# Transition From IPv4 To IPv6: A Method for Large Enterprise Networks

Nguyen Phu Minh Nguyen, Nguyen Quynh Anh, Torsti Rantapuska, Jari Utriainen, Marianne Matilainen
Lahti University of Applied Sciences
Lahti, Finland
Emails: {mnguyentc@gmail.com, quynhanh89@gmail.com, torsti.rantapuska@lamk.fi, Jari.Utriainen@lamk.fi, Marianne.Matilainen@lamk.fi}

*Abstract* - **This study analyzes experiences of several large enterprises that had deployed IPv6 addresses. Key factors on the success and failure of IPv6 addresses deployment were synthesized from findings from those enterprises. This research utilizes qualitative method, both inductive and deductive reasoning along with design science approach. Seven guidelines of design science method are followed strictly for better end results. Open-ended interviews will be data collection methods of the study. Documents, such as articles, books, and websites also provide lots of information. Content analysis helps the authors to look directly into context of documents to find the core meaning. The content of this study was examined on two scales: technical side and managerial side. Findings upon data collected reveal several significant factors, which affect IPv6 addresses implementation project. Hence, a solution, the most applicable transition method was concluded. This method was then tested on a virtual environment simulating a large network model. It was proven to be working.**

***Keywords-Internet protocol; IP, IPv4; transition; transition method; IPv6; large enterprise; network; IPv6 readiness.***

## I. INTRODUCTION

On 8 June 2011, over 1000 top websites in the world took part in an event called "World IPv6 Day". As IPv4 addresses are running out, the need for changing to IP next generation, IPv6, is obvious. This study aims at finding the best method of transition from IPv4 addresses to IPv6 addresses for large enterprise networks.

Since the birth of Internet in 1960s [5], it has completely changed the way of communications forever. With its capabilities, the Internet has already become a world-wide broadcasting capability, a mechanism for information dissemination, and a medium for collaboration and interaction between individuals and their computers regardless of geographic location [20]. However, despite the uncountable Internet's phenomenal impact on business and its reach across all sectors, there is still no model which valuing companies' Internet efforts correctly [1]. Besides, according to its nature in the structure of Internet, the TCP/IP has also played an important role in the global expansion of communications. As a result, the more users join the Internet, the better it would be to spread knowledge in every field around the world. However, this is also the problem as the IP address is not unlimited and the Internet community is witnessing the exhaust of IPv4 addresses not year by year but day by day, which calls for a proper solution. The first group of Internet users that would be affected is Internet Service Providers (ISPs), large enterprises, companies, etc. The reason is that they hold the most number of IPv4 for operation and management and before the IPv4 runs out, they will need an appropriate act to handle the exhaustion, and otherwise, the collapse of the worldwide Internet is foreseeable [17].

This study is conducted to answer the question, which is the best method for large enterprise networks to transit from IPv4 addresses to IPv6 addresses? Currently, there have been many papers, documents, or reports about IPv4 addresses exhaustion; the invention of IPv6 addresses and the way administrators can apply IPv6 addresses to existing networks, known as transition. However, there are still very few documents for applying the transition from IPv4 addresses to IPv6 addresses in large enterprise networks with many different geographical branches around the world. Therefore, with this paper, we would like to give our suggestion on a solution for a complete implementation of IPv6 addresses into large enterprise networks with no influence on its current operation. Furthermore, this paper does not only focus on the technical aspects, but also the management side. It would provide an insight into the importance of IPv6 address transition, as well as a careful analysis on its influence to the enterprise network and its operation. For all the information above, this research could be used as a source of reference for network administrators, board of directors, information executives, or students and network researchers who have an interest in the network communication and would like to join the community of IPv6.

Therefore, we will have two main parts: the theoretical and the practical. For the first part, we would propose the research question, our approaches with the qualitative method, and also the data collection. In addition, we would give an introduction about computer network, Internet protocol, especially all the main features of IPv4 addresses and IPv6 addresses to indicate the differences between them. For the second part, we would like to apply the Design-Science method to analyze the current network infrastructure, IPv6 readiness in large enterprises to acknowledge the reasons and willingness for changing to IPv6 addresses. Moreover, this method is also deployed in the IPv6 address implementation for its effectiveness and risks.

## II. RESEARCH METHOD

This section provides the research question and research methodology of our study. Research approach will be presented in detail so that readers will comprehend our research model.

### A. Question and Objectives

The most important and also initial step of a research is to define the research question. Based on the nature of that question, proper methods will be applied to find the expected answers. The research question of this paper is: "*Transition from IPv4 to IPv6: What is the best method for large enterprise networks?*"

These following actions are taken to find the answers:

- Conducting a thorough literature review
- Interviewing some specific large companies which have deployed IPv6 addresses
- Analyzing their experiences and attitudes towards IPv6 address deployment
- Analyzing and comparing some transition methods to find the best one (inductive)
- Building a network model and testing the method
- Concluding the result from data and theory (deductive)

The results from above actions are main objectives of this paper, which include:

- Acquiring thorough understanding about IP as well as definitions, ideas, and arguments IPv6 addresses transition methods.
- Getting better understanding of IPv6 addresses deployment in real life project and experiences from companies who had deployed IPv6 addresses.
- Proposing the best method for transitions from IPv6 addresses to IPv4 addresses for large enterprise networks.

The type of this study's research question is "solution" which means to find a way to solve a problem. Therefore, the purpose of this paper is to define and test the most applicable method for large enterprise networks to transit their current IPv4 network to IPv6.

### B. Research approach and Strategy: Design Science

Design science, as the other side of the IS research cycle, creates and evaluates IT artifacts intended to solve identified organizational problems. Such artifacts are represented in a structured form that may vary from software, formal logic and rigorous mathematics to informal natural language descriptions [10]. Those artifacts are broadly defined as constructs, models, methods, and instantiations to meet with the business strategy, information technology strategy, organizational infrastructure and information system infrastructure, which is presented in Figure 1.

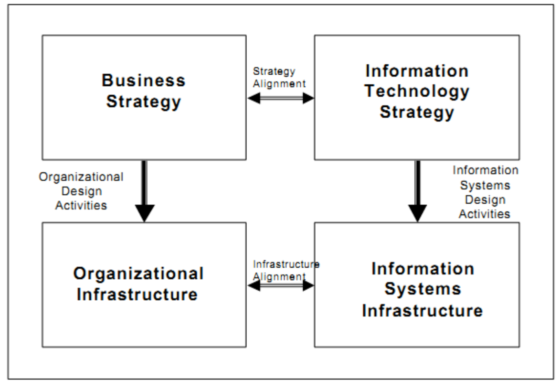


Figure 1. Organizational design and information systems design activities [14]

Therefore, the reason for using design science method is that it is a problem solving process. The fundamental principle of design-science research combines seven guidelines whose knowledge and understanding of a design problem and its solution are acquired in the building and application of an artifact. That is, design-science research requires the creation of an innovative, purposeful artifact (Guideline 1) for a specified problem domain (Guideline 2). Because the artifact is "purposeful," it must yield utility for the specified problem. Hence, thorough evaluation of the artifact is crucial (Guideline 3). Novelty is similarly crucial since the artifact must be "innovative," solving a heretofore-unsolved problem or solving a known problem in a more effective or efficient manner (Guideline 4). In this way, design-science research is differentiated from the practice of design. The artifact itself must be rigorously defined, formally represented, coherent, and internally consistent (Guideline 5). The process by which it is created, and often the artifact itself, incorporates or enables a search process whereby a problem space is constructed and a mechanism posed or enacted to find an effective solution (Guideline 6). Finally, the results of the design-science research must be communicated effectively (Guideline 7) both to a technical audience (researchers who will extend them and practitioners who will implement them) and to a managerial audience (researchers who will study them in context and practitioners who will decide if they should be implemented within their organizations) [10].

### C. Research Method

Quantitative methods are often used to process random sampling data into numbers and statistics [21]. Quantitative research concerns with testing hypotheses, considers cause and effect, and calculates the size of a phenomenon of interest [19]. The end-results are usually statistical report including both descriptive and inferential statistics. Descriptive method summarizes and presents data in an informative way while inferential method generalizes about a population based on a sample. As such nature of quantitative method, data collection often includes closed-ended questionnaire, surveys that classify various experiences into categories, recording numerical data through observing events etc… [42].

On the other hand, the purpose of qualitative method is to understand and interpret processes underneath an observed event and evaluate people's perception involved in the event [18]. It concerns people, objects, words, images not numbers and statistics. In qualitative research, personal feelings and experiences are analyzed. Qualitative research is often used to construct a new theory from the data collected. For that reason, qualitative data collection methods are interviews with open-ended questions, observation, and document review [42]. This paper aims at studying current network conditions of some large enterprises as well as their attitudes toward the transition from IPv4 addresses to IPv6 addresses. Thus, qualitative research method is applied to this paper. As observation was unable to be carried out, interviews and document reviews were done as data collection method in this paper.

### D. *Scope and Limitation*

The scope of this research mainly discusses the most applicable transition method from IPv4 addresses to IPv6 addresses for enterprises with large network. The presentation of the method includes literature review, advantages, and configurations as well as simplified models of the method. As this research aims at large networks, large enterprises with big network traffic may find it more useful than small and medium sized network. There are some transition procedures that may not be suitable for small and medium sized networks due to their complexity. Therefore, this paper is most applicable and limited to large networks.

### E. *Validity and Reliability*

Presently, there are various definitions of validity and reliability in qualitative research method from perspectives of many different researchers. In this paper, the understanding of validity and reliability will be considered and measured by the idea of trustworthiness to establish confidence in the findings. Moreover, Johnson [19] stated that reliability and validity can also be understood as "defensible" [11]. Multiple perspectives from various sources should be compared and tested before the conclusion to strengthen the results and enhance "trustworthiness" [11].

This study relies on a variety of sources, which are from technical papers of leading telecommunication companies. Conclusion is drawn in reference to those data. All the chosen enterprises had carried out IPv6 address deployment with large networks which fall into class B to class A based on IP classes. All the interviewees are people who were in charge of or involved in IPv6 addresses deployment in their companies. All data sources are listed in reference and can be verified. Data collected will be analyzed by proper methods in the right procedures so that the study remains stability, reproducibility and accuracy. It means that data can be analyzed and classified in the same way over a period of time [29].

## III. EVALUATION OF CURRENT TRANSITION METHODS

The transition from IPv4 addresses to IPv6 addresses is not a one-day step and involves a lot of changes in network structures with the use of IP addresses. For the future success of IPv6 addresses, the next step in deploying IPv6 addresses is to vote for the most suitable transition methods and their management. Although many kinds of transition mechanisms have been invented to help with the process such as NAT64, Stateless IP/ICMP translation, NAT-PT, 6over4, and Teredo, the implementation of IPv6 addresses is never said to be easy and simple, even for experienced administrators. As a result, the most difficult problem to make decisions for is which method will be chosen for the implementation process to achieve a smooth and seamless [31].

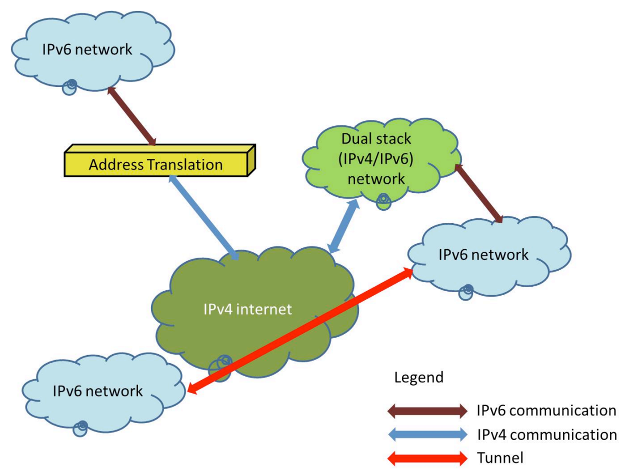


Figure 2. Different transition technologies [38]

According to Figure 2, there are different kinds of technologies which can be applied such as dual stack, tunneling mechanisms, and translation techniques. Firstly, dual stack means to support IPv4 addresses and IPv6 addresses at the same time on all network nodes. Secondly, translation means to convert directly IPv4 addresses to IPv6 addresses or vice versa. Finally, tunneling means to create a tunnel for IPv6 addresses native networks across IPv4 network. Over sixteen transition techniques have been used and tested for the communications between different networks to ensure IPv4 addresses and IPv6 addresses interoperability. Therefore, to make decision on the best suited transition methods, it is really important to have an overview of the current IPv4 networks. In addition, enterprises must analyze needed functionalities, scalability, and securities in the corporation. Besides, "one size does not fit all" and a network can be applied different transition mechanisms together to support a complete distributed system.

In this section, based on the information from the research and literature review, we would present an overview of some major transition methods as well as relevant matter to opt out the best methods for large enterprise networks. Each technique possesses individual attributes and plays an

 ISBN: 978-1-61208-244-8 

important part in the transition process. In general, we can classify various transition techniques into three categories with respect to connectivity and necessary elements for the implementation.

The first category is Dual Stack which uses two IPv4 and IPv6 stacks for operating simultaneously, which enables devices to run on either protocol, according to available services, network availability, and administrative policies. This can be achieved in both end systems and network devices. As a result, IPv4 enabled programs use IPv4 stack and this goes the same for IPv6. The IP header version field would play an important role in receiving and sending packets. In other words, this kind of IPv6 transition is the encapsulation of IPv6 within IPv4.

Next, is the translation category, which means to convert directly protocols from IPv4 to IPv6 or vice versa, which might result in transforming those two protocol headers and payload. This mechanism can be established at layers in protocol stack, consisting of network, transport, and application layers. The fundamental part of translation mechanism in transition process is the conversion of IP and ICMP packets.

Finally, the last category is tunneling which means to transfer data between compatible networking nodes over incompatible networks. It utilizes a protocol whose function is to encapsulate the payload between two nodes or end systems. This encapsulation is carried out at the tunnel entrance and the payload will be de-capsulated at the tunnel exit.

### A. Summary of three methods

Table I below is the summary table containing the advantages and disadvantages for three main methods

TABLE I. SUMMARY OF THREES METHODS

| | Advantages | Disadvantages |
|---|---|---|
| **Tunneling** | - Configure tunnel endpoints only<br>- Simple deployment<br>- No additional management | - Face another problem of NATs<br>- Take more time and CPU power<br>- Harder to troubleshooting and network management<br>- Have single points of failure<br>- Vulnerable to security attacks |
| **Translation** | - The router is used as a translation communicator<br>- Solve network interoperability problems | - Limitations similar to IPv4 NAT<br>- Reduction in the overall value and utility of the network.<br>- Harder to control on a larger scale<br>- Complexity increases in IP addresses |
| **Dual Stack** | - Easy to implement<br>- Low cost<br>- Greatest flexibility<br>- Already supported in all OSs and devices | - Two routing tables<br>- Additional memory and CPU power<br>- Two firewall sets of policies |

### B. Conclusion

Based on the above overview of all mechanisms and current practices in researched enterprise networks, nearly all deployments of IPv6 addresses in enterprise networks apply dual stack mechanism as it gives us a way to know more about IPv6 addresses as well as to improve practical experience with a new address family, which plays an important role in the success of transition implementation. Therefore, in this paper, we choose the dual stack mechanism to build a simulated model for large enterprise networks.

### C. Simulated Enterprise Network Design

To support the transition process, we will use the Cisco Packet Tracer program [48], which is a powerful network simulation software from Cisco, to create a visual model of an enterprise network. Our model has three main areas. At first, the headquarter network area consists of four groups which are the Demilitarized Zone, the Intrusion Prevention, the Service Provision, and the Client Group. Secondly, a branch network area is a division of the business that can be located in various geographic areas. Therefore, the network model of each branch is similar to the headquarter model only without the DMZ. Thirdly, the network area of ISP routers with VPN users who perform the work outside the enterprise network still needs to get access to data from protected servers inside the network.

After successfully building the simulated network model, we implemented the chosen Dual Stack method [47] with specific technologies such as Dynamic Host Configuration Protocol (DHCP) [49] to assign IP addresses automatically for end devices, Open Shortest Path First (OSPF) [50] as an IP routing protocol, Border Gateway Protocol (BGP) [52] for the simulation of Internet among ISPs, Virtual Private Network (VPN) [51] for simulating the group of mobile users, and finally the security establishment, as illustrated in Figure 3.

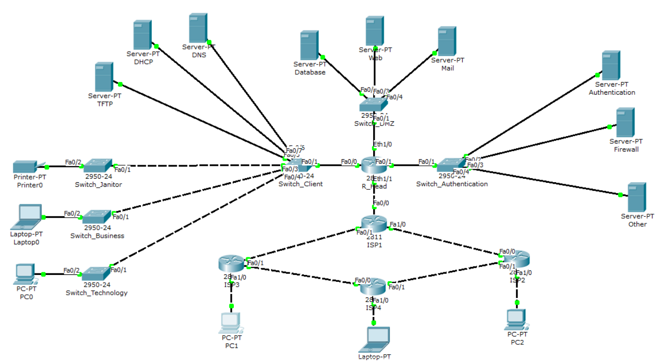

Figure 3. Simulated Enterprise Network Design

Based on practical results from the simulated network model, we have an opportunity to put our chosen method to test and prove that it is the best choice for large enterprise networks to switch from IPv4 to IPv6.

## IV. RESEARCH DATA

This research collected data by interviews with several specific organizations and documents review.

Standardized, opened-ended interviews were conducted with people in charge of IPv6 addresses deployment or network maintenance to find out their experiences on this

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topic. The questions are made so that answers are open-ended; which means participants can fully express their points of views [41]. The same questionnaire was provided to the interviewees to make the process of analyzing and comparing more easily. Before the interviews were conducted, emails concerning the issues were sent to all appropriate organizations asking for permissions. Those organizations were several large Vietnamese enterprises and Finnish organizations listed in the list of IPv6 addresses deployment status of Finland (derived from www.vyncke.org/ipv6status/detailed.php?country=fi). The authors contacted sixty companies and universities; however, only five of them answered back or gave permission for the interview. It means that interview answer percentage was only 8.3 %.

Overall, the most common reasons for deploying IPv6 addresses were testing, preparing for the future, and gathering user experiences. The organizations that the authors had the permission to conduct the interview are university, Internetworking consulting company, training center, and Telecom Corporation. At the moment, those organizations are running well with IPv4 addresses, they have not hit the wall of IPv4 addresses shortage yet. Since all the organizations mentioned above are related to networking sector, training, and service providers, they were aware of the need for IPv6 addresses preparation. IPv4 addresses exhaustion is obvious and it causes future addressing problems. Our interviews also revealed IPv4 addresses exhaustion as the most common reason stated. As we know that IPv4 addresses free pool is out, new Internet connections are rising fast in developing countries. Once those remaining IPv4 addresses are out, new connections will be provided with IPv6 addresses. If enterprises do not prepare for such parallel existence of IPv4 addresses and IPv6 addresses, they may lose a number of customers who cannot access them on Internet.

As inferred from the interview with the Internetworking Consulting Company, the most important aspect to an enterprise is cost saving. Technical features above may not sound very interesting to them. On cost-saving scale, the transition to IPv6 addresses may offer many benefits for large enterprises. It promises to bring better routing performance, improve security and auto-configuration, which generate lower implementation cost, and daily maintenance basic cost. Therefore, it may save long-term IT cost for enterprises.

The interviews revealed that the most commonly used transition method is Dual-Stack. It is because networking devices nowadays already support IPv4 addresses and IPv6 addresses at the same time. Transition technologies are also important factors of IPv6 addresses transition process. There are several common techniques that will be discussed further in this paper.

Moreover, IPv6 is a certain future that it may bring opportunities to early service provider. Since many enterprises are new to IPv6 addresses, service provider can be a consultant in decision making while making some profit. Chip Popoviciu [12] emphasized the value that early adoption can get. Service providers can sell various services if they can play a role in helping enterprises deploy IPv6 addresses.

On the other hand, the research has found out that the most common issue in an IPv6 addresses deployment project was user training. Firstly, training cost was not considered properly in the project planning phase. Then, IP maintenance staffs were lack of IPv6 addresses experiences and knowledge. It not only raised the cost but also lowered the efficiency of the project.

Lastly, there is no backwards compatibility in transition to IPv6 addresses. Microsoft has no intention to implement IPv6 addresses for older Window OS such as Windows 98 or Windows Millennium Edition or Windows 2000 [23]. Therefore, there are some concerns with the cost of replacing a variety of application, which needs to be IPv6 addresses compatible. However, most of the networking software support IPv6 addresses comes as an upgrades based on old software version, thus there is not much extra cost, even no. Nevertheless, specific software tailored for company is much more different. If an enterprise wishes to transit all software to IPv6 addresses compatible and eliminate IPv4 addresses, it may come up with huge costs. It also costs a lot of time and efforts of applications developer to change the applications according to information from the interview with employee from Telecom Corporation.

A request for Comments (RFCs) is a document system invented by Steve Crocken in 1969 to keep the record as well as improve technology being used on the ARPAnet. An RFC describes a research or applications on networking technology or define a new one. TCP/IP was developed by the RFC method of development. In this research, we consulted RFCs as our data on technical issues. RFCs are the most updated and trustable papers on networking technology. A set of RFC, which will be used in this paper, consists of: RFC 2373, RFC2647, RFC2765, RFC2766, RFC2767, RFC3022, RFC4057, RFC4861, RFC5735, RFC6343, and RFC791. Besides RFCs, a set of journal papers on networking technology is also used as technical data in this study.

## V. RECOMMENDATION OF IPV6 TRANSITTION FOR ENTERPRISES

"*Readiness is a state of preparedness of persons, systems, or organizations to meet a situation and carry out a planned sequence of actions. Readiness is based on thoroughness of the planning, adequacy and training of the personnel, and supply and reserve of support services or systems*" (BusinessDictionary).

In expression of IPv6 addresses, this means being ready for the implementation of IPv6 addresses into a network when business requirements arise.

The University of Helsinki, Axu TM Oy, and FPT Telecom Corporation have already taken initial steps to implement IPv6 addresses into the network system based answers gathered from the research. Although these efforts are now just meant for testing, the message from the international community is clear. The transition from IPv4 addresses to IPv6 addresses will become a must for enterprises, especially ones that currently provide online

 ISBN: 978-1-61208-244-8 

services based on IP addresses. They must be able to handle large requests from internal and external customers who are applying their emails or web or other services to everyday working lives over the Internet. It is impossible to predict exactly when IPv6 addresses will become mandatory for most companies. However, in accordance with Mr. SeppoSyrjanen, Data Network Specialist from IT Center of University of Helsinki, although IPv6 addresses adoption is a need for current companies to prepare for the future, aside from the exhaustion of IPv4 addresses for stakeholders to take into consideration, it is not an easy and single step that can be achieved in a short time but this requires a great amount of thorough planning and preparation to develop and adjust an IPv6 business case. Therefore, it is not when IPv4 addresses come to the point of complete exhaustion, IPv6 addresses have already been considered as purely strategic because this is not only to establish global connectivity of enterprise networks for the future, but also to guarantee growth as well.

In this part, based on information from the interviews with large companies and enterprises, we would like to categorize different preparation activities that can be applied as a plan in this IPv6 addresses implementation. This part would become a great asset to assure that a common method is ready to make plans and to check IPv6 readiness when it falls into place for each enterprise network. It is an outline of phases which have both technical infrastructure and business readiness taken into account for an enterprise to initiate the transition to IPv6 addresses.

### *A. Business Side*

**Phase 1**: The determination of business grounds and demands to implement IPv6 addresses

An enterprise must have strong and reasonable desires to initiate the IPv6 addresses transition project. They need to realize business requirements, motives and mark the features of IPv6 addresses to those particular objectives. Five main conditions that need to be acutely considered are business operations after the depletion of IPv4 addresses, support for a great amount of network devices, enterprise policies for IPv6 addresses transition, requests from customer, partners, suppliers, and the global-scaled trade, said by Nguyen Dac Thuan, from FPT Telecom.

**Phase 2**: The analysis of profits, expenses, and risks

Enterprises need to assess the impacts of IPv6 addresses transition and which kinds of benefits it brings to the business. Specifically, they need to perform thorough analysis to decide which certain line of business or programs can be benefited from IPv6 addresses transition. In addition, Aleksi Suhonen, from Axu TM Oy, has said that there were other relevant subjects that also need to be taken into serious consideration such as enhancement of new services as well as the maintenance of existing services, development of network efficiency and cost savings (the elimination of NAT or other work-around methods), the high performance of large enterprise network, simple configuration of online operations, and the supply of tactical advantages.

Phi Long, from Nhatnghe Network Traning Center, has said that costs estimation is the most important part and it can decide the progress of the implementation based on his own experiences from many concerned network projects. Therefore, once enterprises would like to initiate the IPv6 addresses transition, they also need to be prepared for the budget that can be used for planning, design (infrastructure upgrades if needed), implementation testing, deployment, personnel training as well as operational costs.

In IPv6 addresses transition, risk includes business, legal, privacy, security, reliability, interoperability and technical risks. Only when we can identify risks and its impact, will we be able to apply action plans to prevent or reduce the influence on the whole project. These plans should put emphasis on major program activities, specific solutions, and impacts.

**Phase 3**: The settlement of a supervised group (SG) for administration of IPv6 addresses transition project. Nguyen Dac Thuan, from FPT Telecom, indicated that the supervised group would temporarily act as a centralized management office (CMO) to make plans, administer, and control the progress of IPv6 addresses transition throughout the entire enterprise. Furthermore, the SG will arrange sufficient resources such as staffing, training, and budget to support the IPv6 project successfully. Specifically, the SG will be responsible for recruiting suitable members to the group for different roles and responsibilities; gaining authority rights within the enterprise to support financial matters for the transition project and set policies to become the priority in case of shortage of resources; organizing an administration structure to guarantee the success implementation of IPv6 addresses transition. The SG will be the leader to set the milestones and targets for the working team and control the progress through successful results.

### *B. Technical Side*

***Phase 4*****:** The assessment of all assets of current network infrastructure

As shown by by Head of IT center, from the University of Helsinki, we suggest that before starting to implement the IPv6 transition project, the enterprises need to carry out a complete analysis of current networks to get an overview of components that may need to be changed or upgraded to be suitable for transition to IPv6 such as address allocation, networks services (IP, wireless, VoIP, DNS, DHCP, NTP…), network management, applications, operational systems and support.

***Phase 5*****:** The establishment of architecture for IPv6 project

When implementing the transition from IPv4 addresses to IPv6 addresses, there must be an overall IPv6 architecture for various impacted areas. It should be standard based and support IPv4 to perform a smooth transition. Moreover, this architecture should also expect new networks and services as well as foreseeable traffic growth after the implementation. There are some concerned major areas such as IPv6 addressing plan, IPv6 routing, IPv6 interconnection, IPv6 foreseeable traffic, IPv6 enabled systems, IPv6 deployment plan, transition mechanism (dual stack, tunneling, and translation), network services, security, management, scalability & reliability, and service level agreements [32].

***Phase 6*****:** The outline of a specific structure on the influence of IPv6 project

The IPv6 project, once established, will place influence on every platform and service in the network. As a result, IPv6 capability and its influence will be decided according to enterprises' standard for each platform and service, which consists of commercial and industry standards. This includes the required resources (devices, personnel, budget, etc.) and the communication between system integrator and vendor, said by Nguyen Dac Thuan, from FPT Telecom.

***Phase 7*****:** The development of an IPv6 project plan

In this phase, the SG is required to gather all information and resources to design a final plan for IPv6 addresses transition in the enterprise network. Because of its importance, this plan is required to contain a schedule of small projects to be implemented along with dependencies and priority. Furthermore, in accordance with Phi Long, from Nhatnghe Network Training Center, there should be a testing environment for members to gain experience with new IPv6 addresses features and also to demonstrate the architecture, plans, and policies... One more thing is that the SG should perform trials on the real enterprise network as well as operational processes to ensure that all devices and services acquired or developed are IPv6 capable.

***Phase 8*****:** The provision of a personnel-training program

This IPv6 addresses transition project involves either business or technical aspects and this also means the attendance of many users from the board of directors to ordinary staff to maintain IPv6 readiness. As a result, training is required to update knowledge and skills for users to familiarize with the new system [36]. However, based on the position of users in the enterprise, there will be many types of training programs to be suitable for all. Based on the information of Nguyen Dac Thuan, from FPT Telecom, we divide the training into four categories:

*General training program* aims to give normal users primary information about IPv6 addresses and its related issues.

*Engineer training program* is to give detailed information about IPv6 addresses technologies and this is suitable for staff members who are responsible for analyzing, planning, designing, testing and deploying IPv6 addresses.

*Operational training program* presents specific IPv6 education to employees who take care of the support for an IPv6 network.

*Special training program* includes advanced information in certain technology are, which is suitable for technical specialists or experts in a certain technology area such as security, mobile, etc.

### C. Stages of Readiness

In this part, based on the information from literature review and interviews, we have combined that information to create a checking tool for enterprises to assess IPv6 readiness level in the network. Based on the result from this tool, the board of directors can have an overview of the current network and make decisions or plans according to the result. The stages of IPv6 readiness can be arranged into six ranks, which represent the work to be achieved before implementing IPv6:

***Rank 1*****:** The enterprise has no intention to implement IPv6.

At this stage, enterprises have no business requirements and decide not to integrate IPv6 into the system as they analyze that the expenditure for IPv4 addresses shortage is lower than the effort and budget spent for transition to IPv6 addresses while IPv4 addresses exhaustion will not place influence on their business.

***Rank 2*****:** The enterprise has taken IPv6 into consideration but is still unprepared to initiate it.

At this stage, enterprises may hire IT experts to advice on the IPv6 project or methods to prevent IPv4 addresses exhaustion. Moreover, there may be discussions within the executive group (CIO, CEO, CTO…) to collect information in relation with IPv6 project such as business and technical requirements as well as cost and risk for transiting to IPv6.

***Rank 3*****:** The enterprise has an IPv6 program in place and is determining important issues.

At this stage, enterprises may establish a business case and a budget for the IPv6 migration. A supervised group is also formed to control and manage the progress of IPv6 implementation. The members and roles of the IPv6 Transition Group should be identified. Furthermore, a thorough analysis of current network infrastructure should be done to check the IPv6 capabilities.

***Rank 4:*** The enterprise possesses an IPv6 project associated by a final plan.

At this stage, enterprises may already have a sponsored IPv6 project that includes a detailed report of current infrastructure and a tested architecture design of IPv6 implementation.

***Rank 5*****:** The enterprise is in possession of an IPv6 project without any unresolved crucial issues.

At this stage, enterprises, supported by all detailed documents such as an IPv6 deployment plan, training plan, architecture design, may actively put into practice those plans and design to perform the first testing on the real networks.

***Rank 6:*** The enterprise has successfully accomplished the IPv6 addresses transition project.

At this stage, enterprises have deployed IPv6 addresses into the system and finished the testing part. Furthermore, the training programs are also provided for every user. The system is ready to communicate with other IPv6 networks from customers, partners, and suppliers.

Table II below describes the phases that are suitable for each rank.

TABLE II. RANK DESCRIPTION

| Phase | Description | Rank | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | The determination of business grounds and demands to implement IPv6 addresses | | X | X | X | X | X |
| 2 | The analysis of profits, expenses, and risks | | X | X | X | X | X |
| 3 | The settlement of a supervised group (SG) for administration of IPv6 addresses transition project | | | X | X | X | X |
| 4 | The assessment of all assets of current network infrastructure | | | | X | X | X |
| 5 | The establishment of an architecture for IPv6 project | | | | X | X | X |
| 6 | The outline of a specific structure on the influence of IPv6 project | | | | | X | X |
| 7 | The development of an IPv6 project plan | | | | | | X |
| 8 | The provision of a personnel training program | | | | | | X |

In general, it is necessary for enterprises to thoroughly analyze and implement an IPv6 addresses transition with clear instructions to serve expectations. However, because of the specific expectations may change from time to time, and they can be different by various enterprises, a complete approach with careful planning and preparation as listed in this part, accompanied by the details for each phase will allow the IPv6 addresses implementation project to be achieved successfully, which will open a new path for each enterprise to be ready for the next generation of communication networks.

## VI. CONCLUSION AND FUTURE WORK

### A. *Research result*

There are three transition methods that were most applied i.e. dual stack, translation and tunneling. Each of them has its own advantages and disadvantages.

The second objective was to analyze real life experiences of enterprises that had deployed IPv6 addresses. We learned that the reasons for starting IPv6 could be:

- Preparing for IPv4 addresses shortage coming in near future
- Testing the transition process
- Better features
- Getting support from top executives on the project

On the other hand, some enterprises were not interested in IPv6 addresses transition for the following reasons:

- Business is still going on well
- Training costs
- No instant advantages
- No solution from service providers
- No backward compatibilities

For those above reasons, dual stack seems to be the best method

### B. *Recommendations*

*Understand the situation.* Most companies are running well with IPv4 addresses. They won’t have troubles until several years. What will come then? Developing countries with increasing numbers of new computers and devices connecting to the Internet will need their IPs, which will be IPv6 addresses. Being slow to adopt new technology will lead to losing access to these potential customers. Besides, IPv6 addresses have new features that promise to bring better management and administration as well as improve security. Moreover, service providers who can offer enterprises services in transition obviously can make profit out of it.

*Be prepared.* Proper budget must be considered in advance including planning, design, testing, deployment, personnel training and operational costs. IPv6 support products should be integrated into product lifecycle replacement. The reason is that the network will still be able to communicate with IPv6 addresses from the outside world and it makes the transition process much more fluent in case the organization needs to deploy IPv6 addresses later on. Software or a system tailored for specific organization should be considered an IPv6 matter, as it is very difficult to change in the future.

*Pay attention to human factor.* The human factor includes staffs of project teams and the operational administrator. Project team members must be people who really understand internal network structure because they will decide which method of transition to apply. Choosing the right method will avoid many troubles for administration. The operational administrator must be the one who has knowledge of IPv6.

### C. *Methodology*

The paper followed seven guidelines of design science method. It was an inductive study looking for a solution to a problem. The interviews in this study were conducted with people who are involved in IPv6 addresses deployment projects in large network enterprises in Vietnam and Finland. Additionally, document review was essential for this study since this paper concerned a lot of technical issues and evaluated situations based on existing techniques, which were documented in various published sources. It was important to study documents on technical experiences of previous projects as well as new technology coming.

Content analysis was the right choice for analyzing those documents and interviews’ transcripts.

### D. *Limitation and Further Study*

The authors of this study are Vietnamese students who are studying in Finland. Finland is a developed country in technology. For that reason the authors intended to focus on Finnish enterprises. However, very few companies had answered back. Then, Vietnam was chosen as the author had more relations to companies in Vietnam and hoped that there would be some more companies participate. About 60 organizations were contacted and there were only five enterprises answered. Four of that were large network enterprises. Half of enterprises that answered back had successfully carried out IPv6 project while the other half had

 ISBN: 978-1-61208-244-8

failed. That number might not be representative. The author had reference other sources to synthesize a model of enterprise network. Because there was no specific answer of people who administrate the enterprise network, this study could not give more details. It is the biggest the limitation of this study.

This study was limited to large enterprises that had a network size of over 1000 computers. Consequently, the research results may not be true for smaller network.

Finally, there are various areas for further study based on this research. Firstly, a study with a larger sample or more cases could be done for better results. Another topic could be transition method for small and medium network enterprises. Or it is possible to find the critical factors for the failure of IPv6 deployment in general or large network size enterprises in particular (or small and medium sized ones). Additionally, further study on IPv6 for mobile devices can be considered.

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