# IPv6 Deployment and Transition Plans in Croatia: Evaluation Results and Analysis

Ognjen Dobrijevic[1], Velimir Svedek[2], Maja Matijasevic[1]

[1] University of Zagreb, Faculty of Electrical Engineering and Computing, Unska 3, 10000 Zagreb, Croatia
[2] Croatian Post and Electronic Communications Agency, Jurisiceva 13, 10000 Zagreb, Croatia
E-mail: {ognjen.dobrijevic, maja.matijasevic}@fer.hr, velimir.svedek@hakom.hr

*Abstract:* **The Internet Protocol (IP) is one of the pillars of the Internet's operation. Currently employed IP version 4 (IPv4) is gradually being substituted with IP version 6 (IPv6), to facilitate scaling to ever increasing number of connected devices and to introduce various protocol improvements. In our previous work, we have reviewed past experiences with IPv6 deployment in Croatia, and described the means to evaluate IPv6 readiness in its public and private sectors. The main contribution of this paper is to present the results of the IPv6 readiness evaluation and analysis thereof. The evaluation involves twelve (12) Internet Service Providers (ISPs), which constitute more than 99% of the relevant market in Croatia, as well as fourteen (14) public administration bodies (PABs). The results indicate that most Croatian ISPs have already started the transition to IPv6, but their IPv6 support is generally under test, while the PABs still lag in planning the transition mostly due to the lack of practical knowledge and experience.**

## 1. INTRODUCTION

The Internet today is a global communication platform that serves everyday's business and social activities. From a technology perspective, a fundamental property of the Internet is the common network-layer protocol, the Internet Protocol (IP). Currently employed version of IP, which has been in operation since the 1980s, is IP version 4 (IPv4) [1]. IPv4 is gradually being substituted with a new version of IP, IP version 6 (IPv6) [2]. IPv6 was designed as a successor to IPv4 to facilitate scaling to numerous connected devices and to introduce various protocol improvements. The latter include extended addressing features, simplified header format, and better support for authentication and privacy. The key driver behind IPv6 was the exhaustion of the Internet Assigned Numbers Authority (IANA) pool of available IPv4 addresses, which happened in February 2011 [3]. IPv6 has also been selected as the main network layer protocol for converged next generation networks.

Despite of many initiatives and efforts worldwide, IPv6 has still not experienced a large-scale deployment. One of the challenges for the transition from IPv4 to IPv6 stems from the protocol design, as IPv6 is not backwards compatible to IPv4, thus making the transition more complex. Other issues, for example, relate to security and costs. As end user devices and equipment need to be IPv6-enabled and properly configured, which also applies for local area network (LAN) and wide area network (WAN) infrastructure, network operators and Internet Service Providers (ISPs) are reluctant to consider new deployment and configuration costs, and often postpone the transition.

In our previous work [4], we have reviewed past experiences with IPv6 deployment in the Republic of Croatia and described the means to evaluate IPv6 readiness in its public and private sectors. In order to assess the current status of IPv6 transition in Croatia, the Croatian Post and Electronic Communications Agency (HAKOM), the Faculty of Electrical Engineering and Computing (FER), University of Zagreb, and the Croatian Academic and Research Network (CARNet) have carried out a public consultation to obtain information about the knowledge of IPv6 technology, and status of and plans for IPv6 deployment. The purpose and main contribution of this paper is to present the IPv6 readiness evaluation results and analysis thereof. As such, they may provide a valuable input towards planning a large-scale IPv6 deployment in Croatia. In response to public consultation, responses have been obtained from twelve (12) ISPs, which constitute more than 99% of the relevant market in Croatia, as well as fourteen (14) public administration bodies (PABs). The main finding was that that a majority of Croatian ISPs have already started the transition from IPv4 to IPv6, but their IPv6 support is still under test, while the PABs in general lag in planning the transition mostly due to the lack of practical knowledge and experience.

The rest of the paper is organized as follows. Section 2 gives a brief overview of the similar studies and the IPv6 deployment status in the world and Europe. We summarize the methodology for evaluation of IPv6 knowledge and deployment in Croatia in Section 3. Section 4 presents the evaluation results and analyzes them, while Section 5 concludes the paper.

## 2. RELATED STUDIES

The Organization for Economic Co-operation and Development (OECD) published a report in April 2010 which states that the "progress in actual usage of IPv6 remains very slow", with only "over 5.5% of networks on the Internet were IPv6-enabled" [5]. But the report also indicates that "IPv6 networks have grown faster than IPv4-only since mid-2007" and that "Internet infrastructure players seem to be actively readying for IPv6, with one out of five transit networks handling IPv6". According to BGPmon [6], in

December 2010 the global IPv6 deployment rate was around 7.95%, which is still rather small, but constitutes a significant increase with respect to April 2010 (the rate of around 5%) and 2009 (the rate of around 4.4%). When analyzing the types of ISPs that are deploying IPv6, the latter report states that "it's primarily the larger ISPs that are originating IPv6 networks and hence are taking the lead in IPv6 deployments".

The Global IPv6 Deployment Monitoring Survey is an annual evaluation that is supported by the Number Resource Organization (NRO), the body involving representatives of the five Regional Internet Registries (RIRs). The 2011 NRO's survey [7] includes 1656 respondents from 135 countries/economies, with 53% of them being ISPs. As such, this survey can be considered as a reference and will, therefore, be used to compare our results to. Its overall results state that "more ISPs are confronted with customers wanting to use IPv6 and only 7% have not yet considered deploying IPv6" and that "by July 2011, 27% of all ISPs were still to deploy IPv6". Regarding the European space, the European Commission (EC) has actively stimulated the transition from IPv4 to IPv6 and set the goal in 2008 of reaching 25% IPv6 share by 2010 [8]. A study from February 2011 shows that this "has not been achieved in all aspects by 2010" and concludes that "ISPs are key actors in this transition [from IPv4 to IPv6]" [9]. Finally, at the workshop "IPv6 deployment in Europe" organized by the EC in June 2011 it was noted that ISPs in Europe are growing prepared for IPv6, but that still only 16% of the European ISPs announce IPv6 presence and that 57% of them are not even planning to deploy IPv6 [10].

A preliminary assessment of IPv6 deployment related to the Croatian ISPs was presented in [4]. ISPs in Croatia started adopting IPv6 a couple of years ago and some progress in that respect may be supported by a few indicators. For instance, the share of autonomous systems that announce IPv6 presence has grown from 3.03% in June 2010 and 8.45% in June 2011 to 10.98% in June 2012 [11]. One sign of progress is also in terms of rating of Local Internet Registries (LIRs) with "stars" in the scope of "IPv6 RIPEness" [12], a grading system established by the RIPE Network Coordination Centre (NCC) in which LIRs are given a "star" for each IPv6 service they provide. (An indication of the level of IPv6 deployment in a country can be acquired by grouping LIRs' rating for that country.) In Croatia, there are 25 LIRs as of June 2012 – 14 LIRs (56%) have at least one star, while 4 LIRs (16%) have (all) four stars (as opposed to June 2011, when only 11 LIRs had at least one star and 3 LIRs had four stars [4]). On the other hand, 11 LIRs (44%) have no stars awarded, meaning they provide no IPv6 services.

Another indication of IPv6 adoption in Croatia is IPv6 Border Gateway Protocol (BGP) peering established at the Croatian Internet eXchange (CIX), which is the national point of Internet traffic exchange among Croatian ISPs. As of June 2012, there are only five ISPs that connect to CIX over IPv6 and exchange IPv6 traffic [13] (the same as in June 2011).

## 3. EVALUATION METHODOLOGY

HAKOM, in cooperation with FER and CARNet, started a public consultation named "Usage of IPv6 addresses in Croatia" [14] to evaluate the general status of IPv6 address space usage and IPv6 deployment in Croatia. The consultation was started on June 17, 2011, and it closed on August 16, 2011.

For the purposes of the consultation, a questionnaire was designed to acquire information about the respondents' knowledge of IPv6 technology, and status of and plans for IPv6 deployment [4]. The questionnaire was primarily aimed at ISPs registered in Croatia. Another version of the questionnaire was prepared for the PABs, aiming at their general IPv6 knowledge and plans for the transition to IPv6. All interested stakeholders were invited to participate in the consultation and to contribute to the analysis. The questionnaire encompasses the following main aspects:

- technology (knowledge and equipment),
- cost,
- motivation,
- security concerns, and,
- transition strategy.

Figure 1 illustrates the structure of the questionnaire and the flowchart intended to guide the respondents through the questions. The questionnaire comprises six sections: (A) general (administrative) information, (B) knowledge and understanding of IPv6 technology, (C) reasons for not planning or postponing, the transition to IPv6, (D) IPv6 deployment planning, needs, and current status, (E) IPv6 deployment regarding network infrastructure and services, and (F) general feedback/comments.

Section (A) involves general information, such as the responding entity's name, address, contact person, etc. Section (B) involves the major "branch point", which distinguishes two groups of the ISPs. The first group refers to the ISPs not planning the transition to IPv6, or postponing it for as long as possible (the questionnaire is then completed along the sections A-B-C). The goal is to explore whether these ISPs have sufficient information on IPv6, and transition mechanisms in particular, and if not, what kind of help they would require to build their knowledge (e.g., training and technology demonstrations). In addition, it is of interest to discover what they regard as main barriers to transition to IPv6, and how to address them (section (C)).

The second group refers to the ISPs that have already started IPv6 deployment, or are planning to in near future (completion of the questionnaire along the sections A-B-D-E). For these ISPs, the aim is to determine the number of IPv4 addresses available to them (section (D)), and whether they have requested/received IPv6 addresses from a RIR. Moreover, it is of interest to examine actual progress for the ISPs planning the transition, and to find out whether they already have a technical specification of IPv6 deployment, and what the projected costs and potential risks are.
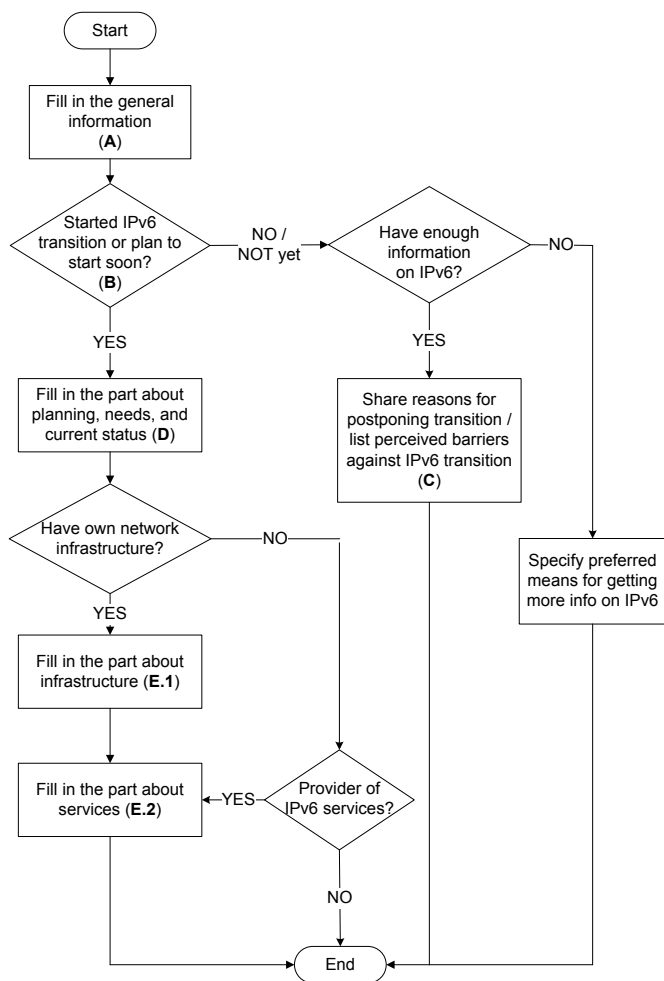
*Figure 1 – Questionnaire structure (taken from [4])*

Section (E) deals with the IPv6 deployment status, and it is intended for the ISPs which have already initiated the transition. This part relates to state of the IPv6 network infrastructure (the access network part and the core network part) and of the service provisioning over IPv6, including IPv6 connectivity for business/residential customers and services provided (or planned) over IPv6. In the end, there is a free text space for feedback/comments.

## 4. EVALUATION RESULTS AND ANALYSIS

Twelve (12) Croatian ISPs have participated in the evaluation, while in August 2011, when the consultation was closed, there were 76 ISPs registered in the Republic of Croatia. It should be stressed, however, that even though the response ratio calculated in terms of the number of respondents is only 15.8%, the given 12 ISPs constitute more than 99% of the relevant market in Croatia as per the gross income and the number of subscribers. Thus, the responses

obtained from them provide a rather solid base for evaluation. Along with ISPs, fourteen (14) public administration bodies (PABs) responded to the questionnaire. They include different government ministries and state administrative organizations. The analysis presented next shows the results for ISPs and PABs.

### 4.1. IPv6 deployment by ISPs

The first important aspect of the evaluation was directed at planning the transition to IPv6. Out of the twelve (12) ISPs, eleven (11) are planning to deploy IPv6 in their networks – only one (1) ISP does not plan the deployment, which is the share of 8.3%, and it states inadequate knowledge of the protocol as the main reason (Figure 2). If this ratio is compared to the ratio of 7% indicated in [7], it is evident that the Croatian ISPs which participated in the survey follow the global statistics trends in that sense. Furthermore, seven (7) ISPs have already started the transition, which indicates that the majority of the Croatian ISPs which participated in the survey (around 58.3%) are aligned to the world trends (Figure 3). As mentioned before, the key driver behind IPv6 transition was the exhaustion of IPv4 address space.
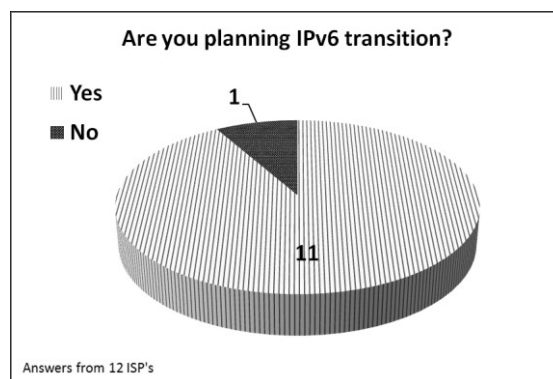


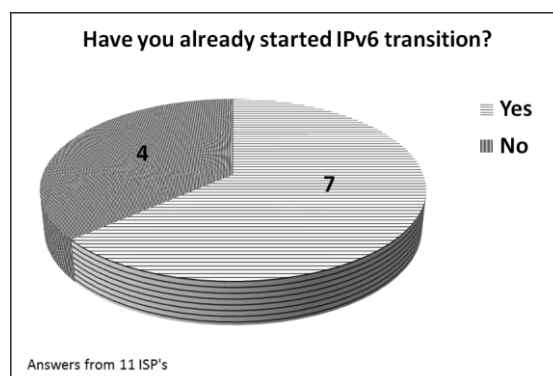*Figure 2 – ISPs: planning IPv6 transition*



*Figure 3 – ISPs: starting IPv6 transition*

Regarding the number of currently assigned public IPv4 addresses and its estimated sufficiency for the 2011-2014 period (Figure 4), one (1) ISP has not responded to the question, while nine (9) ISPs do not consider this number to be sufficient. This information clearly emphasizes the chance to resolve the long-term need for an adequate number of public IP addresses by immediately deploying IPv6.

With respect to progress in transition to IPv6, ten (10) Croatian ISPs which participated in the survey have already requested and acquired public IPv6 addresses – this is the share of 83.3%, which is above the average of 71% indicated in [7]. Regarding the IP connectivity, six (6) out of seven (7) ISPs that have established peering use IPv6, while four (4) ISPs yield IPv6 transit to international destinations. (As recording data in the peering matrix at CIX is not obligatory, the obtained information regarding established IPv6 peering differs from the CIX matrix.) If the ratio of the ISPs supporting IPv6 peering (6 out of 12, i.e., 50%) is compared to the ratio of around 57%, indicated in [7], it may be concluded that the Croatian ISPs which participated in the survey are aligned to the global trends. Supporting transit of IPv6 traffic is somewhat below the NRO's average – four (4)

out of seven (7) ISPs enable the transit through their own networks (the share of 33.3% versus the ratio of around 46% stated in [7]).

Figure 5 depicts status of IPv6 deployment related to a part of the ISPs' operation that is most important for end users – providing services over IPv6. The figure shows the main IPv6-supported services and their implementation status ("in production", "under public test", or "under internal test"). The questionnaire considers the following services: Domain Name Service (DNS), e-mail, web access, virtual private network (VPN), web hosting, and firewall. The majority of the ISPs which participated in the survey offer DNS and web access via IPv6 – five (5) ISPs for each of these services – but in different implementation phases. (This is in line with the guidelines described in [15] and [16], which state that these 2 services should be deployed first during the transition to IPv6.) The deployment ratio of around 41.7% (5 out of 12) for both DNS and web access is close to the global ratio of around 47% for DNS and is above the global ratio of around 40% for web access [7]. Although most of the services are still under test, two (2) ISPs offer DNS via IPv6 "in production", while two (2) ISPs offer web hosting in the same manner.

Regarding the underlying network infrastructure and IPv6 support, we analyze IPv6 implementation in ISPs' access networks (Figure 6) and core networks (Figure 7) separately. In the access network, different implementations are typically present. For the mobile access, two (2) ISPs have implemented IPv6 over Packet Data Protocol (PDP), while with respect to the fixed access, two (2) ISPs have deployed IPv6-over-IPv4 tunnel (indicated as IPv6 over IPoE) and two (2) ISPs have realized IPv6 over PPP-over-Ethernet (PPPoE). On the other hand, dual stack dominates as the transition mechanism in the core network (that is also in line with [15] and [16], which recommend dual stack to be deployed in the first phase of the transition to IPv6). Dual stack is used by six (6) out of the eight (8) ISPs that have answered the given question (the respective ratio from [7] is 85%). In addition, seven (7) ISPs which participated in the survey offer IPv6
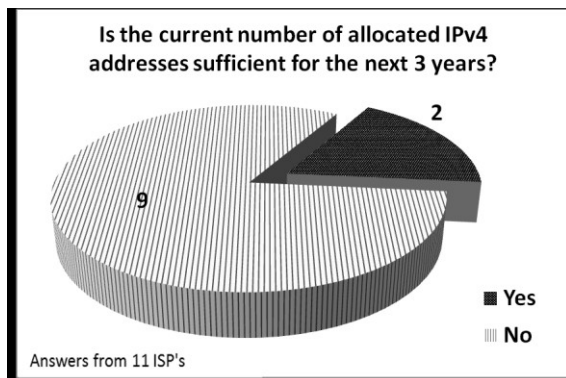


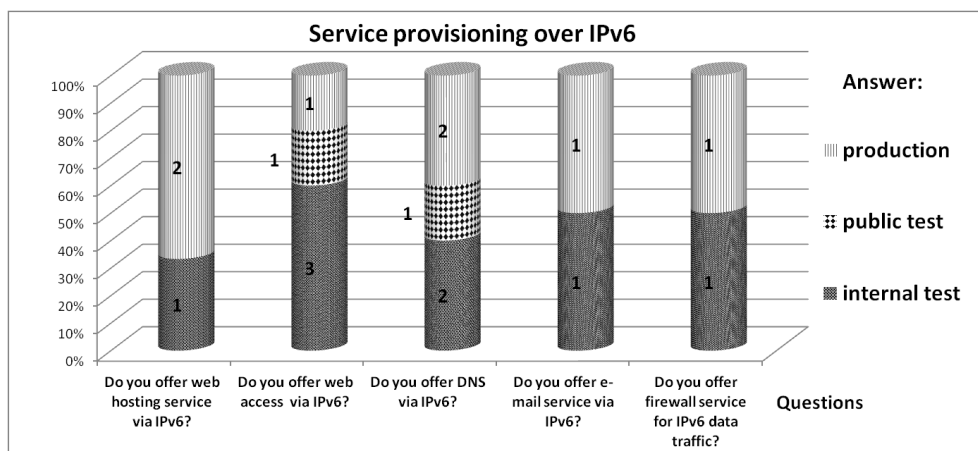Figure 4 – ISPs: sufficiency of allocated IPv4 addresses



Figure 5 – ISPs: service provisioning over IPv6

connectivity for the business customers, of which three (3) ISPs offer native IPv6 connectivity and four (4) ISPs offer connectivity based on the dual stack mechanism.

Regarding the plans for finishing the transition to IPv6 (Figure 8), the results are encouraging and imply that the Croatian ISPs which participated in the survey could further improve a positive trend of IPv6 adoption in a near future. Four (4) ISPs have IPv6 support for the core network "in production", while two (2) of them are still testing this support. Furthermore, one (1) ISP planned to enable IPv6 support for the core network until the end of 2011 and the other one (1) until the end of 2013.

With respect to the access network, one (1) ISP stated that it offers IPv6 support "in production", while four (4) ISPs still have this support under test. Moreover, one (1) ISP plans to offer IPv6 support in the access network until the end of 2012, one (1) until the end of 2013, while one (1) ISP has still not made any plans about it. From all this information, it can be deduced that several Croatian ISPs which participated in the survey have progressed to an advanced transition phase in some aspects, which will, we believe, stimulate all other ISPs to invest an additional effort in that sense.
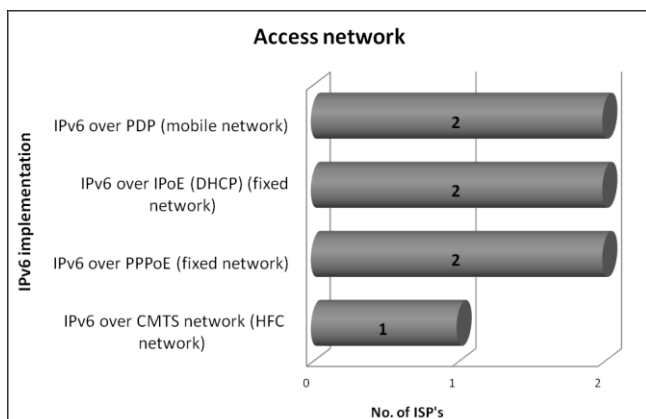

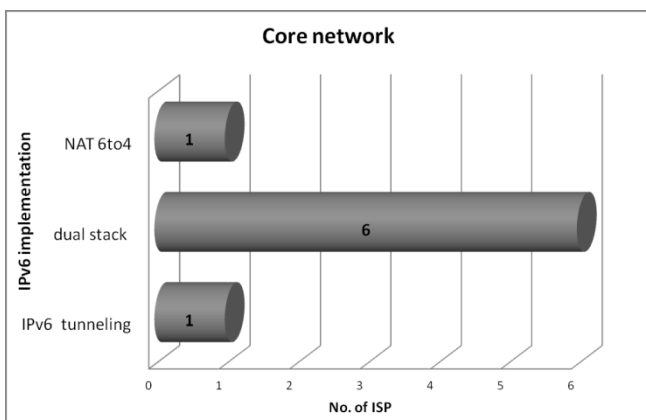
*Figure 6 – ISPs: IPv6 implementation in access network*


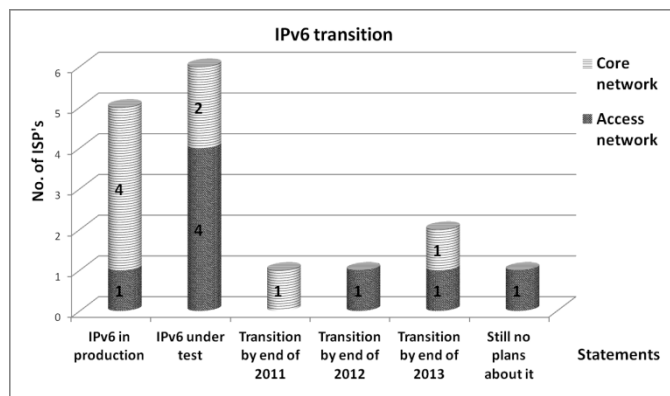
*Figure 7 – ISPs: IPv6 implementation in core network*



*Figure 8 – ISPs: (expected) completion of IPv6 transition*

### 4.2. IPv6 deployment by PABs

As mentioned before, the evaluation regarding the PABs was aiming at the general IPv6 knowledge and planning the transition to IPv6. Eight (8) of the fourteen (14) PABs which participated in the survey rated their general knowledge on the transition to IPv6 with "good" (Figure 9), four (4) of them with "very good", one (1) PAB rated it as "excellent", while only one (1) PAB rated its knowledge on the transition as "superficial". Moreover, seven (7) PABs rated knowledge of their network administrators on the transition with "good" (Figure 10), three (3) of them with "very good", while one (1) PAB rated it as "poor" and three (3) PABs rated the knowledge of their network administrators as "superficial".

Similarly as with the Croatian ISPs, management within the PABs recognizes the need to deploy IPv6 in their networks, and stimulate the transition – in eleven (11) out of the fourteen (14) PABs which participated in the survey – but still, most of the PABs have not started the transition (Figure 11). What is interesting and specific for the PABs which participated in the survey is that to them the shortage of IPv4 addresses is not a motivational factor, since thirteen (13) PABs estimate that the currently assigned number of IPv4 addresses will be sufficient for the 2011-2016 period. Only one (1) PAB has acquired public IPv6 addresses.
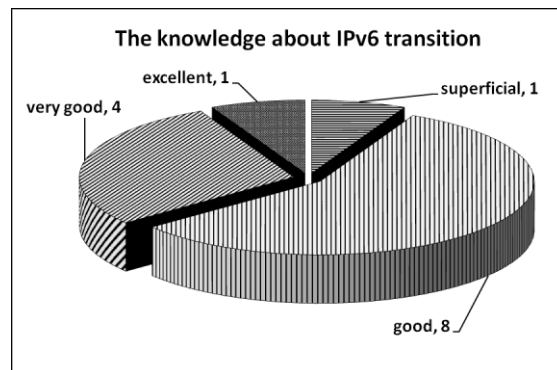


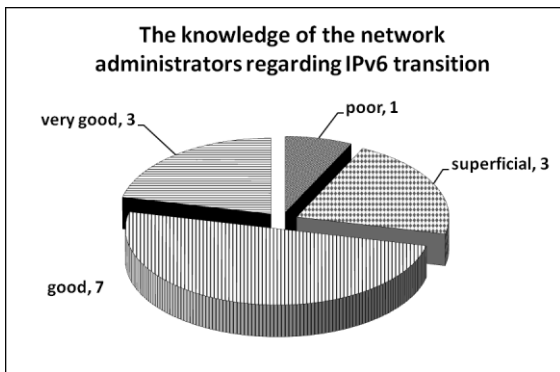*Figure 9 – PABs: general knowledge about IPv6 transition*

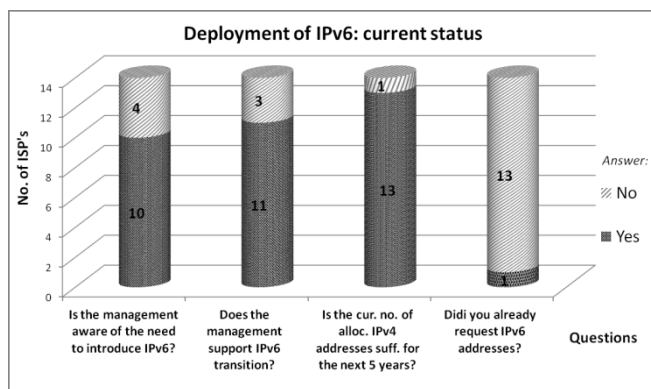*Figure 10 – PABs: network administrators' IPv6 knowledge*



*Figure 11 – PABs: IPv6 deployment status*

Insight into the reasons for not planning/starting the transition to IPv6 has revealed some interesting information (Figure 12). Although twelve (12) out of fourteen (14) PABs which participated in the survey rated their general knowledge on the transition with "very good" and "good", six (6) PABs stated that they lack "enough knowledge (and

experience)" to improve their network infrastructure, which can refer to other problems, e.g., employees' lack of information, training, and knowledge regarding practical aspects of the transition to IPv6. The latter can be related to the results presented in [7], where "availability of (knowledgeable) staff" was the second most influential drawback for the organizations that did not plan the transition – around 35% of the respondents indicated this as the reason (the major drawback relates to "costs (required financial investment/time of staff)", with the share of around 42%). The next most common reasons of the PABs for not planning/starting the transition to IPv6 include lack of financial resources in general, high expense of the transition, lack of the services and content that are offered via IPv6, absence of proper support from suppliers/vendors, and lack of the IPv6 connectivity support from transit operators.

## 5. CONCLUSIONS AND FUTURE WORK

In line with global trends, successful IPv6 deployment should be supported by government organizations and led by the private sector that identifies IPv6 as a needed investment. We have presented the assessment of IPv6 deployment status and transition plans of the 12 ISPs and 14 PABs in Croatia, based on the results of public consultation. The results indicate that major Croatian ISPs have already started adopting IPv6, though with varying degrees, while PABs still lag behind in adoption plans, mostly due to the lack of practical knowledge and experience. The obstacles noted by the respondents should be overcome for the IPv6 deployment to progress beyond the current status. Based on the results, future work will focus on designing suitable strategies, guidelines, and plans to assist in IPv6 transition and deployment in Croatia.
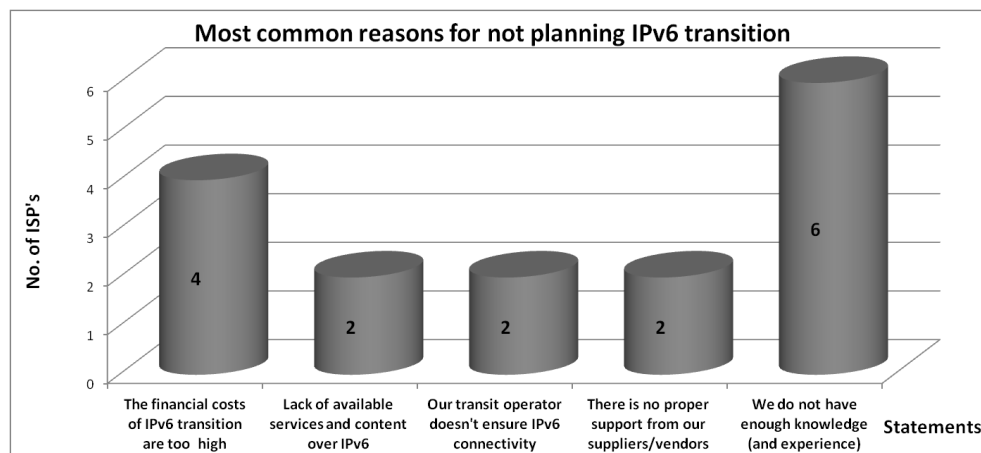


*Figure 12 – PABs: most commonly cited reasons for not planning IPv6 transition*

**REFERENCES**

[1] J. Postel, "Internet Protocol," RFC 791, September 1981

[2] S. E. Deering, R. M. Hinden, "Internet Protocol, Version 6 (IPv6) Specification," RFC 2460, December 1998

[3] –, "Free Pool of IPv4 Address Space Depleted," The Number Resource Organization (NRO), Press release on February the 3rd, 2011, Montevideo, CA [On-line: http://www.nro.net/news/ipv4-free-pool-depleted]

[4] V. Svedek, O. Dobrijevic, M. Matijasevic, I. Golub, T. Stivojevic, "Towards Assessment of IPv6 Readiness, Deployment and Transition Plans in Croatia," in Proc. of The Workshop on Electronic Communications Regulatory Challenges - Experiences from the Looking to the Future Project, Hvar, Croatia, September 2011, pp. 52-58.

[5] -, "Internet addressing: Measuring deployment of IPv6," OECD, April 2010 [On-line: http://www.oecd.org/]

[6] –, "IPv6 Deployment in 2010, how far are we?." BGPmon.net, December 2010 [On-line: http://bgpmon.net/blog/?p=340]

[7] –, "Global IPv6 Deployment Monitoring Survey," NRO, July 2011 [On-line: http://www.nro.net/wp-content/uploads/IPv6_deployment_survey_2011.pdf]

[8] –, "Advancing the Internet: Action Plan for the deployment of Internet Protocol version 6 (IPv6) in Europe," European Commission (EC), Brussels, Belgium, COM (2008) 313 final, May 2008

[9] K. Ahmed et al., "IPv6 Deployment monitoring - Final study report," IPv6 Deliverable D-S3, February 2011 [On-line: http://www.ipv6monitoring.eu/]

[10] –, "IPv6 deployment in Europe," EC, Brussels, Belgium, Report from the workshop, June 2011 [On-line: http://ec.europa.eu/information_society/events/cf/daa11/document.cfm?doc_id=18306]

[11] –, "IPv6 Enabled Networks," the RIPE Network Coordination Centre (RIPE NCC), June 2012 [On-line: http://v6asns.ripe.net/v/6]

[12] –, "IPv6 RIPEness information," RIPE NCC, June 2012 [On-line: http://ripeness.ripe.net/]

[13] –, "Peering matrix (IPv6)," The Croatian Internet eXchange (CIX), June 2012 [On-line: http://www.cix.hr/en/peering-matrix/]

[14] –, "Public consultation – Use of IPv6 addresses in the Republic of Croatia," The Croatian Post and Electronic Communications Agency, June 17, 2011 [On-line: http://www.hakom.hr/default.aspx?id=116&subid=781]

[15] A. Vives, J. Palet, "Report of 4th Deployment Case Study," 6DEPLOY Deliverable D2.1.4, October 2010 [On-line: http://www.6deploy.eu/index.php?page=publications2]

[16] –, "IPv6 deployment scenarios," 6DEPLOY, [On-line: http://www.6deploy.eu/index.php?page=tutorials]