Overview of the progress of IPv6 adoption in Croatia

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***Summary* - As a specification proposed in a far-away year of 1998 in a response to critical outage of available IP address space, one would assume that IPv6 protocol is adopted a long time ago, and one would be very much wrong. Where does the world and European Union countries stand with IPv6 enabled traffic, and Croatia in respect to them? This paper will provide an outline of current IPv6 adoption progress status worldwide, in EU countries with a focus on Croatia, based on information available from online resources. An overview of available online sources and metrics for measuring IPv6 deployment is gives as well.**

Key words – IPv6; IPv6 adoption progress; IPv6 Croatia; IPv6 deployment

I. INTRODUCTION

Many years have passed since first drafts and final version of very much needed protocol for IPv4 replacement - IPv6 protocol, were presented. Still, it is far away from its full implementation worldwide.

First IPv6 protocol specification draft RFC2460 was published in 1997 with final version published in 1998, by IETF. In 2015, new IPv6 protocol specification draft was published in RFC8200 and in 2017 the IETF ratified it as the Internet standard, obsoleting the RFC2460 draft standard [1].

Even though the IPv4 address pool distributed by the IANA (Internet Assigned Numbers Authority) was exhausted in February 2011 [2], consequently the last IPv4 address assigned by a RIR (Regional Internet Registry), RIPE NCC in November 2019 [3], currently, 36% of Google users worldwide use IPv6 for accessing their services , with 22.6% in average in EU (varying form 0.24% in Malta to up to 55.3% in Belgium) and 6.54% in Croatia with very similar statistics available from Akamai and APNIC [4] [5] [6].

There was an organized attempt to engage worldwide IPv6 deployment, World IPv6 Launch Day event held on 8 June 2011, organized by the Internet Society. They gathered major internet service providers (ISPs), home networking equipment manufacturers, and web companies around the world to initiate faster IPv6 deployment. There was no significant growth in following years, mostly due to the fact that it was not common for equipment those days to have IPv6 support [7].

The networking industry has initiated a global effort to transition to Internet Protocol version 6 (IPv6) with mechanisms like stopping the IPv4 compatibility requirements for new protocols (IETF in 2016) or 3GPP considering mandating IPv6 in 5G Standalone (SA) [8].

Current situation is mainly sustainable thanks to various policies for IPv4 address distribution, defined by RIRs, and available technologies for bridging the IPv4 gap.

For example, in 2012 RIPE NCC began to limit the address allocation to single prefix and respectively in 2019 shortened it to multiple smaller prefixes. Current IPv4 policy is based on waiting lists, where RIPE NCC members (LIRs – Local Internet Registries – organizations with assigned IP address space, usually providing addresses to its customers) can submit an IPv4 address request, and when there is available allocation, they receive a single /24 allocation (256 address). At the moment, there are no LIRs in queue (only LIRs that have never received an IPv4 allocation from the RIPE NCC can make a request via the waiting list.). Internet Service Providers and users still use various techniques to mitigate the IPv4 exhaustion: NAT and dynamic IPv4 address assignment.

IPv4 address inter-organization transfer is one more option for service providers IPv4 address acquisition (only available where RIRs allow it). For example, Google and Amazon acquired large IPv4 address blocks form Merit and MIT back in 2017 [9].

IoT evolution and 5G networks, with their necessity for high number of accessible Internet devices and high access speed, have certainly given their mark on the IPv6 adoption progress in some countries with high IPv6 adoption rate (Belgium, Germany, etc), but apparently didn't elsewhere.

II. RELATED WORK

In [10] authors state that the IPv6 adoption trend was in exponential growth in the 2010 – 2012 period, and onwards is going in a very slow pace, which reflects in a quantity of relevant work, dating majority of papers on the IPv6 adoption progress in a 2010 – 2015 period, with a spike in 2019 [12].

First articles by Croatian authors, regarding IPv6 in general, were published in 2003 [11], while first work regarding IPv6 adoption progress in Croatia was published in 2011 [13] with a follow up in 2012 [14]. At that time, there were only 0,3 % in 2011 and 0,6 % in 2012 of IPv6 enabled Google users. In [14] authors present results on Croatian ISP IPv6 status and plans, stating 92 % of ISPs are planning IPv6 migration, 57% started with the transition, 17% claim they offer their clients IPv6 enabled web hosting and DNS services and 8% claim they offer IPv6 enabled

web access, mail services and firewall services. If we look at the available data on IPv6 statistics in Croatia, we can conclude they were too optimistic.

III. AVAILABLE DATA SOURCES

There are various sources available for IPv6 deployment statistics. Main starting point for resource research was Internet Society web page with an overview of available sites with IPv6 statistics [15].

Some of the sources use their own data, some sources use data collected from various sources and presented with composite metrics.

Most common metrics for IPv6 implementation measurements are as follows:

- Users: number of IPv6 enabled users accessing the content, meaning the user has assigned functional IPv6 address reachable on internet.
- Content: number of IPv6 enabled domains; meaning domains providing content, configured with IPv6 and reachable.
- Transit AS: number of IPv6 enabled AS, meaning AS with configured IPv6 prefixes.
- IPv6 prefixes: number of IPv6 enabled BGP peers, meaning the number of advertised IPv6 prefixes.

A. Akamai

Akamai is content delivery network (CDN) services provider for media and software delivery, and cloud security solutions. Their adoption rates are based on the percentage of IPv6 requests they receive to a selection of dual-stacked properties on Akamai's content, site, and application delivery platform. The hundreds of billions of IPv4 and IPv6 requests analysed across a 24-hour window represent traffic to a diverse set of customer sites across various industries, geographies, and user populations [16].

B. APNIC

APNIC is the regional Internet address registry for the Asia-Pacific region. APNIC recruits random measurements of IPv6 capability and preference through advertisements placed in web sites worldwide. The advert runs specially crafted HTML5/Javascript and measures a range of properties across wired, wireless and cellular networks. Per-Economy and Per-ASN daily totals are calculated through the RIR delegation stats and daily BGP dumps to map origin - AS and economy of registration of each tested clients IP addresses. The measurement has run continuously since 2010 and currently collects around 10 million samples per day [16].

C. Google statistics

Google statistics continuously measures the availability of IPv6 connectivity among Google users, showing the percentage of users that access Google services with IPv6 address.

D. Cisco IPv6 Lab

Cisco IPv6 Lab presents consolidated metrics of IPv6 adoption, globally and at country level. The overall IPv6 deployment ratio depends on three metrics: IPv6-enabled transit AS (AS weight based on number of connections for AS IPv4 and IPv6 networks), IPv6 content (AAAA record for top 50 webpages per country from Alexa) and IPv6 users (Google statistics and APNIC)[21].

IV. IPV6 ADOPTION STATUS

A. IPv6 worldwide

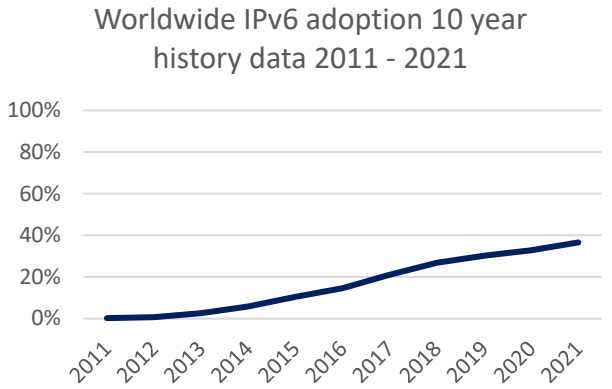

Figure 1. IPv6 worldwide adoption history visualization [4]

Looking at the worldwide average IPv6 implementation, by Google, it goes around 36% (varying from 0% in Greenland or Afghanistan to up to 61.17 % in India). Data from Akamai are fairly the same with 0.7 % for Greenland, 0.1 % for Afghanistan and 58.7 % in India as top country worldwide. Cisco's data puts Belgium on top with 65.44 % implementation followed by Saudi Arabia with 65.11% and India at 62.82%. APNIC puts India first at 77.15 % followed by Belgium at 61.87 % and worldwide average 28.33 %.

For the last 10 years, the worldwide growth is slowly pacing at the average rate of 5% per year.

B. IPv6 in EU countries

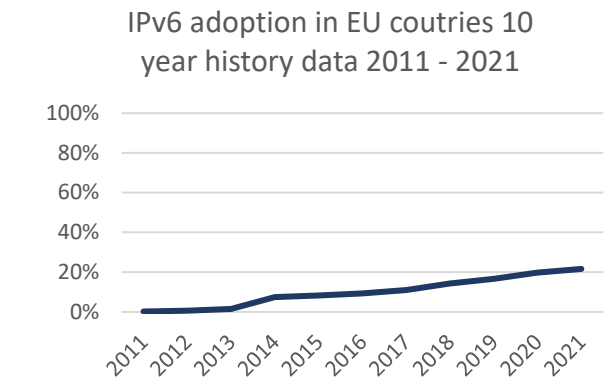

Figure 2. IPv6 EU adoption history visualization [5]

EU IPv6 adoption rounds up at 22% in average which is lower than the world average, varying from 0.16% in Malta to 57.7% in Belgium. Top EU country in IPv6

adoption is Belgium with 57.7 % by Google, and 61.52 % by APNIC, followed by Germany at 55.33 % by Google (53% by APNIC) and France at 52 % (43% by APNIC). There is a significant number of countries with less than 10 % adoption rate: Italy, Spain, Slovakia, Denmark, Lithuania, Bulgaria, Malta, Cyprus, Croatia and Sweden.

C. *IPv6 in Croatia*

According to Google data, IPv6 adoption intake in Croatia is at low 6.7 %, which was for years on a 0.5 % till December 2020, when the adoption trend began its exponential rise, but still remaining at the low level.

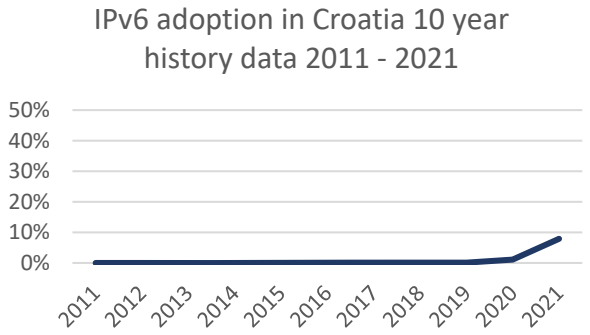

Figure 3. IPv6 Croatia adoption history visualization [5]

There are 323 LIRs offering services for Croatia, with 82 based in Croatia. [17] According to information for Croatia shared by Carnet (Croatian Academic Research Network) and RIPE NCC, there are a total of 78 clients (ISPs, hosting services, etc.) provided with IPv4 and/or IPv6 prefixes, with 54 clients or 69,2% assigned with IPv6 address prefixes [18] [19]. 50% of assigned IPv6 prefixes are assigned to leading Croatian provider holding 50% of landline and mobile networks market, with 0.01% IPv6 capable AS [6]. According to data from Cisco IPv6 lab for Croatia, out of 75 allocated IPv6 prefixes, 24 of them have an entry in BGP tables (which makes them routable) and 10 is alive (detectable traffic), giving us a 13% of "live" IPv6 address space in Croatia. 72.72 % of transit AS is IPv6 transit AS (AS that is transit on IPv4 network, has IPv6 prefix but is not necessarily transit on IPv6), and 77.1 % is IPv6 enabled transit AS (AS that is transit for both IPv4 and IPv6).

Data provided by the Croatian Regulatory Authority for Network Industries (HAKOM) states 149 registered operators for various types of telecommunication services. 83 operators registered for landline internet access services and 17 registered for mobile internet access services, 36 registered for data transfer services, 59 for leased line services, and a various number of them for various telecommunication services [20].

When we look at the data provided by APNIC, we can see that there is only one ISP in Croatia with significant IPv6 implementation intake (out of 163 ASN owners), A1 Hrvatska, with 65 % of IPv6 Capable and Preferred traffic [6]. A test of IPv6 capabilities on A1 networks was made. On landline services, there is IPv6 address assignment to end users, but on 4 out of 5 tests (ping google.hr -6 on 5 different days) the test failed. On mobile A1 networks, there is no IPv6 address assigned.

Croatian Internetwork Exchange (CIX) supports local internet traffic exchange and is coordinated by University Computing Center (Srce) which is open for all ISPs in Croatia. They currently support 40 members, with 38 members with assigned AS numbers. 18 members are defined as service providers, with 6 international providers [23].

In Table I. we can see that top Croatian service providers didn't implement IPv6 at the backbone of their networks and clearly not being able to provide IPv6 to their customers (HT, Telemach, Carnet). By data available from HAKOM, in 3rd quarter of 2021., there is a total of 4.573.422 mobile networks users and 811.272 landline with internet access users. HT holds 50% of landline market and 46 % of market in Croatia, A1 holds around 35% on mobile market and Telemach holds around 19%. HAKOM does not offer detailed data on landline market intake for other operators which makes a total of 50% market share. Carnet is a service provider for education and science institutions in Croatia, counting 3343 member institutions.

TABLE I. Top 20 AS in Croatia sorted by IPv6 capabilities. [6]

ASN	AS Name	IPv6 Capable	IPv6 Preferred	Samples
AS15994	A1HR	65,32%	65,14%	136,03
AS25467	AKTON-AS	3,58%	0,34%	586
AS61094	CRATIS-AS	1,05%	0,00%	95
AS2108	CARNET-AS	0,68%	0,65%	9,361
AS29485	AMIS	0,17%	0,07%	2,982
AS211572	VRW-	0,15%	0,15%	1,359
AS61211	SETCOR	0,11%	0,05%	1,878
AS35549	METRONET	0,09%	0,01%	8,443
AS56681	FASTNET-AS	0,09%	0,09%	1,149
AS13046	ASN-ISKON	0,03%	0,01%	93,528
AS12810	VIPNET-AS	0,02%	0,02%	244,067
AS205714	TELE2	0,02%	0,02%	139,441
AS5391	T-HT	0,01%	0,01%	628,108
AS34594	OT-AS	0,01%	0,00%	98,603
AS31012	DCM-AS	0,01%	0,01%	58,321
AS62161	PRO-PING	0,01%	0,01%	13,243
AS34362	VOLJATEL	0,00%	0,00%	7,714
AS44377	MTNET	0,00%	0,00%	6,953
AS198785	SEDMIODJEL	0,00%	0,00%	1,658

Based on the brief research on most visited sites in Croatia [22], among 20 TOP most visited sites, there are no IPv6 enabled domains located in Croatia, all IPv6 enabled domains are located in foreign countries.

TABLE II. IPv6 enabled domains in TOP 20 visited sites in Croatia

Rank	Site	Country
1	google.com	US
2	youtube.com	US
3	facebook.com	Austria
4	index.hr	US
5	jutarnji.hr	US
6	24sata.hr	Croatia
7	net.hr	Germany
8	vecernji.hr	Croatia
9	google.hr	US
10	slobodnadalmacija.hr	US
11	njuskalo.hr	Croatia
12	tportal.hr	Croatia
13	dnevnik.hr	US
14	instagram.com	US
15	wikipedia.org	US
16	skole.hr	Croatia
17	dnevno.hr	US
18	twitter.com	US
19	telegram.hr	US
20	rtl.hr	US

IPv6 enabled

V. CONCLUSION

Despite the readiness of IPv6 core infrastructure in Croatia supported with IPv6 address prefix allocation and CIX support in IPv6 adoption process (IPv6 services), only one major Croatian ISP offers IPv6 enabled services. IPv6 deployment in Croatia was on 0.5 % for a long time when started to rise in December 2020, with one of the largest ISP in Croatia starting with IPv6 deployment (A1). The intake would be much higher if mobile services were included in the IPv6 deployment as well.

There are many factors influencing the ISP's decision to deploy IPv6. If they have a sufficient IPv4 address space, they do not have the need to use IPv6. Costs of acquiring and installing equipment and configuration upgrades can be quite substantial, especially in a large ISP environment. They would need a good reason, other than to be progressive, for IPv6 implementation.

Leading service provider in Croatia, HT, with around 50% intake both in land-line and mobile networks services, holds just below 50% of assigned IPv4 address space, leaving other 50% to 79 various users (other ISPs and companies), hence the conclusion that HT still has enough IPv4 address space which might be the reason they are not implementing IPv6.

Given the large intake in Croatian internet access services, until HT starts with offering full IPv6 services – assigned IPv6 addresses to end users, IPv6 enabled hosting services, etc., IPv6 traffic intake will remain low as it is now. A1 with around 35% intake in mobile network internet access services should also deploy its IPv6 service in that environment.

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