Research Article

Experts Views on their Higher Education Institutions Readiness and Deployment of IPv6

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Abstract

This study is conducted to investigate experts' views to determine the Omani higher education institutions readiness and deployment of IPv6. In particular, the study aims to assess the institutional awareness, current environment, policy, planning, and resources. Descriptive method was followed and two study instruments were designed and implemented, namely questionnaire and semi structured interviews. Both instruments were validated and implemented on a sample of (12) experts for the questionnaire and (5) for the interviews. The results revealed that IPv6 was not sufficiently attended to by the Omani HEIs and it is partially planned for, implemented, and/or deployed. Efforts should be made to help establishing strategies, research and teaching content. Based on the findings of the research, conclusions and recommendations are suggested.

Introduction

Internet Protocol (IP) is an Internet protocol that allows devices to communicate with each other. IPv6 is the new version of IP that uses a 128-bit addressing structure to support the increasing number of Internet users. It "provides a platform that includes support for real-time flows, provider selection, and host mobility, from start to finish, final security, automatic configuration, and automatic reconfiguration" (Ismail & Abidin, 2009, p. 444). This allows all the connected devices to obtain unique addresses and communicate with each directly through basic protocol translator (Mudziwepasi & Scott, 2014). The transition to IPv6 remains inevitable, necessary, and important for all beneficiaries. However, IPv6 was made primarily to be compatible with the older version (IPv4) so that both versions can work together until the transition to IPv6 is complete and, thus, the users can benefit from the advantages of both protocols at the same time (Main, Zakaria and Yusof, 2015).

Literature Review

To assess the institutional readiness to migrate to IPv6, factors can be classified into two sets: physical factors including the deployment, equipment and cost; and human factors those comprise information, training, and motivation (Main, Zakaria & Yusof, 2015).

Some prominent higher education institutions (HEIs) have started migration process to IPv6 through research, benchmarking, and planning. For the deployment process, universities provided experimental research labs for IPv6 along with collaboration with cross-institutions schemes. In addition, they directed their computer science departments to train the students with pertinent skills for future jobs (Alsulaiman, 2015). The environment setup at a university should allow the entire body of staff and students to access IPv6 based services and to collaborate with external partners. In addition, it should enable the technicians to examine the application of IPv6 standards at the same time (Perkins *et al*, 2012).

Universities perceive that they will be able to raise their cost effectiveness by migrating to IPv6. For example, the Canadian McGill University planned the migration and easily deployed it since IPv6 support is built into the university's existing technology resources. Consequently, they were able to rapidly empower the enhanced protocol support and enable maximum compatibility (F5 Networks, 2019). The British University of New Hampshire (UNH) implemented its IPv6 deployment by starting in a minor controlled environment. Building on this small-scale test network, they expand the deployment to all other parts of the university. Technical issues may involve experimenting of IPv6 and support provision to campus networks.

Table 1: Comparative technical issues of some universities (*)

Institution	Technical status			
	Start IPv6	Procedures	Research/Training/Strategies	Collaboration
University of Southampton	1996	Established IPv6 networks team	IPv6 research implications are reflected on more projects.	1. Partnered on the European Union IPv6 Task Force 2. Chair the IPv6 Working Group.
University of Pennsylvania	2005	Most of the campus has IPv6 enabled in the network	Has useful deployment strategy documentation and staff training material on IPv6	
National University of Singapore	2006	Integrate IPv6 requirements in various infrastructural projects	Migration strategy to IPv6 started with the network infrastructure and online services	Peer with IPv6 research and education partners over the years in Singapore, Los Angeles and Hong Kong.

*Source: (Alsulaiman, 2015); (Infoblox & UNH, n.d).

UNH upgraded its student house wireless network and implemented its IPv6 addressing strategy. Beside this technical effort, the university prepared the students and staff to efficiently deploy, administer, and implement the future IP (Infoblox and UNH, n.d). Table 1 shows comparative technical issues of three universities.

Training of a university's human resources in the field of IPv6 should start by collecting information on the institution's employees especially in IT domains. The institution should prepare appropriate training programs to improve the level of awareness and skills of its staff and students and to bridge the gap between their IPv4 knowledge and the next level of IPv6 knowledge. The training program should achieve the staff and students' satisfaction in completing a crucial training so they boost their potentials and skills in IPv6 and become confident in implementing job projects (F5 Networks, 2019).

HEIs are also required to design and develop courses to prepare their students with the proper IPv6 skills for the job market. Status in computing curriculums shows that IPv4 is being taught in computer network courses rather than IPv6. Al-Sulaiman (2015) was surprised that although IPv6 was implemented in academia and research laboratories, current curricula are still teaching IPv4 in the classroom. IPv6 can be included in curriculums such as education technology, network programming, distributed systems, Internet applications, network security, and graduation projects (Alsulaiman, 2015).

Yang (n.d.) states that some experts consider IPv6 as a topic for public policy discussion as it requires equitable access to IPv6 address, governmental involvement, and migration cost including training, new equipment, and configuration. In addition to the incentive from public sector to help IPv6 uptake. According to his research conclusion, this suggests important obstacles to the implementation of IPv6 connectivity and the difficulties in creating demand for the standard using traditional policy means. "It seems reasonable to look for common technical and economic factors that can influence decisions about the standard. The obvious candidates that limit IPv6 diffusion are the fixed costs of upgrading equipment and administrative capacity to operate under the new protocol." (Patrik and Rajabiun, 2009, p. 5).

Many end users are not aware of the likely global problem of Internet address depletion. Surveys revealed that there were low levels of interest in IPv6 among public and private sector IT managers. Moreover, the public IT professionals demonstrated a lower level of IPv6 awareness than their counterparts at the private sector did. They tremendously questioned that IPv6 could help them reach their organizational IT objectives and failed to realize the importance to upgrade (Denardis, 2006).

In the Middle East, it seems that some Saudi universities have some IPv6 activities by ensuring connectivity, updating the security policy to cover IPv6, providing testing environment, and enabling the IPv6 production environment (Alsulaiman, 2015). In Oman, previous research shows the need to strengthen the HEIs infrastructure to meet the ever-increasing students' needs to employ emerging online technologies such as social media in their learning (Al Musawi & Ammar, 2015). The factors isolated from the literature to improve the readiness of the Omani HEIs for IPv6 migration can be summarized in providing the stakeholders with sufficient time for planning, financial resources, assuring the applications compatibility, and securing the network environment. Al Musawi, *et al.* (2018) recommended that there is a need to investigate the extent to which the status provides for IPv6 readiness in terms of: awareness, current environment, planning, deployment and infrastructure, policy frameworks, training, research, human resources, and courses provision as perceived by Omani HEIs faculty, administrators, and ICT personnel.

This paper describes the findings of the last stage of a two-year funded research project provided by the Sultan Qaboos University (SQU) with the aim of providing a better understanding about the readiness of Omani HEIs for IPv6 transition.

Research Significance

This study will help the decision makers to choose the most appropriate approach to follow in terms of strategizing and deploying IPv6 in their universities. It will also assist the process of implementing the IPv6 adoption in these institutions. As the research in this area in the Omani context is scarce, this research project can represent a preliminary introduction for

further research that can be applied through a range of HEIs.

Research Objectives and Questions

This study was conducted to investigate experts' views to determine the Omani higher education institutions readiness and deployment of IPv6. In particular, the study aims to assess the institutional awareness, current environment, policy, planning and HRD. The study attempts to answer the following questions:

1. To what extent does the awareness towards IPv6 exist in the Omani HEIs?
2. What is the institutional current status to support the deployment of IPv6?
3. What levels of planning, policy and human resources development exist for adopting IPv6?
4. What IPv6 related research and course provisions do these institutions hold?
5. What are the main concerns and issues facing the Omani HEIs in terms of IPv6 readiness and deployment?

Method

Descriptive method was found the most appropriate to answer the questions of this study.

- *Study instruments*

The researchers designed the following two study instruments in light of the literature reviewed and the results of the preliminary questionnaire used and published earlier (Al Musawi, *et al.*, 2018):

1. A questionnaire was designed and validated through a panel of experts who adapted it to the Omani context; the instrument was modified accordingly. The questionnaire was then pilot tested and reliability coefficients of (0.84) was attained which means that the reliability was ensured. The instrument consisted of several sections in addition to participants' demographic information to gather their views on the awareness, current environment, policies, research and course provisions, and concerns as indicators of the Omani HEIs readiness and deployment of IPv6 (see appendix 1). The data were collated using electronic means; and analyzed using percentages to provide answers for research questions.
2. A semi-structured interview inventory was designed to allow for more sub-questions during the actual interview. A panel of expert validated the instrument and their suggestions were included. The instrument consisted of several sections in addition to participants' demographic information to further investigate their views on the same above issues. The data were transcribed,

coded and analyzed using patterns and thematic analysis to provide answers for the research questions.

- *Community and sample*

Although all the Omani HEIs were included in the study community, the research participants were sampled purposively. Those who were identified by their institutions as '*experts*' on IPv6 were few in number and, therefore, only (12) individuals were the subjects (respondents) of this study. They were first approached via telephone to invite their participation, emailed the questionnaire to obtain their responses and then (5) of them were interviewed for in-depth study of their initial responses. Table 2 shows the distribution of the research sample.

Table 2 Study sample (n=12)

Variable	Type	N$\underline{o}$
Job	IT Personnel	6
	Faculty	4
	Administrator	2
Institution	Public	10
	Private	2
Experience	1-5	1
	6-10	4
	>10	7

Findings and discussions

- *Awareness*

To answer the first study question: "To what extent does the awareness towards IPv6 exist in the Omani HEIs?" The participants were asked to describe the status of IPv6 awareness amongst the their staff given the following options: (1) everyone has been trained; (2) recruiting new people with IPv6 knowledge; (3) creating a structured training program; (4) self-education about IPv6; (5) no current plan. Fig 1 shows the responses of the study sample.
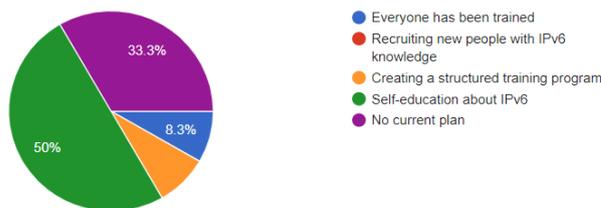

Fig 1. Awareness about IPv6

Fig. 1 shows that 50% of the experts viewed that their universities' staff are aware of IPv6 through their own self-education followed by 33.3% of the respondents thought that there is no current plan in implementation to raise the awareness. This finding indicates that the awareness towards IPv6 is generally low with only self-efforts and initiatives to educate the staff members. The responses patterns of the

interviewees support this finding in that the respondents viewed that "…the university staff are not informed at all about the IPv4 depletion" said interviewee 1. Interviewees 2 and 3 contended that they were both adequately, but not specifically, informed on this issue. Interviewee 4 mentioned "…I think that our software developers are knowledgeable about IPv6". This again shows that the awareness towards IPv6 generally needs more attention by the HEIs.

- *Current status/environment*

To answer the second study question: "What is the institutional current status to support the deployment of IPv6?" the participants were asked to describe the IPv6 situation at their institution given the following options: (1) have been deployed; (2) deployment in progress; (3) deployment is being planned; (4) no current plan. Fig 2 shows the responses of the study sample.
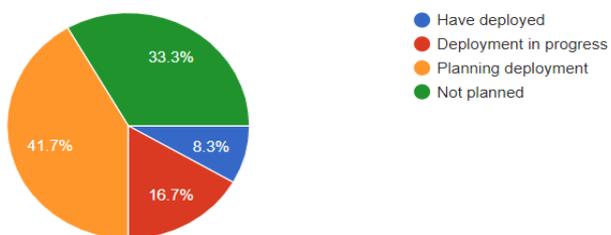

Fig 2. IPv6 situation

Fig. 2 shows that 41.7% of the experts viewed that IPv6 has not been deployed followed by 33.3% of the respondents thought that there is no current plan to deploy it in their institution. This finding shows that IPv6 is not largely considered for implementation by the HEIs. Despite this, most interviewees viewed that the current network supports IPv6. However, interviewee 5 thought "…I would say that the existing network partially supports IPv6 and can be upgraded to support IPv6".

Findings above reveals that awareness in th Omani HEIs about IPv6 is generally low with exception of the self-learning efforts among their staff members to educate themselves. The HEIs administration do not put enough efforts to inform their staff the new protocol. This is attributed to the fact that IPv6 is new to the country's context in general and HEIs in specific. These results support findings of Denardis (2006) and F5 Networks (2019) studies which revealed that IT professionals demonstrated at public and private sector's showed low level of IPv6 awareness and called on the universities to prepare appropriate training programs to improve the level of awareness and skills of their staff. The findings also show that the Omani HEIs should give more attention to raising awareness towards IPv6 on campuses.

- *Planning, policy and resources*

To answer the third study question: "What levels of planning, policy and human resources development exist for adopting IPv6?" the participants were asked to describe if any plan for deploying IPv6 to Internal Network exist at their institution. They were given the following options: (1) already planned; (2) will be planned within 2 years; (3) will be planned within 3 years; (4) no plans at all. Fig 3 shows the responses of the study sample.
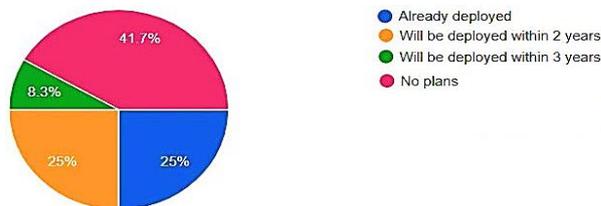

Fig 3. IPv6 plans

Fig. 3 shows that 41.7% of the experts viewed that their institutions have no plans to deploy IPv6 followed by 25% of the respondents thought that than plans are envisaged within 3 years. This finding supports the previous one and show that HEIs are not in the process of planning for IPv6 deployment.

To further investigate this finding, the respondents were asked to state the reasons for not planning IPv6 transition. They were given the choice to select one or more options. The options included: (1) the financial costs of IPv6 transition are too high; (2) our transit operator does not ensure IPv6 connectivity; (3) our infrastructure does not support IPv6; (4) there is no proper support from our suppliers/vendors; (5) IPv6 security mechanisms are not as proven and reliable as in IPv4; (6) we do not have enough knowledge and experience. Fig 3 shows the responses of the study sample.
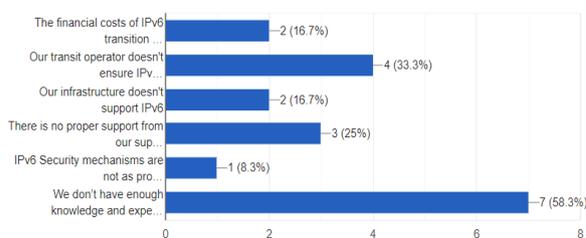

Fig 4. IPv6 plans

Fig. 4 shows that 58.3% of the study sample viewed that their institutions do not have enough knowledge and experience to deploy IPv6 followed by 33.3% of the respondents thought that their transit operator does not ensure IPv6 connectivity. This finding emphasizes the internal and external factors impeding IPv6 planning process characterized by the lack of qualified human and technological resources. However, interviews 1, 2 and 4 perceived "…there are sufficient human resources to implement IPv6 but little or no

training is provided to develop their knowledge and skills in this area". Most of the interviewees echoed this finding by identifying other lack of resources "...although IPv6 is one important factor in the institution, (it)... neither has a defined organizational policy nor IT procurement resources to deploy it".

- *Research and education*

To answer the fourth study question: "What IPv6 related research and course provisions do these institutions hold?" the participants were asked to determine whether or not their institution conduct any research on IPv6. Fig 5 shows the responses of the study sample.
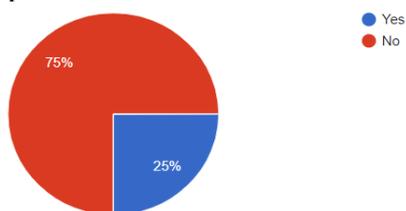

Fig 5. Research

Fig. 5 shows that 75% of the study sample viewed that their institutions do not conduct any IPv6 research. The interviewees were asked to determine the number and type of publications in this area, interviewee 3 stated that the whole institution "...published less than 5 articles during the last 2 years in areas related to IPv6..." the interviewee added "Unfortunately, this is really insufficient, no projects at all...we need to be active in the future...". The participants were also asked to determine whether or not their institution provide any IPv6 courses or related contents. Fig 6 shows the responses of the study sample.
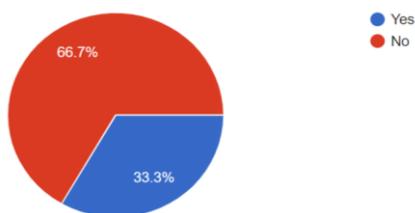

Fig 6. Course provision

Fig. 6 shows that 66.7% of the study sample thought that their institutuions do not provide any course in the area of IPV6. This and above findings show that HEIs need to keep itself up-to-date and give more attention to research and teaching delivery as a vehicle to train and prepare the next generation in this important field.

Findings above show that IPv6 implementation does not take the priority at the Omani HEIs despite it was found that the current network supports IPv6. Some of this late action can be attributed to the lack of planning for IPv6 deployment due to internal and

external factors, namely deficiency in qualified human technological resources. The literature shows that some universities, such as McGill University and University of Southampton, have started the deployment process of IPv6 (F5 Networks, 2019). While these universities has also provided experimental research labs for IPv6 (Alsulaiman, 2015), the findings of this study shows that the Omani HEIs do not conduct any IPv6 research. The study sample thought that this is unacceptable and there is a need for more activity. This means that these institutions need to update their research rapport and give more attention to research and teaching to prepare their students for the job market. Course and curriculums based on the IPv6 content need to be redesigned and taught by the academic computer department (Alsulaiman, 2015; Infoblox & UNH, n.d).

- *Concerns and issues*

To answer the last study question: What are the main concerns and issues facing the Omani HEIs in terms of IPv6 readiness and deployment?" The participants were asked to rate their opinions towards IPv6 benefits for their institutions using a scale of five categories: strongly agree, agree, neutral, disagree and strongly disagree with values of 1, 2, 3, 4, 5 respectively. Fig 7 shows the responses of the study sample.
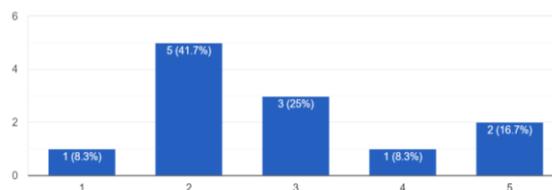

Fig 7. Benefits of IPv6

Fig. 7 shows that 41.7% of the study sample agreed that IPV6 has benefits to their institution but, interestingly enough, 50% were either neutral or diagree to those benefits. This finding shows hesitation or reluctance among the experts themselves to adopt Ipv6. To further invesigate this point, the participants were asked to rate their opinions towards IPv6 value for their institutions using a scale of five categories: strongly agree, agree, neutral, disagree and strongly disagree with values of 1, 2, 3, 4, 5 respectively. Fig 8 shows the responses of the study sample.
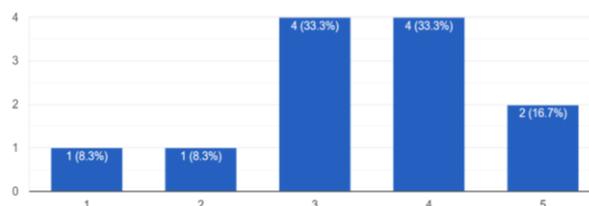

Fig 8. Value of IPv6

Fig. 8 shows that 33.3% of the study sample agreed that IPV6 has benefits to their institution but the same ratio of respondents was neutral in addition to 16.7 diagree to this value. This finding substantiate the previous one and indicate that some HEIs administrators and faculty members are not advcates of the adoption of IPv6. When the interviewees asked about their justifications for this trend, they raised the several reasons. For example, interviewee 1 said "Although it is important, it is not necessary to implement IPv6 on our network in the foreseeable future". Most of the interviewees support this by arguing, "No need for fast IPv6 deployment as no plan has been set yet". Interviewee 2 clarified, "IPv6 is not mature enough in our institution to deploy with confidence that it will perform as expected". Interviewee 4 added, "There is not a strong enough return on investment to deploy IPv6". Interviewee 5 commented, "Technically speaking, IPv6 is required for deployment only on Internet-facing servers". It seems that the participants view that IPv6 deployment as a vehical for financial investment with the least efforts and change.

Findings above show some hesitation among the IT experts to adopt Ipv6 due to some financial constraints and reluctance to change. This finding is corroborated by research findings elswhere (Yang, n.d.; Denardis, 2006; Patrik and Rajabiun, 2009). These accounts found that these experts preferred to stick with traditional technology and not to upgrade to the new protocol despite the fact that some universities perceive they raise cost effectiveness by migrating to IPv6 (F5 Networks, 2019).

Conclusions and recommendations

This study was conducted as the final part of a research project through which Al Musawi *et al.* (2018) recommended to investigate experts' views to determine the Omani higher education institutions readiness and deployment of IPv6 in terms of: awareness, current environment, planning, policy frameworks, research, human resources, and courses provision. In general, the results of this study revealed that IPv6 was not sufficiently attended to by the Omani HEIs and it is partially planned for, implemented, and/or deployed. Efforts should be made to help establishing strategies, research and teaching content. Since this sample of this study is small in number, its results are not generalizable and transferrable except for the contexts similar to this research context. Future research should look into ways to strategize and implement for IPv6.

Based on the findings of this research, the followings were recommended:

1. Migration plans and strategies should developed and disseminated throughout the Omani HEIs.
2. IPv6 should be injected in the curriculum with computer sciences and educational departments to cooperate in delivering the courses.

3. Research groups should be created and work on IPv6 supported with funded research.
4. Training courses and workshops should be conducted to staff and students.

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