IMPROVING IPV6 ADDRESSING TYPES AND SIZE

Dr. Khaldoun Batiha

Dean of Faculty of Information Technology, Philadelphia University, Amman, Jordan

E-mail: kh_batiha@philadelphia.edu.jo

ABSTRACT

IPv6 protocol is the next candidate protocol after IPv4 protocol that used for a long time. For this protocol the addressing types and address size are discussed to list some modifications that could improve its performance through the internet. At the same time, we prove that multicast addressing type is the most important addressing type since it can mimic any other addressing type. Finally, a short study is developed in order to reduce the current IPv6 address size to have less overhead in the basic header packet, this reduction omits about 40% of the over all basic IPv6 basic packet overhead.

KEYWORDS

IPv6, addressing types, IPv6 header and Exhibition date.

1. INTRODUCTION

Due to the growth of the internet size and applications, the current address space and features provided by IPv4 may not be sufficient [5] [9]. There for, a new protocol that has larger addresses space and improvement features is needed. IPv6 was developed as a solution for these problems by offering a huge address space which will be more than enough, and by providing improvement and new features in comparison with IPv4.

This paper outlines suggested modifications on the IPv6 protocol addressing type and size in comparison with current IPv6 protocol and shows how badly we really need these modifications to improve the over all internet performance as much as possible. It not only takes a deep look at the addressing type and size that IPv6 presents, but it also gives a good idea of what really the IPv6 modification based on significant needs for these modifications. Also, this paper presents an attempt to implement the suggested modifications to improve over all performance in the internet. It also discuses the predicted exhaustion dates of unallocated IP addresses for size range between 32-bit and 128-bit in the internet. The unallocated address pool exhaustion for this range with size interval of 8-bit is discussed using a study that we develop based on IPv4 address report generated at 30-Jan-2013 [7] the remaining addresses in RIR pool and world population projection growth rate including the derivation of new formula that predict IP Address consumption. On other hand, it shows which address size will solve the exhaustion problem at the same time this size should be less than 128-bit, to reduce the overhead in IPv6 packet basic header by 40%.

After all modifications that we will introduce in this paper, the IPv6 still has the same main functions, which are the routing between different networks until it reaches the destination network. The other main function is to identify a destination host that has the destination IP address within the destination network. Our goal is to improve the over all internet performance and avoid some of IPv6 problems. In order to do that we discussed the IPv6 addressing type and we introduced some problems and suggested solution for these problems.

2. IPV6 ADDRESSING TYPES

IPv6 supports three main addressing types:

2.1. Unicast Addressing

In unicast addressing only a source interface sent the packets to only one destination interface with unique IP address [8]. This type of addressing may have n bit prefix with arbitrary length starting from 0 bit prefix (no prefix)[1]. This prefix is used as subnet or interface identifier. So the length of address prefix depends on the number and size of needed different subnets in each region.

We haven't any suggested modifications on this addressing type at all.

2.2. Multicast Addressing

In some situations, the same packets may be sent to more than one destination. In this case IPv6 uses an addressing type called multicast addressing. In this type of addressing the network infrastructure is used to send a datagram only once even if many replication of this datagram are needed to be delivered for several (groups) hosts joining a particular IP multicast address [8] [1], where the replication of the packet is done by dedicated nodes in the network.

IPv6 uses the address block with the prefix ff00::/8 for multicast applications[1]. A message sent to a multicast IP address will be sent to all members of this group. It is often employed for streaming media applications on the Internet and private networks.

In this type of addressing two protocols are used to discover the set of multicast addresses for which there are listening nodes for each attached interface. The first one is called Multicast Listening Discovery protocol (MLD) and the other used protocol is MLDv2 [8] [2]. Where MLDv2 is distinct from MLD by allowing a multicast listener that has a specific multicast source addresses interest to register this interest with their neighboring routers. This feature is very useful in solving the problem of A **denial-of-service attack** (**DoS attack**) or **distributed denial-of-service attack** (**DDoS attack**) by isolating attackers (removing thier source addresses from the registered source addresses list in the neighboring routers)[10] [11]. This means that MLDv2 is much secure than MLD.

For this reason MLD can be omitted from modified IPv6 multicast addressing and only depend on MLDv2 instead.

2.3. Anycast Addressing

On the other hand, anycast addressing is used in situations where the packets need to be sent to only one member of a group typically which is closest to the sender [1]. For example, consider a client needs to access a server with multiple instance of **www.helpe.com** with IP address 1c::32 that is shared in a group of 4 members when a client uses DNS lookup for the www.helpe.com IP address then the return address will be 1c::32 and since there are 4 servers with this address the router to which the client is attached directly will decide which one the packets will be send to (Figure1).

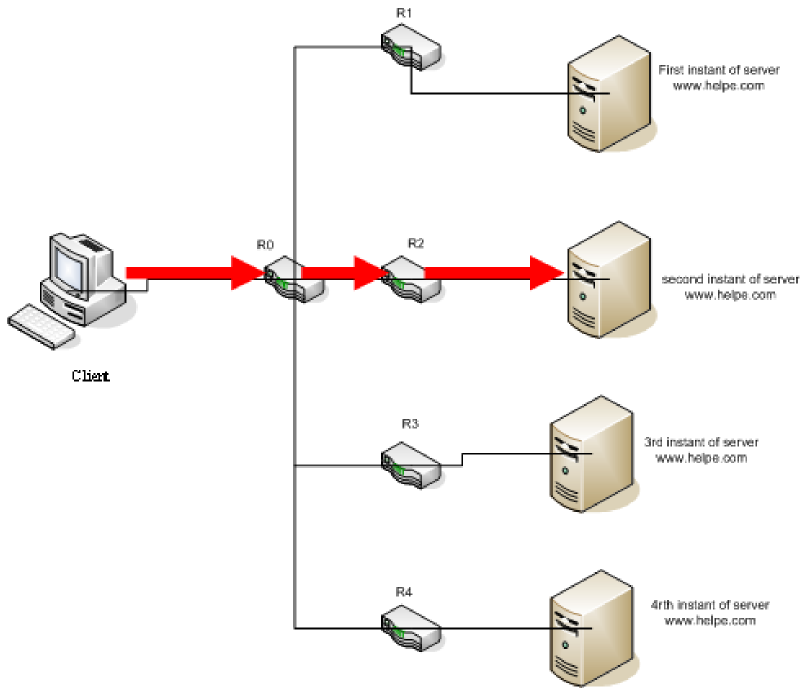


Figure1: a client needs to access a server with 4 instance of www.helpe.com server with IP address 1c::32 that is shared in this group.

2.3.1. Anycast addressing problems

This type of addressing has many problems that can affect the over all performance of packet exchanged between a client and a member of a group. The following are some of these problems:

- If the client is multi-homed then there may be a number of switching between members of the group while the client is moving across different regions [4]. This switching process may cause a flap problem while changing the upstream provider.
- If any attacker pretends to be the closest member for some anycast groups by using a fake IP address.
- Instability of one or more anycast member's location would have severe impact on the reachability of any cast prefix [4].
- For each anycast address, a prefix P identifies the topological region in which all interfaces belonging to that anycast address reside. If the prefix P is null, the members of the set may have no topological locality [1]. If the prefix P is null for the anycast address it must be advertised as a separate outing entry throughout the entire Internet, which presents a severe scaling limit on how many such global anycast sets can be supported
-

2.3.2. Solution for Anycast addressing Problems

To avoid most anycast addressing type problems, a number of restrictions can be considered, such as anycast addresses must not be used as source addresses on IPv6 packets. Anycast addresses must not be assigned to IPv6 hosts that is, they can be assigned to IPv6 routers only [1] [4].The important question now is whether these problems will prevent using this type of addressing mode in the modified IPv6 or not? And if we decide to omit this addressing type in the modified IPv6, can anycast addressing be mimicked with another addressing type that will implement the most important benefits of this addressing type and avoid at the same time many of its problems?

One of two solutions can be suggested here either to choose the only candidate for implementing anycast addressing which is the multicast addressing or use anycast addressing type with a number of restrictions.

3. LIMITED BROADCAST ADDRESSING

There is one addressing type that is used in IPv4, no more used in IPv6, which is the limited broadcast addressing. This type of addressing is used in situations where a packet needs to be sent from one sender to all attached recipient nodes in the same LAN [3]. It is called limited since it does not reach every node in the internet.

This type of addressing can be implemented by using multicast addressing type, by joining all nodes attached to the same LAN of the sender. The same multicast IP address will be used as a destination address of the packet needed to be sent to all nodes [1]. This is more secure than the limited broad cast addressing. So there is no need to use this type of addressing in the modified IPv6 addressing schema.

4. IPV6 ADDRESSES SIZE

The main reason for introducing IPv6 is to overcome the concerns of the rapid growth in internet which demands more and more unallocated IP addresses to be available to accommodate this growth. IANA IPv4 unallocated address pool exhaustion will be very soon [9] [6] [8]. Since the address space that IPv4 provides is no more sufficient for the internet needs today, where many studies predict that a platform to provide flexibility for further growth and expansion has become urgent. And the main feature of this platform should be the address space size that it represents.

IPv6 was present as a life saver for IPv4 exhaustion problem since it supports 128-bit IP address. Sixteen bytes or 128-bits can accommodate 340,282,366,920,938,463,463,374,607,431,768,211,456 IPv6 addresses which mean that there are enough IPv6 addresses for every portion in the Universe [9] [8]. This address space will not face the exhaustion problem even after a billion years.
If we look at IPv6 packet header given in figure1, it is clear that IPv6 source and destination IP address occupy a 32 bytes from 40 bytes of the basic IPv6 header total size as illustrate in Figure2, which is 80% of header total size [3] [13]. This is considered a big overhead, in comparison with the basic header total size. So in order to make an effective reduction in IPv6 packet over all overhead, a reduction in IPv6 address size is the ideal solution. But the question here is how much should the reduction be? To answer this question we need to take into consideration that the new address size should be large enough so that it can accommodate the needs of the world in the far future.

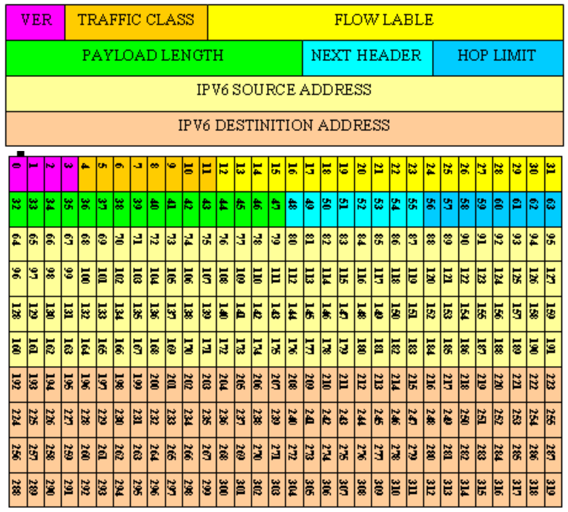


Figure2: 320-bits IPv6 basic header: each color represents part of the header so the first part of the figure shows the names of IPv6 parts while the second part shows bits numbers for each part, (VER ➔ 0 -3, TRAFFIC CLASS➔4-11, FLOW LABLE➔12-31, PAYLOAD LENGTH➔32-47, NEXT HEADER➔48-55, HOP LIMIT➔56-63, IPV6 SOURCE ADDRESS➔64➔191, IPV6 DESTINITION ADDRESS➔192➔319)

5. IP EXHAUSTION PREDICTION USING WORLD POPULATION PROJECTION

The ipv4 can provide address space up to 256/8 blocks, 14% of these blocks are reserved and the remaining (86%) are available for allocation, and so 220/8 blocks is the total address space available for allocation [6]. According to IPv4 address report generated at 30-Jan-2013 [7], the remaining addresses in RIR pool (/8s) is as following: for APNIC is 0.8905/8 block, for RIPE NCC is 0.9357/8 block, for ARIN is 2.9634/8 block, for LACNIC is 2.6080/8 block and for AFRINIC is 3.8019/8 block which means that the total remaining address in RIR pool is 11.1995/8 block.

IPv4 addresses exhaustion date is the time when the pool of available addresses in RIR reaches the last /8 block available for allocation, in other words if the remaining unallocated addresses for RIR address pool are less than 16,777,216 addresses[7]. From what has been stated above we can conclude that the total allocated RIR address space of IPv4 in 2013 is 209.7225/8 blocks. The main question that we need to answer is: when will RIR remaining unallocated addresses exhaust? And if we have the choice to increase the size of IPv4 address, what is the most effective size? Is the IPv6 address size is the most effective size? In order to answer these questions we need to predict the exhaustion date for several IP address sizes and then try to choose the smallest size with acceptable exhaustion date.

5.1. Available Address Space for IP Address of Size N

As we mentioned before IPv4 address are equivalent to 256/8 blocks of IP address space. That means if we use 33-bits in IP address, this will be equivalent to 512/8 blocks. In Table 1 we have listed the equivalent number of /8 blocks for the range of IP size in bits (32-bits to 128-bits). We have also listed the expected unassigned address space for each size in 2013. We have picked this year since this is the year of IPv4 address report generated (30-Jan-2013) [7] of remaining addresses in RIR pool (/8s) which will be used as a base for our prediction for IP address exhibition date. That means the values in the unassigned IP address column represent the remaining IP addresses blocks in 2013 if we use the corresponding IP address size N.

Table 1: The equivalent number of /8 blocks is listed for the range of IP size in bits (32-bits to 128-bits) together with the expected unassigned address space for each size in 2013.

IP Address Size (N)	Unassigned /8 blocks	IP Address Size (N)	Unassigned /8 blocks	IP Address Size (N)	Unassigned /8 blocks
32	11	65	2.19902E+12	98	1.88895E+22
33	267	66	4.39805E+12	99	3.77789E+22
34	779	67	8.79609E+12	100	7.55579E+22
35	1803	68	1.75922E+13	101	1.51116E+23
36	3851	69	3.51844E+13	102	3.02231E+23
37	7947	70	7.03687E+13	103	6.04463E+23
38	16139	71	1.40737E+14	104	1.20893E+24
39	32523	72	2.81475E+14	105	2.41785E+24
40	65291	73	5.6295E+14	106	4.8357E+24
41	130827	74	1.1259E+15	107	9.67141E+24
42	261899	75	2.2518E+15	108	1.93428E+25
43	524043	76	4.5036E+15	109	3.86856E+25
44	1048331	77	9.0072E+15	110	7.73713E+25
45	2096907	78	1.80144E+16	111	1.54743E+26
46	4194059	79	3.60288E+16	112	3.09485E+26
47	8388363	80	7.20576E+16	113	6.1897E+26
48	16776971	81	1.44115E+17	114	1.23794E+27
49	33554187	82	2.8823E+17	115	2.47588E+27
50	67108619	83	5.76461E+17	116	4.95176E+27
51	134217483	84	1.15292E+18	117	9.90352E+27
52	268435211	85	2.30584E+18	118	1.9807E+28
53	536870667	86	4.61169E+18	119	3.96141E+28
54	1073741579	87	9.22337E+18	120	7.92282E+28
55	2147483403	88	1.84467E+19	121	1.58456E+29
56	4294967051	89	3.68935E+19	122	3.16913E+29
57	8589934347	90	7.3787E+19	123	6.33825E+29
58	17179868939	91	1.47574E+20	124	1.26765E+30
59	34359738123	92	2.95148E+20	125	2.5353E+30
60	68719476491	93	5.90296E+20	126	5.0706E+30
61	1.37439E+11	94	1.18059E+21	127	1.01412E+31
62	2.74878E+11	95	2.36118E+21	128	2.02824E+31
63	5.49756E+11	96	4.72237E+21		
64	1.09951E+12	97	9.44473E+21		

As we can see in Table1, if IP address size is 32-bit, the unsigned blocks are 11. but if we increase the size to 33-bit this will expand the number of unsigned blocks to 267. And so number of unsigned blocks is grows exponentially as the address size increases until it reaches the value of (**2.02824E+31**) blocks for 128-bit address size. This number of blocks is equivalent to address space of (3.402822057984E+38) IP addresses.

5.2. World Population (1950 - 2050)

The World Population numbers issued by international programs which list the world populations for years from 1950 to 2050 [12] contains two parts: a short-term projection to 2050, together with historical population estimates back to 1950. Table2 shows world population for each year.

Table2: Total Midyear Population for the World: 1950-2050 [12]

Year	Population	Year	Population	Year	Population
1950	2,557,628,654	1985	4,855,387,634	2020	7,628,361,509
1951	2,594,919,657	1986	4,939,332,441	2021	7,701,503,831
1952	2,636,732,631	1987	5,025,796,394	2022	7,773,787,217
1953	2,681,994,386	1988	5,113,007,284	2023	7,845,094,405
1954	2,730,149,884	1989	5,199,760,484	2024	7,915,343,988
1955	2,782,001,154	1990	5,287,166,778	2025	7,984,471,678
1956	2,835,182,293	1991	5,370,142,696	2026	8,052,555,718
1957	2,891,211,793	1992	5,455,057,523	2027	8,119,653,594
1958	2,947,979,287	1993	5,537,583,721	2028	8,185,704,067
1959	3,000,544,325	1994	5,618,516,091	2029	8,250,680,127
1960	3,042,828,380	1995	5,699,516,291	2030	8,314,556,118
1961	3,083,799,968	1996	5,779,912,412	2031	8,377,397,726
1962	3,139,919,051	1997	5,858,582,659	2032	8,439,275,616
1963	3,209,631,895	1998	5,936,039,484	2033	8,500,179,665
1964	3,280,981,862	1999	6,013,121,531	2034	8,560,091,213
1965	3,350,186,115	2000	6,089,810,661	2035	8,618,975,745
1966	3,420,416,498	2001	6,166,582,980	2036	8,676,879,132
1967	3,490,051,163	2002	6,243,351,444	2037	8,733,854,464
1968	3,562,007,503	2003	6,319,822,330	2038	8,789,875,606
1969	3,636,825,800	2004	6,396,726,866	2039	8,844,910,290
1970	3,712,338,708	2005	6,473,525,274	2040	8,898,921,851
1971	3,789,941,225	2006	6,551,256,997	2041	8,951,939,549
1972	3,866,158,404	2007	6,629,668,134	2042	9,003,999,017
1973	3,941,664,971	2008	6,708,196,774	2043	9,055,061,670
1974	4,016,159,586	2009	6,786,381,274	2044	9,105,083,460
1975	4,088,619,689	2010	6,863,770,931	2045	9,154,029,673
1976	4,159,715,844	2011	6,940,712,355	2046	9,201,933,427
1977	4,231,636,519	2012	7,017,543,964	2047	9,248,825,693
1978	4,303,675,842	2013	7,095,217,980	2048	9,294,674,737
1979	4,378,583,227	2014	7,172,800,105	2049	9,339,454,816
1980	4,450,924,299	2015	7,250,104,524	2050	9,383,147,855
1981	4,533,807,914	2016	7,327,047,197		
1982	4,613,830,568	2017	7,403,533,981		
1983	4,694,935,057	2018	7,479,340,547		
1984	4,773,643,742	2019	7,554,324,522		

As we can see in the above table, World population growth rose from 2,557,628,654 for year 1950 with growth rate about 1.5 percent per year up to 3,209,631,895 with growth rate about 2.223 percent per year for year 1963, then growth rate start decrease until it reached 0.468 for year 2049 with total population 9,339,454,816. For 13 years growth rate keep increases while the decreasing interval extend to 87 years and expected to keep decreasing after year 2050.

Growth rate formula:

The projection of world population is performed using annual growth rate, where the annual growth rate is calculated for each year using the current and next year population. The growth rate formula for calculating the growth rate for any year is as following:

r(t) = [(P(t+1) – P(t)) / P(t)] * 100 -------------- (eq. 1) [12]

Where:

t: year, r(t): growth rate from midyear t to midyear t+1, P(t): population at midyear t.

5.3. IP Exhaustion Date Prediction

We can obviously note that the relation between IP addresses consumption and world population is proportional. This relation can be strongly proved if we take a look at the table of annual IP addresses consumption and the table of annual world population. And so, we will use the population projection to predict the exhaustion date for several IP address sizes.

First of all, we will derive an equation that we will use in the prediction of IP addresses consumption for next year depending on IP addresses consumption for the current year. In order to do that, we will use population growth rate equation to generate predicted needed address space for years after 2013. The following is IP address consumption prediction equation that we derived assuming that IP consumption growth rate is equal to population growth rate:

IP(t+1) = [(IPr(t) * IP(t))/100] + P(t) ------------------- (2)

Where:

IP(t): allocated IP addresses at year t, IP(t+1): allocated IP addresses at year t+1,
IPr(t): growth rate from midyear t to midyear t+1.

After that, we will use equation (2) to generate expected unsigned IP blocks for each years starting from 2013 to the year corresponding address space that 128-bit IP address can provide. In order to do that we need growth rate of IP address consumption for each year in that range. If we take a look attable 2 we will see how the growth rate of population start decaying from year 1967 and keep decaying to the last year of projection and if we made a long- term projection it expected to decay also to the last year of projection. In other word, the growth rate of the year 2050 is expected to be the maximum growth rate from year 2050 until any year the long term projection will end with. So, for our approximation we will use the growth rate of year 2050 as an approximation for IP growth rate consumption for any year after 2050. This assumption is not the ideal assumption but this paper tries to predict the expected IP address consumption from world population point of view.

5.3.1. Expected Allocated IP Address Blocks (2013 – 16285)

In this part, we will focus on generating the expected needed IP address blocks for years form 2013 until 16285 (figure) as a first step. So we can use these numbers together with Table1 as a base for the generation of the expected exhibition date for different IP address sizes. We accomplish this task by matching the address space that each address size can provide with the expected needed block addresses for each year.

The chart in figure 3 represents the relationship between the number of expected allocated addresses and the year for that allocation. The duration that this figure covers is 14272 years which could be considered as a long term prediction, the importance of this kind of study is based on developing solution for IP address exhibition for thousands and thousands of years.

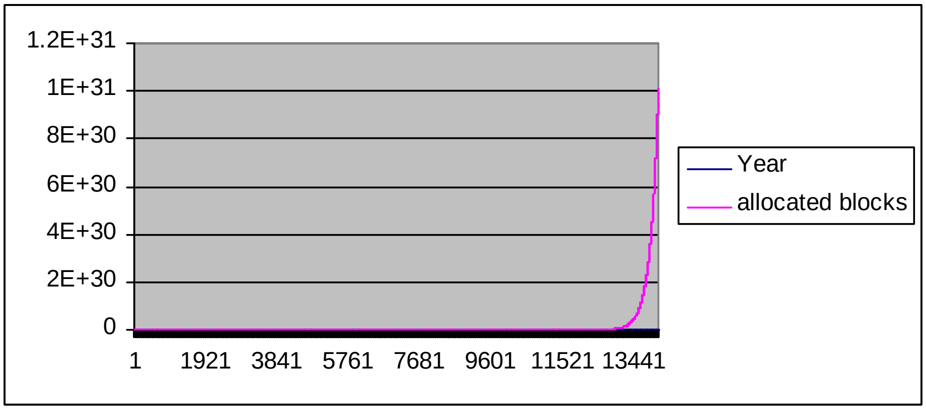
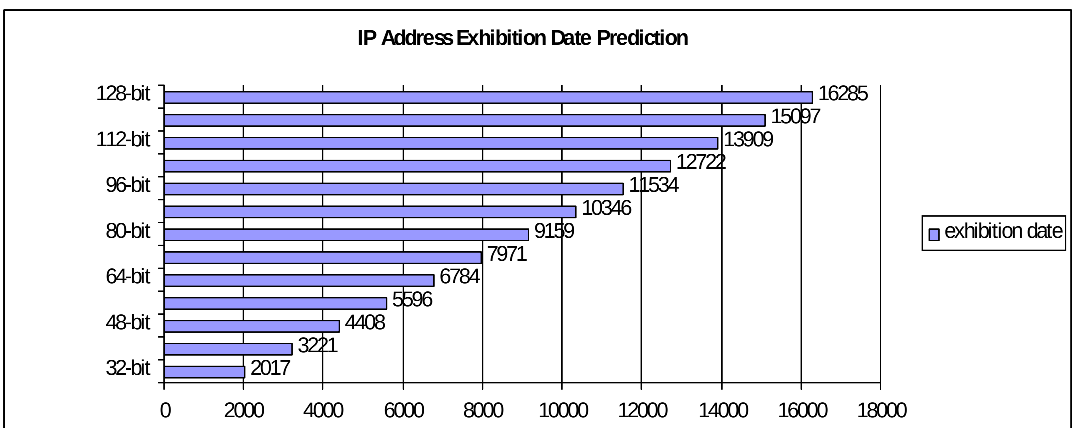


Figure 3: the relationship between the number of expected allocated addresses and the year for that allocation

As we can see in the above figure 3 the number of expected allocated IP address blocks is exponentially increasing towards 1.01047E+31 blocks in year 16136. Also we can note that the number of allocated blocks for the first 1000 years after 2013 increases slowly compared with allocated blocks from 4000 to 16136 which increases from 2486934 to 1.01047E+31 blocks.

5.3.2. Exhibition Date for IP Address of Size N

Now we will use the expected allocated IP address blocks prediction together with available address space for IP address of size N (Table1) to predict the exhaustion of the available address space for an IP address range from 32-bit to 128-bit. (For example, the study predicts that the unassigned address for the 32-bit address space will be exhausted by 2017). In the same way, we will predict when the address space for each IP address size will be exhibited. To cover the range from 32-bit to 128-bit, we pick an interval of 8 bits length between two consecutive addresses size. Figure 4 shows the prediction for this range of addresses size.



	32-bit	40-bit	48-bit	56-bit	64-bit	72-bit	80-bit	88-bit	96-bit	104-bit	112-bit	120-bit	128-bit
exhibition date	2017	3221	4408	5596	6784	7971	9159	10346	11534	12722	13909	15097	16285

Figure 4: prediction for exhaustion of the available address space for an IP address range from 32-bit to 128-bit.

As shown in Figure 4, the number of years that ranging between 32-bit and 128-bit of IP address that can be accommodated is growing up starting from year 2017 for address size 32-bit until the year of 16285 for address size 128-bit with difference equal to 14268 years.

For IP address size 40-bit the exhibition date will be in year 3221, and for the next IP address size in the figure the date becomes 4408. After that, the exhibition date that 56-bit address size will offer is 5596 which means 1188 years more than the previous one and this number increases for 64-bit address size to 2376 years. Then, for 72-bit address size the exhibition date will be 7971 and for 80-bit it will be 9159 which will be increased to 10346 for 88-bit address size. This increase in predicted exhibition date continue for 96-bit where it is 11534 and so on. Finally, for 128-bit address size the exhibition date will jump all the way to 16285.

If we reduce the IPv6 address size from 128-bit to 64-bit, this size can accommodate 18,446,744,069,599,100,000 IPv6 addresses and exhibition date will be at year 6748, which is more than 4000 years from now. So why should we stick to IP address size of 128-bit while 64-bit address size providing reduction of basic header IPv6 packet overhead up to 40% of the packet header total size which is considered as a significant reduction, that will improve the over all IPv6 performance for at least 4000 years.

6. CONCLUSION

This paper explained the need to add some modifications on IPv6 protocol addressing types and size, by determining some addressing type weak points that affect the protocol performance and cause many problems that we could face. At the same time, it discusses its large address size that occupies 80% of IPv6 basic packet header total size. Also, a short study is developed to improve the IPv6 overall performance through the internet by reducing source and destination address size to 64 bit for each one.

For multicast addressing and by a simple comparison between the two multicast addresses discovery protocols MLD and MLD2, it is clear that only MLD2 protocol can be used in modified IPv6 since it can solve serious problems like DDOS attack. On the other hand, for any cast addressing type the paper mentioned major problems that can affect packet exchanging with a group member, then solutions were suggested for most of these problems by either using some restrictions on this addressing type or by implementing it using multicast addressing. This addressing type also was presented as a replacement of limited broadcast addressing since it is more secure. So multicast addressing is the most important addressing type in IPv6 protocol.

Finally, this paper explained the redundancy of waste space that is reserved to IPv6 source and destination addresses and it concluded that it should be reduced. To make that possible we developed a quick study based on IPv4 address report generated at 30-Jan-2013 [7] the remaining addresses in RIR pool and world population projection growth rate including the derivation of new formula that predict IP Address consumption. On the other hand, it shows that choosing 64-bit address size will solve the exhaustion problem. At the same time, this size reduces the overhead in IPv6 packet basic header by 40%. Our study predicts that exhibition date for each IP address size starting by 32-bit and increments this size 8 bits at a time until we reach 128-bits size.

7. REFERENCE:

[1] Charles M. Kozierok, "TCP/IP GUID A COMPREHENSIVE, ILLUSTRATED INTERNET PROTOCOLS REFERENCE", Online: http://nostarch.com/download/tcpip_ch25.pdf, chapter 25, pp.373-381, October 2005.

[2] Daniel Minoli, "IP MULTICAST WITH APPLICATIONS TO IPTV AND MOBILE DVB-H", chapter 10, pp. 215-233, 2008.

[3] Doglase E. Comer, Department of Computer seines, Purdue University, West Lafayette, "Internetworking with TCP/IP Principles, Protocols and Architectures", Fourth Edition, Volume 1, chapter 7, pp. 95-107, 2000.

[4] Hitesh Ballani, Paul Francis, Cornell University, Ithaca, NY, "Understanding IP Anycast", Online: http://pias.gforge.cis.cornell.edu/unpub/any-measure.pdf

[5] Geoff Huston, "IPv4 Address Report", Online: http://www.potaroo.net/tools/ipv4/index.html, 15-June-2010.

[6] Geoff Huston APNIC, "IPv4 Address Utilization", Online: http://www.potaroo.net/papers/2005-03-ipv4.pdf, March 2005.

[7] "IPv4 Address Report", Geoff Huston, Online:http://www.potaroo.net/tools/ipv4/index.html

[8] Microsoft Corporation, Windows server 2008, "Introduction to IP version 6", Online: http://download.microsoft.com/download/e/9/b/e9bd20d3-cc8d-4162-aa60-3aa3abc2b2e9/IPv6.doc, Jan 2008.

[9] Patrick Grossetete, Ciprian P. Popoviciu, Fred Wettling, "Global IPv6 Strategies: From Business Analysis to Operational Planning" Online: http://media.techtarget.com/searchNetworking/downloads/IPv4_or_IPv6.pdf, 1st Edition, chapter 2, pp. 18-53, May 15, 2008.

[10] Samuel Sotillo East Carolina University ss0526@ecu.edu, "IPv6 Security Issues", Online: http://www.infosecwriters.com/text_resources/pdf/IPv6_SSotillo.pdf, 2006.

[11] Sean Convery ***(sean@cisco.com)***, Darrin Miller ***(dmiller@cisco.com)***, **"**IPv6 and IPv4 Threat Comparison and Best Practice Evaluation (v1.0)***"***, 2004.

[12] "World Population, Online: http://www.census.gov/population/international/data/worldpop/table_population.php Source: U.S. Census Bureau International Database.

[13] IPv6 Headers", Online: http://www.cu.ipv6tf.org/literatura/chap3.pdf, chapter 3, pp. 40-55, Des 12 1997.