IPv6 Readiness towards Future Internet of Things (IoT)

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Abstract—**The Internet of Things (IoT) plays a vital role in the evolution of future Internet as billions of objects interconnected over public or private Internet Protocol (IP) networks. These interconnected objects can sense, communicate and share information, and acts as inputs to intelligent planning, management and decision making. IoT services and application connect to network backbone of Internet Protocol version 4 (IPv4) for the internet connectivity. The rapid growth in connected devices and users increase the challenges in networking performance and management. Hence migration to new version addressing namely Internet Protocol version 6 (IPv6) become inevitable for the service providers throughout the world and has become a global agenda to prioritize the IPv6 migration. Thus, to support this agenda, this paper aims to examine the contribution of IPv6 infrastructure preparedness towards the readiness for IPv6 migration with emphasis on the aspect of physical infrastructure comprises of deployment, equipment and cost. Quantitative study has been carried out by using questionnaire as data collection towards 126 respondents which were network administrators and data has been analyses using regression analysis. Besides, Statistical Package for the Social Sciences (SPSS) version 19 has been used as the tool for data analysis. Findings clearly show that the roles of equipment and deployment, specifically planning, are very important factors that contribute towards the readiness for migration in an organization. The research undoubtedly shows the contribution and importance of infrastructure aspect in the direction of the IPv6 migration. Therefore, top management and policy makers should promote the upgrading of existing IT infrastructure and equipment before deployment phase in their IPv6 roadmap towards achieving an open, innovative, scalable, and reliable of future IoT.**

Keywords—Internet of Things (IoT); IPv6 Migration; readiness

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I. INTRODUCTION

INTERNET of Things (IoT) is a type of huge network which connects anything with the Internet based on protocols through sensors, actuators or other objects. [1] defines the IoT as an internet of three things which are people to people, people to things, and things to things. It is a concept that expand the traditional Internet to a ubiquitous network connecting a variety of things or objects through wireless and wired connections and unique addressing schemes. The interaction among people and the objects is enhanced through creation of new applications and services. IoT offers several advantages and new capabilities for a wide range of application areas. For example, home automation, industrial automation, transport, logistics, intelligent energy management and smart grids, healthcare, retail and marketing [2]. IoT ecosystems are composed of smart objects, services and networks. Several technologies are involved such as Radio Frequency Identification (RFID) [3][4] and Near Field Communication (NFC) [3][4] for the digital identification of resources, 6LoWPAN [3][4] for wireless sensor networks, and Cloud Computing for providing cloud services. The objective of the IoT is the integration and unification of all communication systems in order to provide ubiquitous communication and computing with the purpose of defining new generation of services.

Currently, the number of things or objects that are connected to the Internet is growing exponentially and expanding towards an ecosystem that links billions of smart things. It is expected in 2020, the number of relevant connected nodes will increase substantially from 25 to 50 billion devices, based on estimates from standard bodies, network equipment vendors and network operators [5]. Therefore, the advantage of all this is that the physical information system can be used, and some of them work without human intervention [6].

The IoT provides many new opportunities to the industry and end user in many application fields. However, a number of major issues are highlighted in [7], and one of the main concerns is the technical issues involving networking capabilities and performance. Most debates about IoT are based on the illusion that IP address space of current internet IPv4 is unlimited resources. This is obviously untrue as according to [8] Asia is the first continent where shortage of IPv4 was faced. APNIC announced the depletion of IPv4 address in early 2011. Hence the next generation of Internet Protocol (IP), also known as IPv6, is expected to bring solutions. Besides extents the addressing space in order to support all the increasing Internet-enabled devices for IoT, IPv6 is deliberated the most suitable technology, since it offers scalability by providing the address space of 2^{128} IP addresses compared to IPv4 with only 2^{32} address space [9]. Thus, no connectivity issue of huge IoT network as sufficient IP addresses for the connected things in the future to support and realize the vision of achieving 50 billion of connected devices in 2020. At this point, the transition towards IPv6 is mandatory to enable the full comprehension of the vision of IoT, as IoT relies on the connectivity and reliability for its communications on future internet architecture and the IPv6 protocol to cover the addressing and scalability requirements [10].

The IPv6 was developed by the Internet Engineering Task Force (IETF) in the 1990s to provide space for a larger number of addresses [11] and also facilitates the development of other features that do not exist in the IPv4 such as automatic configuration for address and support IP security [12]. While IoT is much more readily related with end user electronics, however, the transition to IPv6 has been slow at currently, only about 5 to 10% of users are able to support IPv6 [13] and it has been reported that the diffusion of the IPv6 traffic worldwide was approximately only 3.5% as of April 2014 [14]. Meanwhile, in Malaysia, it was reported that in 2012, only 1.4% of the domain names with IPv6 were enabled [15]. In fact, an IPv6 test reported that until September 2017, almost 100% of hosts were still supporting the IPv4, with a slow growth for the IPv6. Large-scale of implementations seems still a long way off, because the fully deployment is quiet at an early stage and lacking in technical standards [13] resulting IPv6 has not been fully deployed. However, recent growth tends to afford a wide range of IPv6 networks around the world able to interconnect the future IoT [16].

The challenge on IPv6 deployment that support the IoT environment seems to be contributed by the issue of organisation readiness. Previous research has shown that low levels of readiness and preparation influence the progress of the IPv6 deployment, especially when the network environment is still not available for the IPv6 [17]. It shows that the percentage of network equipment supporting the IPv6 is still low at less than 50% [17]. According to [18], organisations that are not quite ready for the IPv6 and have a low level of readiness can contribute significantly to problems in the ICT industry. Readiness is a condition of preparedness of individuals, systems or organisations to meet a condition and to carry out a scheduled arrangement of actions and is one of the important factors that affect the successful implementation of change for entire systems in an organization.

The rest of this paper is organized as follows: Section II provides a summary of IPv6 infrastructure preparedness. Section II and IV discuss the methodology and result, respectively. Finally, Section V presents a discussion and concludes this study.

II. IPV6 INFRASTRUCTURE PREPAREDNESS

The implementation of the IPv6 in an organisation involves major changes in the physical infrastructure and the redesigning of organisational networks including costing, diverse policies and standard operating procedures [19]. Any physical components that support the changes are significant to be analysed in assessing the readiness towards any change especially the technology adoption. According to [20], physical capital resource which comprises equipment, geographic location, access to raw materials, and physical technology is a subset of the technological IT resource.

Therefore, [21] claimed that the effect of technical aspect in particular, increases the pattern of change and they mention that technology is still considered as an important variable in relation to organisational structure. In addition, [22] acknowledged that the effectiveness of any change process relies on the interrelation between physical aspects and the organisation that manages the change. In the case of IPv6, [23] expected two constraints that slow down the migration process which are smaller number of IPv6 users, and the physical aspects which refer to the missing infrastructure required for a realistic IPv6 deployment such as hardware support, operating systems, middleware, applications and management tools in order to complete the deployment. Hence, physical assets such as infrastructure and resources also support the human factor to make any changes in the organisation despite few researchers' claims that in many industrial sectors, physical asset is less important than human knowledge in order to prepare for the changes [24]. In addition, physical factors in terms of the resources of an organisation has been concluded as physical assets, technology, and organisational capabilities and operational procedures [25]. It consists of equipment (infrastructure), cost and deployment [5], [26], [27] and [28].

In view of the above scenario, it is believed that there is a need to conduct a study on IPv6 readiness to help organisations to take the appropriate action to migrate towards the IPv6. Therefore, in this paper we examine the contribution of IPv6 infrastructure preparedness towards the readiness for IPv6 migration for effectively implementing various IoT application in the future with emphasis on the aspect of physical infrastructure comprises of deployment, equipment and cost.

III. METHODOLOGY

This study applied the quantitative method using a questionnaire for the data collection. The quantitative method was used in this study as it is able to collect information that can describe the characteristics of a subject [29]. The information was collected using an instrument on a sample of the population.

The questionnaire consisted of two (2) main sections. The first section included demographic data related to gender, race, scheme code, workplace region and work experience. The other section was used to obtain information related to (a) Equipment which is networking requirement needed in the migration of IPv6, (b) Deployment where organization needs to plan the tasks before initiating the migration process, and (c) Cost involves in the migration phases.

More specifically, the second section of the questionnaire used a 5-point Likert-type scale (Strongly disagree, Disagree, Neutral, Agree and Strongly Agree) to measure the IPv6 infrastructure preparedness.

The questions for equipment variable were related to technical specification for hardware need to be upgraded and replaced, core network equipment's must be IPv6 ready, software platform for service software must be enable to run in IPv6 environment, operating system that run in the public network services must be IPv6 enable, platform for router must support IPv6 routing protocol, and higher support IPv6-enable vendor for equipment and operating system vendors.

Whereas, the questions for deployment variable were related to business and technical planning in the deployment phase. For example, preparing the IPv6 business plan including analyzing potential risk of IPv6, procurement policy, exception strategy, and involvement of in-house an outsource teams, and creating an IPv6 testing environment. In the case of cost variable, most questions related to costing involved in the migration process.

Participants of the study which totaled 126 people, comprised of network administrators in all the polytechnics and community colleges throughout Malaysia. The whole population was used as a sample because the sample met all the requirements and conditions for the study. Polytechnics were selected because they are public educational institutions that should be leading the adoption of this latest technology in order to provide good infrastructure for end users [29]. Meanwhile, the geographical location of these institutions are spread all over Malaysia, covering different types of areas (urban and non-urban), and using the same MyREN [30] network backbone, hence the sample is sufficient to represent the education sectors. In fact, according to [31], higher education institutions have the largest number of users of information technology (IT) that provide services in Malaysia. Network administrators were selected as sample because the migration requires high awareness and technical knowledge of network administrators

Regression analysis was applied using the Statistical Package for Social Science (SPSS) Version 19 to examine the contribution of the IPv6 infrastructure preparedness towards the readiness for migration within the organization.

IV. RESULT

Based on the findings, only two of the three independent variables under IPv6 infrastructure preparedness had a significant relationship with the dependent variable which is readiness to migrate (RFM), namely equipment (NE) and deployment (D) as shown in Table 1.

TABLE 1. SUMMARY OF MULTIPLE REGRESSION MODELS FOR THE ENTIRE READINESS

Model	Accepted variable	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	Equipment	.886[a]	.785	.750	.21638
2	Deployment	.972[b]	.944	.922	.12117

Predictors: (Constant), NE

Predictors: (Constant), NE, D

Dependent Variable: RFM

To determine the relative contribution of each independent variable, the standard regression coefficient (β) was used as a reference. According to Table 2, the variable of equipment was the highest contributor towards the readiness among the respondents ($\beta = 0.860$, $t = 8.106$, $p < 0.05$). This meant that for every unit increase in the equipment, the readiness would increase by 0.860 units.
By using the formula:

$$X_1 \text{ contribution} = \text{Standardized coefficient } (\beta),\ X_1 \times \text{Zero-order Correlation, } Y \text{ and } X_1 \quad (1)$$

equipment contributed 76.20 % to the readiness for migration in organizations.

TABLE II. COEFFICIENT MULTIPLE REGRESSION ANALYSIS USING STEPWISE METHOD

	Unstandardized Coefficients (B)	Standardized Coefficients (ß)	t	Sig	Correlation	Collinearity Statistics
					Zero-order	Tolerance
Constant	-1.811		6.411	0.001		
Equipment	3.648	0.860	8.106	0.000	0.886	0.996
Deployment	1.135	0.399	3.759	0.013	0.455	0.996

Dependent Variable: RFM

Note: Standard error = 0.282

The second contributing variable to the readiness was deployment ($\beta = 0.399$, $t = 3.759$, $p < 0.05$). This meant that for every unit increase in the deployment, the readiness would increase by 0.399 units.
Likewise, by using the formula:

$$X_2 \text{ contribution} = \text{Standardized coefficient } (\beta),\ X_2 \times \text{Zero-order Correlation, } Y \text{ and } X_2 \quad (2)$$

deployment only contributed 18.20 % to the readiness for migration in organizations.

In conclusion, it is shown that the level of readiness for IPv6 migration in an organization can be influenced by the factors of equipment and deployment. The higher the preparation of equipment and deployment in the organization, the higher was the impact on the readiness for migration to the IPv6 of the organization.

Moreover, readiness is the condition among personnel and organizations of being ready for change and in this case a change is needed to provide worldwide compliance for IoT applications [32]. IPv6 is critical for all IoT applications which depend on publicly routable IP addresses for sensing, monitoring, and data collection. Thus, proper assessment of IPv6 readiness is crucial to ensure a successful migration and mitigate risk.

V. DISCUSSION

Based on the findings of the analysis, only two of the three independent variables in the IPv6 infrastructure preparedness, namely equipment and deployment, had a significant relationship with the dependent variable in the readiness. It was shown that to increase the level of readiness to migrate, the factors of equipment and deployment need to be considered.

The finding was proven by [33], who emphasized that the IPv6 requirements cannot be met by old equipment that do not support the IPv6, and the upgrade of such devices have to be done before getting ready to migrate. This is in line with the current study which has concluded that equipment in infrastructure networks contribute to the decision of IT staff to recommend the IP migration [34]. Indeed, enhancing the performance or replacing current network equipment with new and better equipment has been the main goal of those who have been engaged in network infrastructure enhancements.

Besides equipment, deployment is also a contributing factor to the readiness for migration in an organization. This factor is significant as it relates to the planning task, based on previous studies and findings. Planning and discussion are the only tools that can help to achieve the organization's readiness and make a better migration possible [35]. Meanwhile, [36] highlighted that any technological change that has a universal impact on services and businesses needs a well-established plan.

However, the findings showed that cost does not contribute significantly to the readiness for change. This could be because the respondents believed that the most recent equipment in their organization is IPv6 ready, thereby reducing the cost of obtaining new equipment.

In conclusion, these findings clearly show that the roles of equipment and deployment, specifically planning, are very important factors that contribute towards the readiness for migration in an organization. Issues on IPv6 readiness may be a major concern in implementing the success of IoT in the future as discussed in this paper, therefore top management and policy makers should promote the upgrading of IT infrastructure in their IPv6 roadmap. Successful migration leads to efficient and smooth functioning of the IoT technology as IoT services and application connect to IPv6 backbone for the internet connectivity.

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