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Guidelines to the Implementation of National Integrated Strategic Plan to IPv6 Transition

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Abstract— The transition to IPv6 is having big time, since a considerable amount of Internet traffic is now carried over IPv6 packets. The transition process is no more an option to all ICT related businesses to reach transparently end-users who should not require updates or reconfiguration. To do so, a transition plan should be defined. The goal of the plan is to perform an efficient and smooth enough transition without interrupting the critical online services. This paper outlines the guidelines of an integrated strategic plan for the IPv6 transition nationwide for public administrations, and presents a case study of a country transition.

Index Terms— Dual-stack, ICT, Internet, IPv4, IPv6, Transition, Tunnel

1 Introduction

Internet is, without any doubt, the fastest and the most effective means of communication making it possible to reach a great number of people in the world.

It draws its power from the Internet Protocol (IP) with IP Addresses that are used to identify devices, machines, services and any other Internet objects. Most of the IP addresses currently in use are IP version 4 (IPv4), which has been used for almost forty years and now it has come to the end of its lifetime because of the tremendous growth of users and devices connected to the Internet, which was not anticipated when designing the protocol [1]. A new version was standardized in 1998 [2], to replace the previous one. However, it's still not widely used as only 15% of the world is using it as of November 2016. [3]

The rest of this paper is organized as follows: a description of the current situation including the problems in IPv4 and the complexity of the transition is given in the next part. Part three and four will address the development of the transition plan. The former, present the hypotheses and the methodology, while the later goes through the plan features. Then a case study for the Sudanese IPv6 transition is highlighted in part five. Finally, the conclusions are drawn in part six.

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2 The Current Situation

2.1 Problem with IPv4

In February 2011, IANA announced in a press conference the exhaustion of the IPv4 central pool under their responsibility. Considering the rapid growth of Internet usage, most Regional Internet Registries, RIRs have run-out of IPv4 resources by 2015 except AfriNIC which anticipated depleting its remaining range by the end of 2016 [4].

Meanwhile, some technologies have been developed to extend the lifetime of IPv4 and can be further extended in the future such as NATing, Dynamic Allocation, and CIDR [5], [6], [7]. However, adopting these solutions has broken the original Internet architecture [5] and increases its complexity, security and management and applications development costs.

2.2 Standardization of IPv6

In 1998, IPv6 (initially known as IP Next Generation - IPng) has been developed by the IPv6 Task Force at the IETF to replace the previous version. The address space exceeds 3.4×1034 unique address comparing to 4.2×109 unique address in IPv4 [2].

The address exhaustion is the main driver to the transition, moreover the new protocol designers benefit from the 40+ years of experience in using IP, keeping all its strengths while adding new features to improve the Internet services, such as auto-configuration, embedded multicast and the possibility to use end-to-end build-in security mechanisms [2].

2.3 Complexity in Deploying IPv6

An important aspect is that IPv4 and IPv6 are neither forward compatible nor backward compatible. This allows future divorcing from IPv4 when we move to IPv6 only networking. This is also because the first field in the IP header must specify the version then the network node will act accordingly [8], and to create the new protocol it was required to change the header fields and header size. So the interoperability between the two protocols is not an option and we can't switch off the Internet to perform the migration overnight. Therefore, we need to define a period for the two protocols to coexist which we call dual-stack, and furthermore transition mechanisms based on Tunnelling, and/or Protocol translation [5]. Those techniques may reduce network functionality and increase the OPEX, thus we should shorten the coexistence period to the minimum. On the other hand, rapid transition may affect the stability of the service and required dedicated resources to be invested in the transition project which leads to inflation of the CAPEX [9].

2.4 Paper Contribution

The dilemma of IPv4 exhaustion has been noted since early 90s' [1] and IPv6 has been standardized since 1993 [2]. However, looking at the Internet today, IPv4 is still the dominating protocol despite very large implementations of native IPv6 worldwide. A fair number of papers address this issue and encloses some reasons of this delay - or rather excuses [10], [11], [12]. Despite that, more and more, complete networks become IPv6 ready, even IPv6-only, such as the bigger cellular networks which already surpassed 60% of IPv6 traffic, by means of using 464XLAT. This is becoming more prominent because the recent Apple announcement that it will retire from the AppStore all the applications that don't support IPv6-only service.

In the Internet context, stakeholders are divided into two main divisions, service providers and customers. The formers argue that there is no demand for IPv6 service, so no motivation to invest in it. While the later complaining about the availability and the stability of the new protocol. IPv6 activists spend time and effort to break this cycle. Nowadays no one asks the questions why and when deploying IPv6. A [13] realistic model has been developed to answer these questions.

This paper aims to answer the question how to perform the transition. More specifically, it will give the guidelines to implement an integrated transition plan and seek to define the optimum transition and coexistence model(s) to be utilized in an optimum time frame.

3 Development of IPv6 transition Plans

3.1 Paper Methodology

It's essential to use the project management concepts in order to assure a smooth and cost effective transition to IPv6. Thus, we assume the transition is a unique and finite process for any organization. Uniqueness requires that the mechanism used in a specific scenario can't not be replicated exactly again, while each organization should define clearly the goal and the objective of their transition plan.

In this paper we will recommend utilizing Dual-Stack coexistence mechanism whenever possible, or when it can be implemented with reasonable effort and budget, otherwise Tunnels will be created to bypass non IPv6 support segments but as a temporary solution until the next depreciation cycle for this segment. Protocol translation will not be considered in our work since many papers didn't recommend it due to its complexity and questionable performance [14], [15], [16]. However, when IPv4 addresses are no longer available, the only way will be to use a dual –stack core, then deploy IPv6-only to the access/edge, and more recent translation mechanisms on the CPEs, such as 464XLAT or MAP, to provide transparent dual-stack LANs and thus, allow older applications and services to keep working.

3.2 Paper Hypothesis

The complexities associated with the transition process to the new protocol at all operational levels in the Internet, considering the incompatibility between IPv4 and IPv6, leads to the necessity of a good collaboration between the ICT stakeholders to perform a successful move to IPv6 without affecting the ongoing services. Since each of the Internet eco-system players have different interests and specialization, national integrated strategy plans must be developed for each country and region to identify the role and the contribution of corporate and each individual in the transition process. Each of them must accomplish a certain task accurately in its specified intervals to ensure the complementarily of efforts and make benefits from the opportunities by good cooperation between the parties.

This paper will consider the transition process is successfully achieved if both IPv4 and IPv6 traffic are equally treated in the organization autonomous network and both can access other networks seamlessly. This necessitates parity so that each end-host and service should support IPv6 packets in the same way as IPv4 packets.

3.3 Identifying Stakeholders

As the transition to IPv6 requires concerted efforts from ICT stakeholders, it's very important to identify the role of each of them in the transition process to assure a success transition without affecting the running services.

According to WSIS [17], ICT stakeholders can be classified into eight categories as follows;

1. Policy Makers and Regulators,
2. H/W and S/W vendors,
3. Telecom Operators,
4. Internet Service Providers,
5. Applications Providers,
6. Research and Education institutions,
7. Civil Society Organizations, and
8. End Users.

Each of these players has a genuine role in the transition process, and we can't complete a successful transition without a good collaboration between them. Various researches have showed that vendors and ISPs are the most significant effect in the realization of utilizing IPv6 service [11], [13]. However, nowadays, as most H/W and S/W isIPv6 enabled, in many cases IPv6 is preferred if the performance is about the same, as indicated by the standards, in such way that more IPv6 traffic is created, and less IPv4 one. This paper will concentrate to provide guidelines to implement an integrated strategic plan to transition to IPv6 at the country public administration level, with in turn, typically helps the transition of private networks as well.

4 A framework to a national integrated strategic plan to IPv6 transition

4.1 Paper Methodology

The main features of the transition plan are as follows:

Vision

The vision towards implementing IPv6 is to secure enough IP resources to support the ICT sector growth, and of course to satisfy the customers demand for the new protocol.

Mission

It's crucial to maintain the services un-interrupted while transitioning to IPv6. So a smooth but effective plan should be developed.

Objectives

1. To develop a unified national vision toward the future of the Internet usage within the country and the provisioning of the Internet resources to ensure sustainable contribution to the social welfare,
2. Collect and disseminate information to help organization within the country to develop their own action plans aligned with the national plan,
3. Provide capacity building programs to fill the gap in IPv6 experience and create local experts,
4. Provide support to the institutions willing to transition to IPv6, and
5. Increase the engagement with the regional and international organizations to exchange knowledge and experiences in IPv6 transition.

4.2 Plan Milestones

4.2.1 Internet Resources Management

Within the country a specialized unit or a department is needed to look after the country public administration numbering plan including IP resources. This unit can be an inter-governmental agency or a consortium from the main players, thus it has to gain acceptance and power to lightly regulate the usage of IP resources. Normally regulatory authorities formalize this unit and invite other stakeholders to participate. The management task should focus on IPv6 and should also look after IPv4, ASNs, and the target is to secure suitable resource and fair distribution. The unit sometimes is part of a government ministry with handles the public administration network as well, and maybe even responsible for the research and education network, even sometimes, being one, to save economic resources to all the public institutions. Ideally the government should apply and obtain for its own IPv6 address space and thereby become a member or a Lear with the IP registry directly responsible for its region, AfriNIC in this case for Africa.

4.2.2 Capacity Building in IPv6

Paper [18] [19] shows that the main component in the transition cost is to provide the IT engineers with the know-how to manage IPv6 enabled network and services. It is key to ensure that the trainers have not only the right knowledge, but also expertise in IPv6 in different projects and networks, as otherwise, as already happened in many cases, the "IPv4 mind-set" will create very common mistakes at the deployment stage that will invalidate the work done. To do so, the following tips are proposed:

1. Establishing IPv6 test-lab is very essential for testing and training purposes. Numerous organizations have adopted virtual environment [20] to test new deployment scenarios before the real operation on the live network to avoid any unexpected faults,
2. Its highly recommended to organize several workshops in collaboration with international organizations and experts in the field to improve the level of understanding of the decision makers in ICT sector, and
3. Include IPv6 topics in the IT college curriculum.
4. Use the IPv6 Forum Education program to certify engineers.

4.2.3 Global Engagement

It's always recommended to actively participate at the regional and international events related to ICT such as;
IPv6 Forum; is an organization for creating awareness about IPv6 deployment. The organization consists of international Internet vendors, Internet Experts, Researchers & Education Networks. The forum organizes summits, seminars and conferences to promote IPv6 [4].

ITU.int; the union organize several workshops and seminars under the TSB and the BDT which discusses the best practices in various areas related to ICT. For the transition to IPv6, ITU established a council group (CWG-Internet) to discuss the way to support developing countries to perform the transition [21].

ICANN.org; organize three meetings a year which attended by more than 2600 participant worldwide to plan for the future of the Internet [22].

RIRs; all five RIRs organize semi-annual meetings to review the policies that govern Internet in their perspective regions, as well as provide training and technological skills to many networking aspects.
Furthermore, numerous regional and national IPv6 Task Forces are organizing regular events [23].

4.3 Implementation Stages

The national strategic plan can be divided into three phases as follows;

4.3.1 Phase One: Preparation

The development of the plan and making it public to get the required approvals and endorsements from the stakeholders may take some time. This time may vary depending on the maturity of the ICT sector in the country and of course the efforts made by the IPv6 leader. In some cases, this achieved very fast within few months but in the worst case, one year is the maximum period can be given as a measure of seriousness. During this period some initial tasks can be achieved such as;

1. Obtain new Internet resources from the corresponding RIR (Both IPv4 and IPv6, and ASN if the government has not got already one for its network),
2. Establishing a specialized training centre for IPv6,
3. Actively participating in regional and international events related to Internet Governance,
4. Organize local workshops to show the importance of IPv6 deployment for the country development,
5. Evaluate the compatibility of the country ICT infra-

structure, and
6. Preparation of the International Gateways to support IPv6.
7. Revise all the IP-related regulations and laws, to ensure that they mandate IPv6 support and interoperability.
8. Mandate the IPv6 support in all the public services, acquisitions and on-line services (e-government).
9. In order to protect consumers, establish a transition period, so after it, non-IPv6 enabled products can be introduced or sold in the country.
10. Establish a transition period, so after it, Carrier Grade NAT (CGN) can't be longer used to extend IPv4 lifetime, unless IPv6 service is also present.

There is no need to accomplish these goals in sequence, instead, concurrent efforts are recommended to ensure good progress in a short time as the successful termination of this phase is crucial to support next phases.

4.3.2 Phase Two: Dual-Stacking

By the end of Phase Two, all core networks and application services should support IPv4 and IPv6 seamlessly. Native IPv6 packet should propagate in the core network without any discrimination from the core devices this include the routing and switching, the international gateway, transit providers, and the network services and applications. Services such as DHCP, DNS, Web, Accounting, etc. should be reconfigured to support native IPv6 traffic.

If all devices and applications haveIPv6 support, enabling the protocol is not a time-consuming task. However, if several legacy devices are still used, thus in the sake of time and cost, a few tunnels can be implemented as a temporary way-out until the next depreciation cycle for those devices.

4.3.3 Phase Three: Full Deployment

It's obvious that the transition to IPv6 in the access layer is the most time, money, and effort intensive part, thus a gradual but well planned strategy should be implemented for this portion.

The customers demand for IPv6 will start very diminutive; however, as the deployment forewords and the new feature of IPv6 have been experienced, an exponential growth is expected. So the deployment of the new protocol needs support in the elementary phase until the market dynamics takes over and IPv6 becomes a public demand.

4.4 Successful Completion of the Transition Project

It's not feasible to wait until all customers get IPv6 services to determine the completion/updates of the transition, as some legacy established firms may not be willing to make any changes in its working and revenue making infrastructure. Thus, if it's proved that IPv6 service is feasible for all users currently using IPv4 we can declare that full deployment is achieved.

4.5 Transition Plan Budget

The transition costs basically imply the total cost of the required modifications in hardware and software as well as the human resource cost. However, previous experiences showed that the knowledge transfer and capacity building are the highest cost component and can reach up to 75% of the total budget. All stakeholders should contribute to secure the transition budget as all of them will benefit from the stability and sustainability of the Internet services.

As the cost of hardware upgrade (or change) has the highest impact in terms of enterprise assets management, it is better to adopt a policy to replace the unsupported hardware and applications with the normal depreciation policy of the organization, and assure that all new installationsareIPv6 compatible.

4.5.1 Factors that affect the transition cost:

- Type of Internet applications and services used,
- The transition mechanism adopted (Dual-Stack, Tunnelling, translation),
- Network hardware and software specifications,
- Technical expertise in IPv6 protocol,
- Security level during and after the transition period, and
- The transition timing, rapid or smooth.

4.5.1.1 Cost of H/W and S/W upgrade

An inventory control should be performed to check the percentage of the IPv6 compatible devices and applications then the organization can develop the replacement sub-plan to be aligned with the depreciation plan. Thus, for organizations that adopted early transition plan the cost can be minimized as its integrates the hardware and software update cost within the corporate upgrade budget, and therefore no need to allocate specific budget to H/W and S/W transition to IPv6.

4.5.1.2 Cost of Capacity Building in IPv6

Capacity building cost includes the costs of research and development, training workshops, planning and implementation (installation, configuration, and testing) and maintenance. While the hardware and software upgrade is onetime costs, the training and capacity building is an ongoing activity during and after the transition period, same as for IPv4.

Best practices show that countries that decided to transition to IPv6, developed a plan for IPv6 capacity building and established a specialized training centre to bridge the IPv6 experience gap. Since the earlier stage, IPv6 topics must be included in the IT college curriculums. This will assure the forthcoming graduates will be equipped with the IPv6 skills.

4.6 Establishment of IPv6 Task Force

As the IPv6 deployment required collaboration from all ICT stakeholders in the country, a unified body with representations from the all active players is recommended to pursue the plan activities and other tasks as follows:
1. Follow up the implementation of the Plan,
2. Promote IPv6 for the end users especially in academia, industry, and the government,
3. Coordination between interested parties in the transition issues,
4. Dissemination of technical information and promote best practices and training,
5. Conduct surveys to determine the usage level of IPv6in terms of usage and types of applications,
6. Act as an advisory body for the enterprises willing to transition to IPv6, and
7. Collaborate with other regional and international rele-

vant Task Forces.

5 Case Study: Sudanese IPv6 Transition Plan

5.1 Background: ICT Sector in Sudan

With 85% penetration rate and about 70% coverage area the ICT sector puts The Republic of The Sudan among the well-developed countries in ICT in Africa [24]. In Internet services, eight licensed ISPs providing data service and Internet access via wired and wireless technologies and more that 30,000 Km of Fibre with access to international submarine cables [25].

5.2 Experience with IPv6

In 2006, AfriNIC organized the very first IPv6 training workshop in Khartoum. In the same year Sudatel, the incumbent PSTN, got a /32 IPv6 address space. This allocation has been among the first few IPv6 allocations in the AfriNIC region. However, the deployment has never gone beyond some testing in an isolated network. The situation remains as it is until NTC, the telecom regulator, host a workshop provided by the ITU in June 2010. Two months later the Sudan IPv6 Task Force (SDv6TF) was formalized and the national transition plan adopted by the Ministry of ICT.

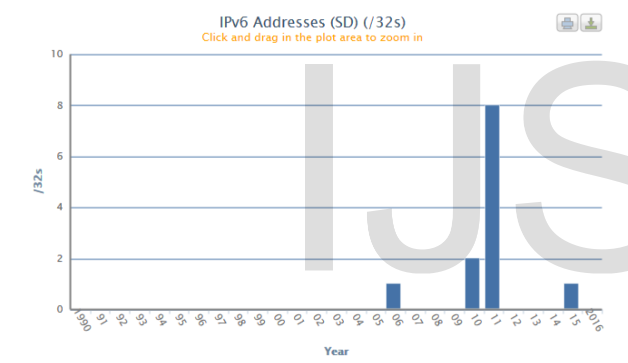

Fig. 1. IPv6 yearly allocation for Sudan

Source: Afrinic.net

5.3 Highlights on the Sudanese IPv6 transition Plan

The plan defines four phases as follows;

5.3.1 Phase One: Preparation – Six months (July-December, 2010)

In this phase, the SDv6TF encourage the local ISPs to obtain more public IP address both in IPv4 and IPv6, Figure-1 show the growth in IPv6 assigned to Sudan. Besides, NTC establishing a specialized training centre for IPv6 in collaboration with NAV6 Malaysia. This centre provides trainings to 400+ participants with CNE6 Level 1 certificates using the IPv6 Forum Education program: http://education.ipv6forum.com/

5.3.2 Phase Two: Dual-staking – twenty-four months (Jan 2011- Dec. 2012)

In this phase the plan concentrates on the operator's core networks by deploying dual-staking wherever possible and installs a tunnel to bypass non IPv6 segments. The core network has been prioritized to be sure that IPv6 is stable and its performance is comparable to its counterpart IPv4 services. However, while this phase forwards, the implementation gap between core and access is getting wider. This alert the SDv6TF to start allocate more effort to the end user and contents providers to utilize IPv6. The first and the most legitimate demand come from Academia. The Sudanese Research and Education Network, SudREN, perform an extensive deployment on its 80+ member institutions, and by the year 2015 one third of universities traffic are routed via IPv6 protocol.

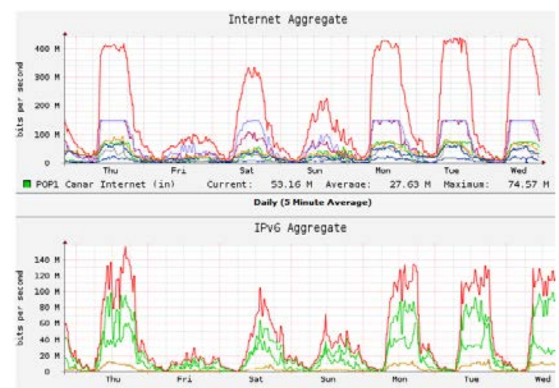

Fig. 2. IPv4 to IPv6 traffic in SudREN Core

Source: mntr.sudren.edu.sd

5.3.3 Phase Three: Preparing Applications to support IPv6 – eighteen months (Jan 2013- Jun. 2014)

The aim of this phase is to assure that all network service (i.e. DHCP, DNS, Web, Mail etc.) and organizational application (ERPs) are IPv6 enabled. This necessitates advance knowledge in IPv6 programming. The training centre organizes a series of advance training sessions in collaboration with NLTVC [28]. However, few web portal and email servers are reconfigured to enable IPv6 service. A list of those web sites can be found at IPv6 Forum [4].

5.3.4 Phase Four: Benefiting from new IPv6 services – eighteen months (Jul 2014- Dec. 2015)

There is a lake of information on how organization deploying IPv6 in Sudan are benefiting from it. However, the Mobile operators are more comfortable when planning for 4G and above technologies since those technologies are IP resource intensive consumer and they use the IPv6 readiness as strength point in their analysis.

6 Conclusion

As the Internet vastly transitions to IPv6, the service providers start providing IPv6 as a complementary service to their IPv4 services while the content providers are adopting the new protocol as well. No one still asks the questions why and when we need to transition to IPv6. The answers are very simple, we need IPv6 to support our business continuity and the development of the Internet and if we didn't begin yet, we must move now.

However, the cost of the transition and the stability of the network services are the most feared by the organizations decision-makers to take the risk of interrupting functioning network. In this paper, we recognise that planning the transition is the way-out, thus we propose an integrated strategic plan to transition to IPv6. We are conscious of the fact that every transition process is unique (a project), so we give the guidelines to be followed when developing transition plans. We finally review a case study of the Sudanese IPv6 transition plan to relate the hypotheses of the paper.

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REFERENCES

[1] M. Boucadair; J-L. Grimault; P. Lévis; A. Villefranque; P. Morand, “Anticipate IPv4 Address Exhaustion: A Critical Challenge for Internet Survival”, 2009 First International Conference on Evolving Internet.

[2] S. Deering, R. Hinden, “Internet Protocol, Version 6 (IPv6)”, Specification, IETF RFC 2460, 1998.

[3] https://www.google.com/intl/en/ipv6/statistics.html

[4] IPv6 Forum, www.ipv6forum.org, Nov. 2016.

[5] K. Egevang, P. Francis, “The IP Network Address Translator (NAT)”, 1994

[6] Y. Cui, Q. Sun, I. Farrer, Y. Lee, Q. Sun, M. Boucadair, Dynamic Allocation of Shared IPv4 Addresses, 2015.

[7] V. Fuller, T. Li, J. Yu, K. Varadhan, “Classless Inter-Domain Routing (CIDR):an Address Assignment and Aggregation Strategy”, 1993.

[8] Raja Kumar, Sureswaran Ramadass, “IPv6 address distribution: An alternative approach”, 3rd IEEE International Conference on Broadband Network and Multimedia Technology (IC-BNMT), 2010.

[9] Sébastien Ziegler, Antonio Skarmeta, Peter Kirstein, Latif Ladid, “Evaluation and recommendations on IPv6 for the Internet of Things”, IEEE 2nd World Forum on Internet of Things (WF-IoT), 2015.

[10] Shibendu Debbarma; Pijush Debnath, “Internet protocol version 6 (IPv6) Extension Headers: Issues, challenges and mitigation”, 2nd International Conference on Computing for Sustainable Global Development (INDIACom), 2015.

[11] Hosnieh Rafiee; Martin von Löwis; Christoph Meinel, “IPv6 Deployment and Spam Challenges”, IEEE Internet Computing Volume: 16, Issue: 6, 2015.

[12] Matěj Grégr; Petr Matoušek; Miroslav Švéda; Tomáš Podermański, “Practical IPv6 monitoring-challenges and techniques”, 12th IFIP/IEEE International Symposium on Integrated Network Management and Workshops, 2011.

[13] Mehdi Nikkhah and Roch Guérin, “Migrating the Internet to IPv6: An Exploration of the When and Why”, IEEE/ACM TRANSACTIONS ON NETWORKING, VOL. 24, NO. 4, AUGUST 2016.

[14] Myung-Ki Shin; Hyoung-Jun Kim; D. Santay; D. Montgomery, “An empirical analysis of IPv6 transition mechanisms”, 8th International Conference Advanced Communication Technology, 2006.

[15] I. Raicu; S. Zeadally, “Evaluating IPv4 to IPv6 transition mechanisms”, 10th International Conference on Telecommunications, 2003.

[16] Saadullah Kalwar; Nafeesa Bohra; Aftab A. Memon, “A survey of transition mechanisms from IPv4 to IPv6 — Simulated test bed and analysis”, 3rd International Conference on Digital Information, Networking, and Wireless Communications (DINWC), 2015.

[17] http://www.itu.int/net/wsis/

[18] Shian-Shyong Tseng; Ching-Heng Ku; Ai-Chin Lu, “Building an IPv6 upgrade model based upon cost-effective strategies”, IEEE Region 10 Conference TENCON 2014.

[19] Tuan Anh Trinh; László Gyarmati; Gyula Sallai, “Migrating to IPv6: A game-theoretic perspective”, IEEE 35th Conference on Local Computer Networks (LCN), 2010.

[20] AfriNIC IPv6 Testbed, http://learn.afrinic.net/en/events/book-ipv6-testbed

[21] Council Working Group on International Internet-related Public Policy Issues, http://www.itu.int/en/council/cwg-internet/Pages/default.aspx

[22] Internet Corporation for Assigned Names and Numbers, https://www.icann.org/

[23] Raja Kumar Murugesan; Sureswaran Ramadass, “IPv6 address distribution: An alternative approach”, 3rd IEEE International Conference on Broadband Network and Multimedia Technology (IC-BNMT), 2010.

[24] http://www.oecd.org/africa/

[25] Rupa Ranganathan and Cecilia Briceño-Garmendia, “Sudan’s Infrastructure: A Continental Perspective”, World Bank, 2011.

[26] Telecom regulatory of Sudan, www.ntc.gov.sd

[27] www.afrinic.net

[28] www.nltvc.com/