Migrating University Campus Networks to IPv6 Challenges and Opportunities

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IPv6 is one of the building blocks for new protocols being developed at the Internet Engineering Task Force (IETF). For example, much of the new work in the domain of Internet-of-Things (IoT) and Machine-to-Machine (M2M) communication requires IPv6. Besides solving the address depletion problem, IPv6 brings several other advantages like delay-efficient routing and packet processing, better security measures, simplified network configuration, and true end-to-end connectivity for peer-to-peer applications. Having said that, migration, especially for large end-user organizations, comes with some challenges in revising operational procedures and understanding the complexities of the new protocol. This article presents the motivation to migrate university campus networks to IPv6, the significance of being IPv6-ready, and the challenges and opportunities depending on the experience gained while migrating a university campus network to IPv6 in India. These might as well apply to other universities in the Asia Pacific region and other countries.

The IPv6 deployment is rising globally, and India has been ranked first in IPv6 adoption in the world with a rate of 61% as per the latest numbers maintained by Google and Akamai in 2021 [1]. One of the largest Internet Service Providers in India has an IPv6 adoption rate above 90% [1]. However, the IPv6 adoption in Indian Universities has lagged, especially on internal networks.

Motivation to migrate Universities to IPv6

Managing university campus networks is challenging due to a large variety of user requirements ranging from accessibility to basic Internet services to providing highly customized features for academic research and development. Due to COVID-19, universities have adopted new teaching-learning methodologies which include virtual and remote-triggered laboratories [2][3]. These methodologies are Internet-based and require multimedia support and scalability. Thus, there has been an enormous increase in Internet usage in the university campus networks and the need for ultra-low latency transport has become apparent. Migrating university campus networks to IPv6 can significantly simplify the network and service architectures such that the requirements of ultra-low latency can be met. One such example is the elimination of Network Address Translation (NAT) boxes which can minimize the packet processing overheads and improve the responsiveness of multimedia and streaming traffic. Another important aspect of the services provided by university campus networks is that some of these are cloud-based services, e.g., Moodle (a popular open-source learning management system) instances may be hosted in the cloud for scalability purposes because the load on servers increases significantly during online examinations or assignment submissions. In the future, it seems inevitable that cloud providers will begin to charge directly for IPv4 addresses due to their scarcity. Universities (and enterprises) can lease IPv6 address blocks from an Internet registry to have better flexibility in managing cloud-based services and to minimize expenses.

Significance of IPv6 readiness

Although migrating to IPv6 might not be on the list of universities' top priorities, being IPv6-ready can be immensely beneficial and lead to technological advancements. It can directly impact the Research & Development budget of the university. For example, one of the review criteria in the Campus Cyberinfrastructure - Infrastructure, Innovation, and Engineering (CC*IIE) Program of the National Science Foundation (NSF) was that the proposals seeking funding through CC*IIE should describe the plan for campus IPv6 deployment [4]. The Government of India is enthusiastically supporting the adoption of IPv6 [5], such initiatives are likely to be introduced as driving factors for IPv6 deployment in universities. Being IPv6-ready provides a competitive advantage in obtaining research partnerships with international universities/enterprises. Funding for R&D and partnerships are key parameters in national and international university ranking frameworks (for example, National Institute Ranking Framework by the Ministry of Education, Government of India). Hence, the consequences of not being IPv6-ready can be more severe than universities might anticipate.

However, simply adopting IPv6 does not make a university IPv6-ready. It is equally important to evaluate the security and effectiveness of the services deployed over IPv6, otherwise, it could lead to security vulnerabilities and poor performance. An international study carried out to evaluate the quality of IPv6 enablement on the top 1000 universities listed by the Center for World University Rankings (CWUR) [6] in 2014 reveals that 87.5% of university websites were not accessible to the end-users connecting over IPv6, 11.5% of university websites were accessible over IPv6 but not effective when compared to accessed via IPv4 and 1% of university websites were highly effective when accessed over IPv6 than IPv4 [7]. Thus, it is recommended that the Indian universities start adopting IPv6 because migration is only the first step, the actual journey to become IPv6-ready might take more time and effort than anticipated.

IPv6 Migration: Challenges and Potential Solutions

The IPv6 migration process has its fair share of challenges as discussed below:

1. Limited training resources

   One of the major factors in the lagging adoption of IPv6 in universities is that the network administrators have limited knowledge of how IPv6 works. Moreover, there is a lack of motivation from the university administration to provide training to network administrators because adopting IPv6 is not a priority. Hence, the process to initiate IPv6 deployment keeps getting pushed to the list of activities to be done at some unknown future date.

   However, this problem is gradually getting resolved nowadays because several organizations like Asia-Pacific Network Information Centre (APNIC) [8], India Internet Engineering Society (IIESoc) [9], and Industry Network Technology Council (INTC) [10] provide basic training on IPv6 via free webinars (theory and practical) that are recorded and made openly available [12]. APNIC provides free access to remote labs to perform hands-on exercises on IPv6-related services, like installing a Kea DHCPv6 server [12]. Apart from utilizing the training material mentioned above, it is highly recommended to set up a local testbed in the university and perform preliminary experiments to gain sufficient knowledge of IPv6 prior to choosing an IPv6 migration strategy (discussed below) or testing it on a live campus network.

2. Choosing an IPv6 migration strategy

   The network administrators often wonder which of the two popular migration strategies would be most suitable for their universities: transition mechanisms like IPv6-to-IPv4 or dual-stack (embrace IPv6 in parallel with IPv4) [13].

   Depending on some of the experiences shared by the universities like the University of Iowa, USA [14] and National Institute of Technology Karnataka (NITK), Surathkal, India [15], it is recommended to adopt the dual-stack approach from the start. Most of the applications (e.g., wget, youtube-dl) default to using IPv6 if it is working correctly. If IPv6 does not work correctly, the dual-stack approach allows a fast fallback to IPv4, thus avoiding disruptions for the end-users while IPv6 migration is in process.

3. Address planning

   Address planning is one of the most crucial and time-consuming activities in the process of IPv6 migration. It answers an important question: how should the network administrators allocate IPv6 addresses to different parts of the campus networks (for example, different VLANs).

   It is recommended that the network administrators study sample address plans (for example, the ones demonstrated in the webinars conducted by IIESoc and INTC) before getting started with the planning for their university. Several iterations might be needed to finalize the address plan. An important aspect to consider during address planning is to predict the growth of campus network (in terms of size, services, and applications) several years from now and accordingly plan to lease the appropriate number of IPv6 address blocks.

4. Leasing IPv6 addresses

   Assuming that most of the Internet Service Providers (ISPs) in India have adopted IPv6, there are several questions about leasing IPv6 addresses that must be answered before initiating the deployment: the university should use IPv6 addresses provided by the associated ISP or lease the IPv6 addresses from the local Internet registry? What are the recurring expenses to lease IPv6 address blocks?

   The answers to these questions depend on several factors: does the university prefer to retain the IPv6 address blocks while moving to a different ISP in the future? Is the university spread across multiple campuses that are geographically apart (for example, located in different states of India)? Are some of the services provided by the university hosted on the cloud? If the university uses IPv6 addresses provided by the ISP(s), it is important to take note of the charges (if any) being levied by the ISP for providing IPv6 addresses. As an alternative, the university may lease the IPv6 address block(s) from the National Internet Exchange of India (NIXI) [5]. All the necessary details, including the cost of leasing, are provided on the NIXI website [5].

5. Migrating network services and applications to IPv6

   Migrating the campus network to IPv6 would require migrating basic network services like DNS, DHCP, SNMP, and web applications (for example, Nginx servers) to IPv6. The questions that are most frequently asked are about the best practices to be followed to migrate these services/applications and monitor and manage the IP infrastructure.

   Past case studies of IPv6 migration from enterprises and universities show that it is safe to migrate these services/applications to IPv6, one at a time. There are several open-source and commercial tools available for migrating DNS, DHCP, SNMP, and other services to IPv6 (for example, Kea is an open-source DHCPv6 server from Internet Systems Consortium [16]). Similarly, there are tools available for IP Address Management (IPAM)

that help the network administrators to perform end-to-end planning, deployment, management, and monitoring of IP address infrastructure.

6. Securing the network
   IPv6 provides a true end-to-end connectivity solution. However, it opens up potential security threats that require extra attention from the network administrators. The question that is most frequently asked is about the best practices to be followed to ensure the security of the campus network.

   The network administrators can refer to the guidelines provided in RFC 9099 (Operational Security Considerations for IPv6 Networks) to analyze the operational security issues associated with different types of networks, and technical and procedural mitigation techniques for the same.

IPv6 Migration: Opportunities for Indian universities

Indian universities can greatly benefit from migrating to IPv6 in terms of offering a better quality of service to their end-users, providing cost-effective and scalable solutions to the administration, and consequently contributing to the efforts led by the Government of India to increase IPv6 adoption in India. Besides developing a roadmap, the Government of India has initiated funding programs to foster the deployment of IPv6 in India. The experience gained by the universities in migrating to IPv6 can immensely help to work on these funded programs and contribute significantly to the adoption of IPv6. The frequent use of IPv6 addresses in the university campus network can help bring more awareness and familiarity to the students, thus creating a natural manpower base that is trained to work with IPv6. The courses can be amended with laboratory exercises to provide IPv6 training to the students.

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