundaries) to enable allocation to networks of various sizes. The three primary IPv4 network address classes are A, B and C. The number of bits reserved for the network and host parts determine the size of the address space for a particular network address class. All hosts on a network must have the same network ID.

Class A Networks (/8): Class A networks have an 8-bit network prefix with the highest order bit set to 0 leaving 7 bits reserved for the network and 24 bits for the host part. This gives a total of 16,777,214 ($2^{24}-2$) hosts for each Class A network. With 7-bits reserved for the network part, there are only 126 (2^7-2) Class A networks available to the entire Internet community. Class A networks account for 50% of the total IPv4 address space.

Class B Networks (/16): 16-bits are reserved for the network prefix with the highest order 2 bits set to 1-0. This leaves 14 bits for the network part and 16 bits for the host part of the address. This gives a total of 16,382 ($2^{14}-2$) Class B networks each having 65,534 ($2^{16}-2$) hosts and representing 25% of the total IPv4 address space.

Class C Networks (/24): 24-bits are reserved for the network prefix with the highest order 3 bits set to 1-1-0 leaving 21 bits for the network part and 8 bits for the host part. There are a total of 2,097,150 Class C networks ($2^{21}-2$) with each having 254 hosts. Class C network account for 12.5% of the total IPv4 address space.

The remaining 12.5% of the IPv4 address space represents Classes D and E reserved for special purposes.

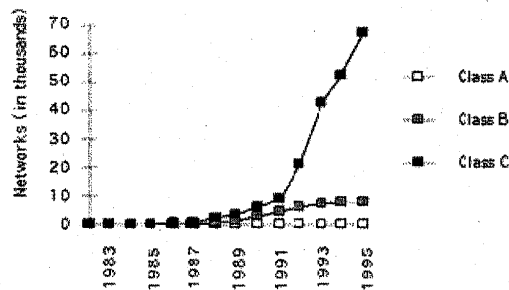


Figure 1. Number of network Classes allocated and assigned.

Up to a few years ago, public IPv4 addresses were assigned based on request and not on the actual needs of the requester. The Classful addressing scheme implied that there were only three types of networks for public IPv4 unicast addresses. Networks with a few hundred hosts were allocated Class B (65,534 addresses) instead of a contiguous block of Class C addresses.

This assignment policy has resulted in the announced premature depletion of the Class B address space. With the current version of the Internet Protocol (32-bit address space) and the address allocation policy, the lower the Internet penetration of a given region, the greater are its difficulties in obtaining adequate addresses. Despite Internet Assigned Numbers Authority's request in RFC 1917 for organizations to return unused address blocks, very few medium sized network are willing to trade in their Class B network for a more efficient allocation based on their actual needs. Returning unused

addresses will create holes in the address space that will result in difficulties in aggregation.

Efficient Use of Available IPv4 Address Space

Since IP addresses are considered a public resource, their management, allocation, assignment and use should take into consideration the global needs of current and future Internet users. The transitory solution to address the Internet scaling problems does not create new addresses but (amongst other goals) tries to make efficient use those that are available. The restrictions imposed by this strategy apply more strictly to networks requesting IP addresses today. A medium sized organization that was allocated a Class B network (/16 prefix) can easily, despite these restrictions, support route aggregation without much effort.

To ensure the growth of IP networks and reachability of all hosts on the Internet, it is recommended that available addresses be efficiently used especially by organizations with insufficient assignments. Such practices will remain valid even when IPv6 is deployed but their implementation does not necessarily facilitate the task of network administrators who have to apply them. Some recommendations for efficient use of available public addresses include:

RFC 1918 recommends the use of private IP addresses for networks and hosts that are not directly accessible on the Internet. IANA has reserved blocks of addresses for this purpose. The network administrator can use any address from this pool without coordinating with any registry body but must make sure that Network Address Translation (NAT) is used if these hosts or networks are to access the Internet.

Use of protocols and software for dynamic allocation of IP addresses. This makes it possible to effectively use a smaller number of public IP addresses than the actual number of network hosts. Addresses are assigned to hosts from a pool on a need-to-use basis and are returned when not in use.

Variable Length Subnet Masks to enable a more efficient use of the assigned address space and the aggregation of routes at the organization's backbone router. The routing protocol (such as OSPF) must support extended network prefixes and the address assignment must reflect the topology of the network.

While waiting for the transition to IPv6, it is hoped that network administrators especially in the African region will follow these recommendations.

Ownership of the Public IPv4 Address Space

Besides the growth rate of the Internet, some of the other factors that have led to the high growth rate of Internet routing tables and the limited *available* number of public IPv4 addresses include: Public IPv4 address assignment on octet boundaries, topological insignificance of address assignment and the limitations of older routing protocols. These factors have also resulted in the stockpiling of public IPv4 addresses by organizations that were assigned addresses before the implementation of current measures to address these problems. A number of recommendations for the allocation and assignment of public IPv4 addresses have been

proposed by IANA and the Regional Internet Registries.

To reduce the overall growth rate of Internet routing tables, **RFC 2050** recommends that networks obtain their public IPv4 addresses from upstream providers. This is to enable route aggregation at ISP backbone routers and hence reduce the overall number of advertised routes. In the African region, most of the upstream ISPs are Supernational Registries with huge blocks of public IPv4 addresses allocated to them by their Regional Registries (mostly InterNIC/ARIN and RIPE NCC).

The Internet Engineering Task Force (IETF) in its draft document (draft-ietf-cidr-addr-ownership-07.txt) discusses the concepts of *Address Ownership* and *Address Lending*. This draft suggests that larger organizations that can express their destinations as a single prefix be allocated address blocks based on the *Address Ownership* model. IPv4 addresses allocation seems to be interpreted today as ownership by many large ISPs who meet the requirements in this IETF draft document. The suggestions in this draft have generated a lot of discussions and concerns within the Internet community. Some of the questions that are being asked are: *When is an ISP considered large ? How does a small ISP become a large one? Who owns the public IPv4 address space?*

What concerns us most in this paper are the consequences of address ownership to networks in the African region. These networks have been assigned addresses by their upstream providers who *own* these addresses and can use them anywhere in the world. Public IPv4 address loans are normally part of the overall package of providing Internet. Sometimes, the organization that receives such addresses on the basis of a loan is not fully aware of the conditions of this loan. It could be argued that the objective of *Address Lending* is to implement hierarchical routing, but that of *Address Ownership* is sometimes conflicting with the CIDR goal of route aggregation and is also more controversial.

The term "allocation" is used when referring to public IPv4 addresses given to LIRs and "assignment" for addresses given by LIRs to end users. However, the conditions for "assigning" Provider Aggregatable addresses to end-users are not clearly stipulated. Addresses are assigned to end-user networks for the duration of the contract with the ISP and are only valid as long as the conditions outlined in the contract are met. Otherwise, the end-user has to obtain new addresses from another upstream provider and renumber all its hosts

and networks. Renumbering can be a costly operation and could result in downtime if not properly coordinated. Based on these IETF recommendations, it is very difficult for an African ISP whose blocks are assigned based on the *Address Lending* model to become *large*. The proliferation of this notion of address lending to IP networks in Africa does not help in the creation of a stable network topology for the region and reduces the capabilities of local ISPs to expand.

Public IPv4 address assignment to end-user networks in the African region is on a loan basis. Current practices also suggest that a large portion of the public IPv4 address space used by networks in the African region is owned by European and American ISPs operating hierarchically under ARIN (previously under InterNIC) or RIPE NCC.

Analysis of the Allocated/Assigned IP Address Space

It is not uncommon to find the use of the terms *depletion* and *exhaustion* in association with Classes A and B IPv4 address spaces. **RFC 1519** mentions the depletion of the Class B IPv4 address space but also credits the CIDR address allocation strategy for the slowed growth rate of the IPv4 Class B address space

RFC 1466 (September 1993) indicates that 49 out of the 126 IPv4 Class A networks and 7354 out of the 16,382 available Class B networks had been allocated. Based on the 1992 estimated growth rate of the Internet, in 15 months Class B address space will be exhausted. There is no reason to believe that this growth trend has reduced. On the contrary, it is reasonable to assume that more hosts are connecting to the Internet today than in the early 1990s when this analysis was done. Since the implementation of the CIDR strategy, addresses assignments are no longer made on octet boundaries (Classful addressing) so it is difficult today to talk of Class A or B address spaces or to know what is left of these spaces.

If we assume that there are no available (unassigned/unallocated) Class A networks in the 32-bit IPv4 address space, then we have left only 50% of the total IPv4 address space (Class A networks represent 50% of the total IPv4 address space). If it is again assumed that the Class B address space is also exhausted, then we have a total of 75% of the IPv4 address space already allocated or assigned (Class B networks represent 25 % of the total IPv4 address space). This does not by any means imply that all of these addresses are

being used. If that were the case, there would be more than 3 billion hosts on the Internet today! This only indicates that a large number of public IPv4 addresses have been stockpiled by those who were allocated or assigned addresses before the application of interim measures to address the scaling problems. These analyses, surveys and estimates suggest the eventual exhaustion of the 32-bit IPv4 address space when less than 2.5 % percent of the total number of allocated or assigned IPv4 addresses are actually being used! If one assumes that 20 million new hosts are added to the Internet each month, it would take more than 16 years for the complete exhaustion of the 32-bit public IPv4 address space. Of course, this result is based on the total IPv4 address space and not what is said to be available today.

An NUA January 1998 analysis estimates that there are 101 million users on the Internet. A July 1997 Domain survey estimates that there are about 20 million hosts on the Internet. Many have seen graphs with exponential growth rates indicating that in a few decades, the number of Internet users will coincide with the population of the earth but more realistic estimates suggest that the number of Internet hosts doubles every 12 months. What this means is that the actual usage of public IPv4 addresses is not responsible for the *limited* number of addresses available today. *Why is the public IPv4 space (with 4,294,967,296 addresses) almost exhausted when most surveys estimate that only about 20 million hosts (less than 2.5 % of the IPv4 space) are on the Internet?*

Classless Interdomain Routing (CIDR)

Classless InterDomain Routing (CIDR) was proposed in September 1993 as an interim solution to address the Internet scaling problems. One of its goals was to eliminate the concept of IP addresses on octet boundaries thereby enabling a more efficient allocation of the available IPv4 address space. CIDR uses bit boundaries to allocate addresses. This means there is much more flexibility in the allocation and assignment of IP addresses. The growth of the Internet, the apparent exhaustion of the Class A (/8 prefix) and the limited number of unassigned and unallocated Class B (/16 prefix) networks resulted in the assignment of small non-contiguous blocks of Class C addresses. Such assignments have resulted in more entries in global routing tables. A medium sized network with a Class B assignment could advertise only one route but if the same organization with were assigned 256 non-contiguous Class C networks, this would mean in 256 advertised

routes for that organization. These resulted in high growth rates for the routing tables. If nothing had been done, many networks would not be reachable today. With CIDR, networks can advertise a few routes that are a grouping of the address spaces of several networks.

CIDR does not only control the size of routing tables but also controls changes in route availability hence providing a more stable environment if the underlying network topology is stable.

An IP Address Space for the African Region

The low Internet penetration in the African region provides an opportunity to the Internet authorities responsible for IP address allocation (IANA and the Regional Registries) to make some necessary changes in the management of public IP addresses for this region.

One of the main goals of the CIDR strategy is the reduction of the growth rate of Internet routing tables. CIDR achieves this goal by hierarchical aggregation of routes based on the network topology. This goal cannot be achieved if the network topology is not hierarchical.

A National IP Address Space (NIPAS) can be created by allocating fixed network prefixes to each African country and a corresponding address space large enough to enable growth of public IP networks in that country. More than 64 /8 public IPv4 address blocks (64.0.0.0/2) are currently unallocated and available in the pool managed by IANA. This represents more than 1 billion IPv4 unicast addresses (Figure 2). Fixed network prefixes and the corresponding address space could be allocated (through a Regional Registry body) to Local IRs for each country. The methodology for estimating the size of each allocation for a country is outside the scope of this paper and will not be discussed.

Address Block	Size (No. of Addresses)	Registry - Purpose
000/8	16,777,214	IANA
001/8	16,777,214	IANA
002/8	16,777,214	IANA
005/8	16,777,214	IANA
007/8	16,777,214	IANA
023/8	16,777,214	IANA
027/8	16,777,214	IANA
037/8	16,777,214	IANA
039/8	16,777,214	IANA
041/8	16,777,214	IANA
042/8	16,777,214	IANA
058/8	16,777,214	IANA
059/8	16,777,214	IANA
060/8	16,777,214	IANA
064-095/8	520,093,634	IANA - Reserved
096-126/8	503,316,620	IANA - Reserved
127/8	16,777,214	IANA
213/8	16,777,214	IANA - Reserved
214-223/8	150,994,926	IANA - Reserved

Figure 2. Internet Protocol version 4 (IPv4) unallocated address space (Source: IANA)

For a successful reduction of the size of routing tables, the Internet has to be divided into addressing domains. In this proposal, the addressing domain is the NIPAS. The NIPAS will consist of all local IP networks in a country that have obtained public IP unicast addresses from the allocation reserved for that country hence have common network prefix for external routing. There will be renegade networks who will obtain their public IPv4 addresses from other sources or who will refuse to renumber to the new addresses but it is hoped that this

number will be small. All local networks will be connected to the NIPAS backbone router that will aggregate all routes for its domain. Because the address assignment to all local networks will be topologically significant, routes will be aggregatable at the NIPAS backbone router.

Detailed information about all the networks in the addressing domain will be available only at the domain backbone router that will advertise a common network prefix for all networks within the domain. This implies that there will be a

single routing table entry for all networks within a domain. Networks external to an addressing domain will have only one route to reach all destinations in that domain and the growth of hosts and networks within a domain will not result in an increase in the overall number of routes in the global routing tables. The routing protocol on the NIPAS backbone router should be running a CIDR-capable Inter-Domain routing protocol and should implement a consistent forwarding algorithm based on

longest match for aggregating routes and for exchanging routing information with other Inter-Domain routers.

Figure 3. shows how routing information from three local IP networks (A, B and C) is aggregated at the NIPAS backbone router as one route. Networks A, B and C can be reached via the backbone router by using only the route 193.14.0.0/21.

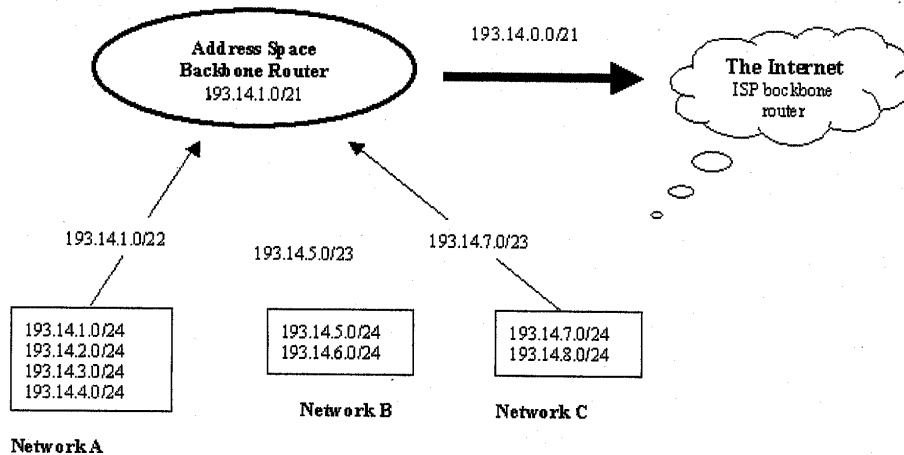


Figure 3. Route aggregation at the Address Space backbone router

In Figure 3. Routers at networks A, B and C connecting to the NIPAS Inter-Domain router will carry extended network prefixes and support Variable Length Subnet Masks for route aggregation. A routing protocol such as OSPF or I-IS-IS should be used at such routers.

Some of the conditions necessary for creating a National IP Address Space:

1. IP addresses should be allocated to an addressing domain such that all assignments to networks within that domain are topologically significant. Each country would have an IP address space from which all assignments are made. Networks within an addressing domain will not use PA addresses from ISPs but should be assigned addresses from the block reserved for that domain. The address assignment should reflect the topology of networks in the address space and not that of the ISP's network.
2. All ISPs operating in a domain should carry the advertised route for that domain and connect to the NIPAS backbone router for

routing purposes. Changes in NIPAS will be visible only at the domain router for that domain.

3. All networks in a domain must be connected to the NIPAS backbone router either directly or via one or more intermediate routers in that domain. This is to ensure a hierarchical topology of the networks in an addressing domain.
4. Only routers with direct connection to the NIPAS backbone routers (e.g. A, B and C in Figure 4) can have (if necessary) direct connection to an ISP core router external to the domain. Such routers should be running CIDR-capable Inter-Domain routing protocols (such as BPG-4).

If the overall growth rate of routing tables is to be contained within the addressing domain, all connections to ISP core routers should be via the domain backbone router. An argument for this restriction is that not all ISPs will accept to include routes for PI addresses in their routing tables especially if the aggregated route is for a network that is less than a /24 prefix. The goal

of having competitive prices for Internet connectivity and that of strictly implementing an address space (as described here) could be conflicting. Point 5. should be applicable only to large networks with at least a /22 prefix.

The NIPAS will be run and operated by a non-profit, non-governmental organization formed for this purpose with membership from local network operators and interested sponsors. This organization will also be responsible for the management of the IP address space for the country (LIR) will chose the ISPs that will link the address space to the Internet. For network reliability, there should be more than one connection from the NIPAS router to the Internet.

The establishment of the Regional IP Address Space (RIPAS) requires that NIPAS backbone routers be connected to each other. Because Africa spends hundreds of millions of US Dollars each year for regional communication routed by international carriers, it is recommended that NIPAS routers be connected directly to each other. For network reliability, backup connections to other NIPAS routers can be made via ISP core routers.

Strict implementation of this proposal to all IP networks in a country and to all countries in the African region will have the following benefits:

- It will enhance communication between local networks within a country (or addressing domain) and other networks in the region. It is not uncommon today to find IP traffic from a network destined to another network in the same country being routed

first to the US or Europe before reaching its destination. In some cases both networks are just a few kilometers way.

- It will contain the growth rate of Internet routing tables for networks in the region and hence reduce the overall number of advertised routes in the Internet. It will enable aggregation for multi-homed sites and reduce injections of routing exceptions because of the topological significance of address assignments within an address space.
- It will result in a more equitable address management policy for the public IP address space.

The Internet Registry System

The Internet Assigned Numbers Authority (IANA) has authority over all number spaces in the Internet. This includes IP address space. IANA allocates IP addresses to Regional Registries who allocate them to Local Internet Registries. The Internet Registry system consist of three Regional Registries (**Figure 4**) hierarchically under IANA. **ARIN**- for North America, South America, Caribbean and Sub-Saharan Africa. **APNIC**-for the Asia Pacific region and **RIPE NCC** for Europe and surrounding regions (including parts of Africa). Since there is no dedicated RIR for the African region, the management and allocation of IPv4 addresses destined for networks in Africa is done by both RIPE NCC and ARIN normally through Local Internet Registries (who are also ISPs) operating in the region and elsewhere.

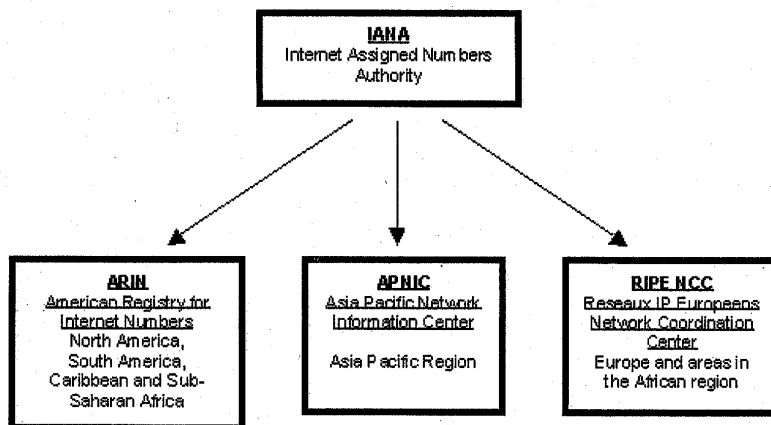


Figure 4. The Internet Registry System and regions served

Because the African region does not have an address space, it is not clear which Regional Registry is responsible for its address allocation and management. RIPE NCC used to be very active in this region (mostly due its proximity) but since 22 December 1997, ARIN became operational and is now responsible for sub-Saharan Africa (in addition to North America, South America and the Caribbean). This practice is in total contradiction with most recommendations and guidelines for the distribution of the roles of regional registries. **RFC 1466** recommends the importance of a single regional registry per geographical region. One of the recommendations that led to the creation of ARIN was that "...the management of IP space should be placed as with RIPE and APNIC under the control of and administered by those that depend on and use it; the end users..." It is hoped that this recommendation will also be applicable to this region so that the management of its IP addresses space is no longer the responsibility of the American (ARIN) and European Registries (RIPE NCC) bodies.

RIPE NCC documentation (**ripe-159**) states that the minimum allocation to an LIR is /19 (8192 addresses) while the maximum is /16 (65,534 addresses) based on the slow start mechanism. After creating an LIR for a sub-Saharan state, it was quite difficult to obtain a /22 (1024) which is 8 times less than the minimum stated in RIPE NCC's Policies and Procedures for address allocation to an LIR. It is easy to obtain the same number of IP

addresses from a European ISP operating in the region (as part of an overall service package of providing Internet services). This is because (as the table in Figure 5 shows) an LIR such as UUNET has an address allocation that permits it to provide Internet services wherever it needs to and can easily assign public IP addresses to networks from its allocation that exceeds 1 million IPv4 unicast addresses. In comparison, the cumulative allocation by RIPE to 4 LIRs operating in 4 sub-Saharan African countries is 32,768! Since the goals of aggregation and conservation could be conflicting, there are no guarantees that future RIPE NCC allocations to these LIRs will be contiguous to previous allocations. In some cases, the LIR is the main Internet Service Provider in the country and also the main source for public IPv4 addresses. In the table below (**Figure 5**), each /16 allocation represents 65,534 public IPv4 address while a /19 represents 8192 addresses. **ALLOCATED UNSPECIFIED** means that assignments from such blocks to networks could either be Provider Aggregatable or Provider Independent. The discrepancy between the allocations made for established developed country LIRs and African LIRs is illustrated in the table below by comparing the allocations for one typical developed country LIR, Pipex of the UK (by no means the largest LIR), with the allocations for four African LIRs. *Can these 4 LIRs/ISPs (even though hierarchically at the same level with UUNET) ever be able to compete with UUNET in the provision of Internet services in their respective countries?*

UK PIPEX (UUNET PIPEX) Allocations	Allocations to 4 African LIRs
Pre-94 146.188/16 ALLOCATED UNSPECIFIED	LIR Cameroon cm.intelcam (INTELCAM) 970403 195.24.192/19 ALLOCATED PA
Pre-94 193.128/16 ALLOCATED UNSPECIFIED	
Pre-94 193.129/16 ALLOCATED UNSPECIFIED	LIR Ghana gh.ncsnet (Network Computer Systems) 960624 193.194.160/19 ALLOCATED PA
Pre-94 193.130/16 ALLOCATED UNSPECIFIED	
940505 193.131/16 ALLOCATED UNSPECIFIED	
940704 193.132/16 ALLOCATED UNSPECIFIED	LIR Nigeria ng.linkserv (Linkserve Nigeria Limited) 971217 195.166.224/19 ALLOCATED PA
941104 193.133/16 ALLOCATED UNSPECIFIED	
941221 194.128/16 ALLOCATED PA	
950307 194.129/16 ALLOCATED PA	
950524 194.130/16 ALLOCATED PA	
950724 194.131/16 ALLOCATED PA	
950921 194.200/16 ALLOCATED PA	
960131 194.201/16 ALLOCATED PA	LIR Kenya ke.net2000 (Net 2000 Ltd, Internet Service Provider, Kenya) 970228 195.202.64/19 ALLOCATED PA
960326 194.202/16 ALLOCATED PA	
960723 194.203/16 ALLOCATED PA	
951207 194.216/16 ALLOCATED PA	
971007 195.217.0/17 ALLOCATED PA	
971007 195.217.128/17 ALLOCATED PA	

Figure 5. Address allocation to UUNET PIPEX compared to those of 4 African LIRs (source: RIPE NCC)

The absence of a registry body for the African region has also resulted in an ambiguous situation for networks in this region. Some networks are assigned addresses from Supernational registries hierarchically operating under RIPE NCC (or directly from RIPE as LIRs) while others get their addresses from LIRs under ARCIN (previously from InterNIC). In the same country, there are networks with addresses from the European and the American Registries.

Conclusion

The growth of Internet in Africa is expected to be significant in the next few years as the underlying telecommunication infrastructure is improved and public awareness of this technology increases. There is a need to create an African IP Space. Public IP address management should be placed under the control of those that depend on and use it. As in other regions, Africa needs a Registry body hierarchically under IANA for the management of its IP space. Without some fundamental changes in current policies and practices, IPv6 might inherit some of the problems encountered today as Internet penetration reaches more homes and offices. The lack of a stable network topology, unfair and contradictory public IP address management policies will hinder future large-scale deployment of Internet in this region. African network operators need to actively participate in the decision making process of the Internet to discuss solutions to the problems they currently face. The ideas and suggestions discussed in this paper are personal to the author and are not necessarily a reflection of the position of the International Telecommunication Union.

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Biography

Alexander NTOKO received his B.Sc. and M.Sc. in Computer Sciences from the State University of New York in 1985 and 1987 respectively. He worked in the U.S as a Software Engineer and did research in the areas of Real Time Operating Systems and Computer Networks. He returned to Cameroon and was Lecturer of Computer Science at Ecole National Supérieur Polytechnique and was later responsible for U.S. Department of State Automation Systems in Cameroon till 1990. From 1990, he joined the ITU and played an important role in the introduction of Internet to the ITU. His main areas of activity today, are in Electronic Commerce, Network Payment Systems and National IP projects for developing countries.