A Survey of IPv6 Deployment

Manal M. Alhassoun
Department of Information Technology, King Saud University
Riyadh, Kingdom of Saudi Arabia

Sara R. Alghunaim
Department of Information Technology, King Saud University
Riyadh, Kingdom of Saudi Arabia

***Abstract*—The next-generation Internet protocol (IPv6) was designed to overcome the limitation in IPv4 by using a 128-bit address instead of a 32-bit address. In addition to solving the address the limitations, IPv6 has many improved features. This research focused to survey IPv6 deployment all around the world. The objectives of this survey paper are to highlight the issues related to the IPv6 deployment and to look into the IPv4 to IPv6 transition mechanisms. Furthermore, provide insight on the global effort around the world to contribute in IPv6 deployment. In addition, identify the potential solutions or suggestions that could improve the IPv6 deployment rate. In order to achieve the said objectives we survey number of papers on IPv6 deployment from different countries and continents.**

Keywords*—*IPv4; IPv6; deployment; Internet

I. Introduction

The use of the Internet is growing over the time. Many day to day activities are depending on the Internet and lot of services are provided through the Internet too such as: social networking websites, search engines, video calls and many more. In order to reach these services; people use devices connected to the Internet such as computers, mobile phones, Personal Digital Assistants (PDA). All these devices are communicating with each other through the network using Internet Protocol (IP) where each device is assigned a unique IP address.

Internet Protocol version 4 (IPv4), has been the standard protocol over the Internet for more than 20 years, it provides over 4 billion IP addresses [1]. However, with the rapid growth of devices that can connect to the Internet and upcoming technologies, the limited 32-bit address space of IPv4 will not able to cope with the internet. Some studies expected that by 2020 there will be 50 billion devices online which are 10 times more devices than IPv4 can handle [2].

Besides the shortage of IP addresses, IPv4 has several major weaknesses that made it difficult to keep up with the rapid growth of the Internet, including the following:

- Security: IPv4 does not provide any security like authenticating or data encryption when transmitting packets
- Network Congestion: packets are sent to all addresses in the network at the same time, this broadcast feature may cause overload and congestion on the network
- Packet Loss: IPv4 Time to Live (TTL) feature set time of expiry for the datagram. So if the data was not able to reach the destination on its time, it will be expired and the receiver will request it again from the sender. This delay and multiple resending of packets are not sufficient for real time data.
- Data Priority: the IPv4 cannot recognize the type of data being transmitted, so it cannot prioritize the transmission of high priority data like video streaming and others[3]

In general, the scarcity of IPv4 address is considered as a major limitation of IPv4 addressing system, thus various techniques used to bridge the gap and extend the life of the existing IPv4 infrastructure such as "Network Address Translation" (NAT) and “Classless Inter Domain Routing” (CIDR) (which are described later in this paper). However, these techniques have their own drawbacks.

For solving the problem, IETF (Internet Engineering Task Force) offered a new Internet protocol for the next generation called IPv6. IPv6 extends the address space from 32-bit to 128-bit. By doing this, it provides about four times larger address space than IPv4. This huge number of address will be sufficient to satisfy the need of IP addresses in the future.

This Internet protocol does not only solve the problem of the address space, but also includes many other features such as:

- Streamlined header format: some IPv4 header fields were removed or made optional in IPv6. The aim of this change is to lower the cost of packet processing and to reduce the bandwidth cost despite the increased size of the IPv6 addresses, as shown in Fig. 1 [7].
- Address auto-configuration: the main usage of the auto-configuration feature in IPv6 is to facilitate the large number of hosts. With this feature, any device connected to the network can easily discover it at any location and get a new globally unique IPv6 address.
- Improved Quality-of-Service (QoS): “Flow label” component in the IPv6 header insures fastest delivery and more efficient performance. This is done by specifying the route of the IPv6 packet till it reach its destination and preventing it from going through unnecessary/bad network route.
- Built-in security: IPv6 requires the support of IPsec in order to provide a standard-based solution to satisfy the security needs in the network and to provide more improbability between IPv6 implementations.

- Better support for mobility: mobility is one of the requirements of IPv6 which enable the roaming between different networks. This is done using a global notification when you leave a network to enter the other one. [4], [5], [6].

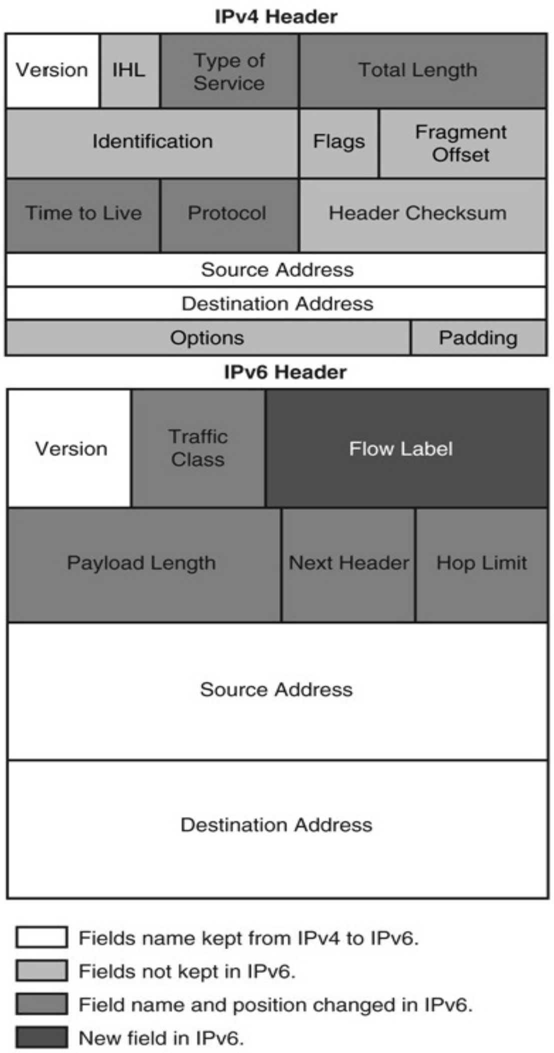

Fig. 1. IPv4 and IPv6 Headers

The rest of this document is structured as follows: Section II is dedicated to several challenges related to IPv6 deployment, Section III contains the critique of existing work and Section IV explains the future work direction. Finally, conclusions are drawn in Section V.

II. Major Research Challenges in the Area

In this section, we outline several problems related to the IPv6 deployment. The techniques used to avoid or delay the complex process of migration to IPv6, the consequences of delay in IPv6 deployment and the hurdles encountered in IPv6 deployment.

A. Problems Related to Extend IPv4 Lifetime

The IPv4 is widely used and deployed in most of the internet architecture which make the transition to IPv6 very risky and challenging. Consequently, various techniques have been used to prolong the lifespan of IPv4 and to avoid/delay the migration such as “Classless Inter-Domain Routing” (CIDR), “Network Address Translation" (NAT) and others.

Prior to the invention of IP addressing scheme “Classless Inter-Domain Routing” (CIDR), IP "Classful" Addressing was used, which divides the address space into different classes to determine the maximum potential size for a computer network. There were three major network classes (A,B,C), each Class A network can have over 16 million hosts, each class B network can have 65,535 hosts and each class C network can have 254 hosts. While the CIDR is based on variable-length subnet masking (VLSM), which allows a network to be divided into variously sized subnets, providing the opportunity to size a network more appropriately for local needs, hence, reduced the problem of wasted address space[8]. Unfortunately, this will fill the gap in the short-term only.

The idea of Network Address Translation (NAT) is to group many machines together and assign to them only one global unique address, while giving a hidden "private" address to each machine individually. The main benefit of this technique is to lower the number of IP addresses any organization may needs. However, this technique suffers from the filtering problem which reduces the network access performance [4].

As these techniques are inefficient in the long-term and the unallocated IPv4 addresses is expected to be exhausted soon or later, the ultimate solution is to move towards IPv6.

B. Problems Associated with Delaying IPv6 Deployment

Not adopting IPv6 may cause several issues. The future growth and global connectivity of the Internet will be negatively impacted. Individual users may not be able to reach IPv6-exclusive websites. Customers expecting or demanding IPv6-compatible or IPv6-enabled products and services may turn to the competitors for their needs, thus the companies will lose market share and revenues. Developers may not be able to introduce new services because they require an unusually high number of IP addresses (for instance, sensor and remote control systems being developed in many different industries including healthcare, automotive industry, disaster prevention, and many others). We may not be able to integrate applications and services because they may require IPv6 features which will not work in an IPv4 network [9].

C. IPv6 Deployment Challenges

Although the transition from IPv4 to IPv6 is necessary for the continuous running and growing of the internet, the IPv6 deployment growth rate is considerably slow. There are some challenges and factors that have contributed towards the slow rate of IPv6 deployment [4], [10], some of them are:

- IPv6 is not backwards-compatible with IPv4. The compatibility problem will create significant challenges for organizations as they move to IPv6.
- The benefits, strength points and necessity of IPv6 remain unknown for the end-users due to absence of campaigns or programs spreading the awareness about

iPv6. This will lower the end-users demand and need for moving towards IPv6.

- With the absence of IPv6 demands from end users, the service providers will not be able invest money in developing new hardware and software and charge their services for their customers.
- Many companies resist the migrating towards IPv6 since it will cost them money, time, resources and expertise.
- Many Internet Service Providers (ISP) and local operators view the IPv6 as a solution for providing more addresses to their clients. They still could not realize the real business value of IPv6.
- There is no enough participation and encourage from the Internet communities to move towards IPv6 which cause the limited number of IPv6 applications developed.
- Lack of practical experience

III. CRITIQUE OF EXISTING WORK

In this section, we survey some of the existing work related to IPv6 deployment in several countries/continents. In order to find the IPv4 to IPv6 transition mechanism used today. And to highlight the worldwide policies and initiatives used to promoting the IPv6 deployment. Additionally, identify the potential solutions and suggestions that could improve the IPv6 deployment rate around the world.

A. Transition to IPv6

The IPv6 and IPv4 are not compatible protocols, thus, the resources available over IPv6 cannot be reached by IPv4 node and vice versa. Fortunately, the network architecture allows the usage of these two protocols in parallel which make the transition from IPv4 to IPv6 done smoothly.

There are different strategies for transition from IPv4 to IPv6 such as [6]:

- Upgrade the whole network architecture along with the operating systems and applications to be IPv6 compatible. This option will guarantee the maximum benefit from all IPv6 features but it is very expensive.
- Wait for the last minute to deploy, which means nothing will be used from IPv6 features till IPv4 address exhaustion. This option is very risky and will lead to loss of market share.
- As a middle strategy, the deployment to IPv6 could be made at incremental levels, which guarantee the benefit from IPv6 features and at the same time it will lower the cost of deployment and allow the risk management.

From our research, we have found that many countries prefer to follow the incremental transition of IPv6 [6], [5],[11], and in order to continue working with their IPv4 infrastructure and to provide an final transition to an IPv6-only infrastructure, they have followed some mechanisms

1) Using Both IPv4 and IPv6: While the network infrastructure is being transmitted from IPv4 only, to IPv4 and IPv6 and at the end to IPv6 only; some services will be reachable over IPv6 only, while other services which still not updated to work with the two protocols will be reachable by IPv4 only. Therefore, this mechanism was implemented to allow network hosts to communicate by sending and receiving IPv4 and IPv6 packets at the same time. This requires the routers and applications to have the capability of Dual-Stack and the application layer needs to decide which protocol to follow.

To use the Internet layers for the two protocols on the same host, the host should be either a Dual IP layer architecture host or Dual stack architecture host.

- Dual IP layer architecture: This architecture has two separate Internet layers one for the IPv4 and the other is for the IPv6, while the Transport layer is implemented only once. The figure below illustrates the concept [6].

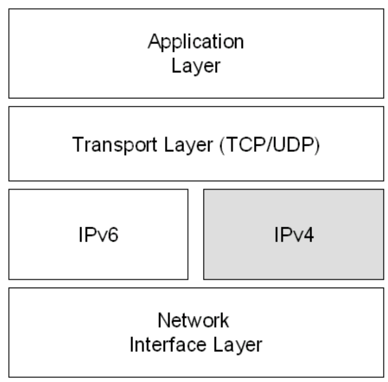

Fig. 2. Dual IP layer architecture

- Dual stack architecture: This architecture has two separate Internet layers one for the IPv4 and the other for the IPv6, and the Transport layer is implemented twice for each protocol. The figure below illustrates the concept [6].

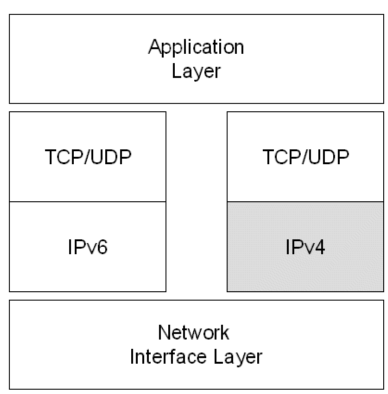

Fig. 3. Dual stack architecture

2) Tunnelling: The main usage of tunnelling is to enable a non-IPv6 device to communicate with other devices in IPv6 network. For example, a packet may be passed through an IPv6 network and suddenly reached one of the devices in its rout which was not upgraded to work with IPv6 packet. In this case the tunnelling is used. This is done by encapsulating the IPv6 packet into IPv4 capsule in order to be recognized and passed through IPv4 device normally. The tunnelling allows two different IPv6 networks to communicate even through IPv4 Networks. The changes on the IPv4 header are:

- The Protocol field value will be set to 41 to point to an encapsulated IPv6 packet.
- The Source and Destination fields are set to IPv4 addresses of the tunnel endpoints.

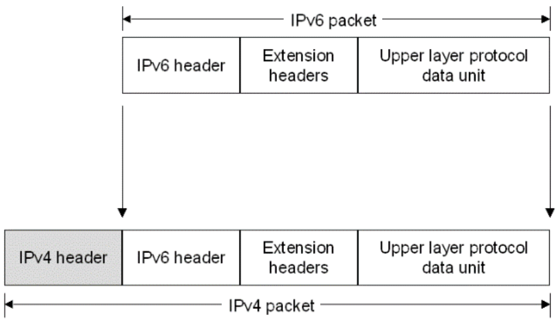

Fig. 4. IPv6 over IPv4 Tunnelling

3) Protocol Translation: This mechanism allows the communication between IPv6 only network and IPv4 only network. It uses translator which serves as an “interpreter” between the two networks. It just translates IPv4 packets to IPv6 Packets and vice versa. Some of the used protocol translation mechanisms are: Network Address Translation - Protocol Translation (NAT-PT6), Stateless IP/ICMP Translation (SIIT7), Bump-in-Stack (BIS8) and Bump-in-the-API (BIA9).

4) DNS Infrastructure: In this mechanism, the Domain Name System (DNS) infrastructure will be updated by populating the DNS servers with records to support IPv6 name-to-address and address-to-name resolutions.

B. Global Deployment Initiatives and Policies

Since the deployment of IPv6 has not been done at global scale in all countries, lot of deployment problems are still unknown. In order to uncover any problem related to the movement towards IPv6; government policies and global experiments and awareness campaigns have been set up such as World IPv6 day and Test-Bed.

1) World IPv6 day: the idea was started on the 6th of June 2012 when major Internet service providers (ISPs), home networking manufacturers and web companies around the world united to launch a new era for the Internet by collaborating in a 24-hour global experiment - World IPv6 Day. The goal of this day is to discover the problems and challenges regarding movement towards IPv6 and to find solutions for these problems. More than 300 organisations participating in the Day have enabled IPv6 for their products and services and advertised both IPv4 and IPv6 addresses in the DNS [1], [2].

2) Test-bed: Test bed allows the examination of the IPv6 environment (development, testing, and deployment) without breaking the production network. There are various Test-bed experiments made around the world [4], [5], we will discuss some of them below.

- Worldwide Test bed – The 6bone: since many people and network manufactures and vendors started to implement and experiment the IPv6; this test bed was established to give more support for the evolution and development of IPv6. It was first started at 1996.
- Indonesia Test Bed: this started when the "Institute Teknologi Bandung" (ITB) in Indonesia was connected to the "Asian Internet Interconnection Initiatives" (AI3) in order to support the academic research on this field.

3) International Policies: a national IPv6 network was established to support the practical testing and usage of IPv6 technology by many developers, researchers and operators around the world. The network was established by many countries such as India, Korea and Japan. [6]. Some of the important examples are shown below:

- India: In 2004, the Minister of Communications and Information Technology declared the Ten Point Agenda to boost IT and communications, and includes the migration to IPv6.
- Japan: Japan believes that IPv6 is very helpful in leveraging the Internet to rejuvenate Japanese economy. Because of that, Japanese took a leadership to design a roadmap for IPv6 in 2000. Japanese government forced the incorporation of IPV6 and decided a deadline for upgrading all existing systems in both public and business sectors. On 2003, the Japanese government announce a tax credit program that eliminates the taxes from the purchase of any IPv6 routers.
- South Korea: In 2003, the South Korean Ministry of Information and Communication announced its funding to the IPv6 products and services as a promotion program.
- China: In 2003, the Chinese government started a plan to make their network fully operated on IPv6 by the end of 2005. The government issued licenses and assigned budget for the construction of the "China Next Generation Internet" (CGNI).

C. Solutions and Suggestions to Improve IPv6 Deployment Rate

In order to facilitate the rate of IPv6 deployment around the world, we have found many suggestions and solutions which based on the distribution of responsibilities [1], [12]. We have divided these responsibilities into three groups as follow:

1) Government Organizations Responsibilities:

- Establish a strategy programs to help in the essential deployment and development of IPv6 technologies and applications.
- Develop IPv6 awareness campaigns for the general populace in order to educate the people about IPv6 features and benefits, thus will create a motivation for switching to IPv6.
- Engage more in the global experiments of IPv6 keep updated on IPv6 activities around the world and understand the necessary requirements and needs to guarantee the readiness for transition at any time.

2) Business Sectors Responsibilities:

- Host content on IPv6 enabled websites
- Provide IPv6 enables hardware and software

3) Civil Society and Academic Society Responsibilities: Build a demand and ensure competitive availability to IPv6 in both government and business sectors, build technical competency among universities and researchers by requesting more IPv6 services and products.

IV. Conclusion

Since 1978, IPv4 was deployed globally with the growth of the Internet, it has served as the Internet Protocol which is responsible of sending and receiving packets through the network. It uses 32-bit addresses, which limits the address space to about 4 billion addresses. Because of the demand of the growing Internet and the problems related to the limited address space in IPv4, IPv6 was developed. IPv6 provides much larger address space and it has lot of features. This protocol was designed to completely replace IPv4, but this will take several years before we completely migrate. The change is rather inevitable, therefore, lot of researches were made to find strategies and mechanisms for transmitting to IPv6 in an incremental level to maintain interconnectivity between the two protocols and allow these protocols to coexist without issues . The implementation and deployment of IPv6 is a challenge, risk and expensive job indeed, but it can be much easier and applicable with the good planning and the optimal choosing of implementation tools and methodologies.

V. Directions for Future Work

Given the examination of IPv6 activities in various regions covered in this paper, the direction of future work would be to conduct similar analysis on the IPv6 deployment in Kingdom of Saudi Arabia (KSA). The aim of such work is to provide a comprehensive study of the current status of IPv6 in Saudi Arabia, the main reasons that make the transmission to IPv6 mandatory, the KSA migration plans and issues involved, the role of KSA in the global effort to deploy IPv6 and what lessons Saudi Arabia can draw from deployment experiences acquired elsewhere.

Future studies also need to be carried out in perform a detailed analysis of a real life experiences of enterprises that had deployed IPv6. Identify what factors significantly contributed to adopt IPv6 in the enterprise. The challenges the enterprise faced during the deployment. Analyze the operational expenses and the risks associated with IPv6 transition efforts and identify the benefits it brings to the business. We hoped this would encourage other businesses to adopt IPv6.

Also, as future work it would be useful to test existing applications for IPv6 readiness. In addition, increase the awareness about IPv6 to the general public and why IPv6 is needed in practice and hopefully therefore increase the demand for IPv6 by customers. This most likely will raise the involvement of the Internet community in upgrading the IPv4 applications and services to IPv6.

References

[1] E. Agbaraji, F. Opara, and M. Aririguzo, “IPv6 Deployment Status, the Situation in Africa and Way Out,” International Journal of Advances in Engineering & Technology (IJAET), Vol. 1, Issue 6, p. 315, Jan. 2012..

[2] Worldipv6launch.org, 'World IPv6 Launch', 2015. [Online]. Available: http://www.worldipv6launch.org/. [Accessed: 12- Oct- 2015].

[3] O. Babatunde, and O Al-Debagy, “A Comparative Review Of Internet Protocol Version 4 (IPv4) and Internet Protocol Version 6 (IPv6)”, International Journal of Computer Trends and Technology (IJCTT), Vol. 13, No. 0, Jul. 2014.

[4] R. Azlina, “Ipv6 Deployment in Malaysia: The Issues and Challenges” SANS-GSEC White Paper, Apr. 2002.

[5] A. Ferry, and T. Shin-ichi. "The Critical Needed of IPv6 Development in Indonesia." In Proc. of the IECI, Japan Workshop. 2003.

[6] S. Gurha, “IPv6 Deployment – Benefit & Opportunities in India with World-wide Experiences”, International Journal of Advanced Technology in Engineering and Science (IJATES), Vol. 03, No. 02, Feb. 2015

[7] D. Teare, and C. Paquet. Authorized Self-study Guide: Building Scalade Cisco Internetworks (BSCI). Cisco Press, 2007

[8] R. Nagar, and A. Ali. “Survey and Study of Next Future Problems in IPV4 and IPV6 Created by Different Unreliable Network Issues,” International Journal of Advance Research and Innovative Ideas in Education, Vol. 1, Issue 4, pp. 195-199, 2015.

[9] Hagen, Silvia, Planning for IPv6, O'Reilly Media, Inc., 2011.

[10] BlueCat. (2011). 6 Steps to IPv6 Readiness: A Practical Approach to Adopting IPv6 with IP Address Management (IPAM) [Online]. Available: http://www.mtechpro.com/2011/mconnect/december/eu/BlueCatNetworksWhitepaper- 6_Steps_to_IPv6_Readiness.pdf.

[11] Microsoft Corporation. (2008, February). Windows Server 2008, IPv6 Transition Technologies. Microsoft Corporation. [Online]. Available: http://download.microsoft.com/download/1/2/4/124331bf-7970-4315-ad18- 0c3948bdd2c4/IPv6Trans.doc.

[12] S. Limkar and R. Jha, “Ipv6: Features, Current Deployment Scenario, Issues and Migration Status in India”, in Proceeding of the International Conference on Software and Computing Technology, 2010, pp. 149–153.