Combinatorial Theorem in Determining IPv6 Address's Lifetime

Reno Rasyad (13511045)[1]
Program Studi Teknik Informatika
Sekolah Teknik Elektro dan Informatika
Institut Teknologi Bandung, Jl. Ganesha 10 Bandung 40132, Indonesia
[1]*reno.rasyad@students.itb.ac.id*

***Abstract*— An IP address is a row of binary numbers used as identification address for each computer in the Internet. In simple words, the IP address is the standard that regulate how and through which way, packets of information sent from the Internet or intranet. In 1977, the designers of the Internet Protocol defined an IP address as a 32-bit number and known as Internet Protocol version 4 (IPv4). It means, the IPv4 has 2^{32} or 4.294.967.296 (4 billions) addresses However, due to the enormous growth of the Internet and predicted depletion of available addresses, a new version of IP (IPv6) was developed in 1995, using 128-bit for the addresses. And now in 2012, the IPv6 has been launched officially, because the IPv4 is undergoing 'exhaustion'. The question is, do we need 'another IP version' in the future? If yes, when? In this paper, we're about to calculate the IPv6 address's lifetime using Combinatorial Theorem.**

***Index Term*—*Internet Protocol, Combinatorial,* IPv6 *Lifetime*.**

I. Introduction

"When I took office, only high energy physicists had ever heard of what is called the World Wide Web... Now even my cat has it's own page." –Bill Clinton

That is quote from the 42nd U.S. President, Bill Clinton. From that line, we know that today, the growth of the Internet is rapidly fast. In 1969, the internet was established by ARPANET, the project of U.S. Department of Defense for military purposes. Because of the high demand of the internet and to access it easily, in 1977 the U.S. Department of Defense built a protocol based on 32-bit number for experimental purposes. That gives 2^{32} or 4.294.967.296 addresses for all devices to access the internet and called IPv4.

They thought the address was enough to support the necessity for internet access, until 2009, IANA (*Internet Assigned Number Authority*) –the organization that manage the use of internet protocol parameter like IP, DNS, etc– predict that the stock of IPv4 address will be run out in the middle of 2012. But, in January 2011, IANA has run out of IPv4 address stock and the IP address stock now depend on RIR (Regional Internet Registry) that manages the allocation and registration of Internet number resources within a particular region of the world. The RIR divided into 5 regions:

- African Network Information Centre (AfriNIC) for Africa
- American Registry for Internet Numbers (ARIN) for the United States, Canada, several parts of the Caribbean region, and Antarctica.
- Asia-Pacific Network Information Centre (APNIC) for Asia, Australia, New Zealand, and neighboring countries
- Latin America and Caribbean Network Information Centre (LACNIC) for Latin America and parts of the Caribbean region
- Réseaux IP Européens Network Coordination Centre (RIPE NCC) for Europe, Russia, the Middle East, and Central Asia

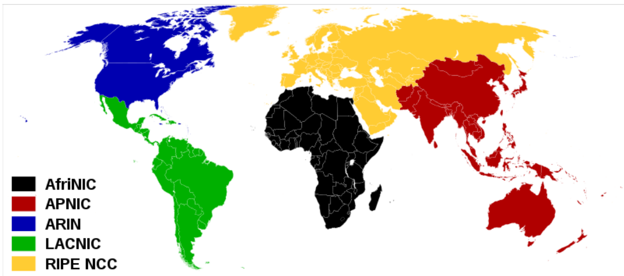

Fig. 1. Map of Regional Internet Registries

Unfortunately, on April 2011, the APNIC has only 1/8 block of IP addresses remaining (1 block consist of 16,7 millions addresses). And for the region that mostly consist of developing countries, the IP address for Asia-Pasific region will decreases rapidly.

Therefore, to encounter this problem, we must switch to IPv6 that has 2^{128} addresses.

II. Basic Theory

2.1 Combinatorics

Combinatorics is the study of collections of objects. Specifically, counting objects, arrangement, derangement, etc. of objects along with their mathematical properties. Counting objects is important in order to analyze algorithms and compute discrete probabilities.

If two events are not mutually exclusive (that is, we do them separately), then we apply the product rule.

Theorem (Product Rule)

Suppose a procedure can be accomplished with two disjoint subtasks. If there are n1 ways of doing the first task and n2 ways of doing the second, then there are

$$n1 \cdot n2$$

ways of doing the overall procedure.

If two events are mutually exclusive, that is, they cannot be done at the same time, then we must apply the sum rule.

Theorem (Sum Rule)

If an event e1 can be done in n1 ways and an event e2 can be done in n2 ways and e1 and e2 are mutually exclusive, then the number of ways of both events occurring is

$$n1 + n2$$

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2.2 Internet Usage Statistics

Since the Personal Computer (PC) became famous all over the world on late 1980s, the Internet grew rapidly, until now.

This is the world internet growth statistic, provided by Miniwatts Marketing Group, the worldwide internet market researcher.

DATE	NUMBER OF USERS	% WORLD POPULATION	INFORMATION SOURCE
December, 1995	16 millions	0.4 %	IDC
December, 1996	36 millions	0.9 %	IDC
December, 1997	70 millions	1.7 %	IDC
December, 1998	147 millions	3.6 %	C.I. Almanac
December, 1999	248 millions	4.1 %	Nua Ltd.
March, 2000	304 millions	5.0 %	Nua Ltd.
July, 2000	359 millions	5.9 %	Nua Ltd.
December, 2000	361 millions	5.8 %	Internet World Stats
March, 2001	458 millions	7.6 %	Nua Ltd.
June, 2001	479 millions	7.9 %	Nua Ltd.
August, 2001	513 millions	8.6 %	Nua Ltd.
April, 2002	558 millions	8.6 %	Internet World Stats
July, 2002	569 millions	9.1 %	Internet World Stats
September, 2002	587 millions	9.4 %	Internet World Stats
March, 2003	608 millions	9.7 %	Internet World Stats
September, 2003	677 millions	10.6 %	Internet World Stats
October, 2003	682 millions	10.7 %	Internet World Stats
December, 2003	719 millions	11.1 %	Internet World Stats
February, 2004	745 millions	11.5 %	Internet World Stats
May, 2004	757 millions	11.7 %	Internet World Stats
October, 2004	812 millions	12.7 %	Internet World Stats
December, 2004	817 millions	12.7 %	Internet World Stats
March, 2005	888 millions	13.9 %	Internet World Stats
June, 2005	938 millions	14.6 %	Internet World

			Stats
September, 2005	957 millions	14.9 %	Internet World Stats
November, 2005	972 millions	15.2 %	Internet World Stats
December, 2005	1,018 millions	15.7 %	Internet World Stats
March, 2006	1,023 millions	15.7 %	Internet World Stats
June, 2006	1,043 millions	16.0 %	Internet World Stats
Sept, 2006	1,086 millions	16.7 %	Internet World Stats
Dec, 2006	1,093 millions	16.7 %	Internet World Stats
Mar, 2007	1,129 millions	17.2 %	Internet World Stats
June, 2007	1,173 millions	17.8 %	Internet World Stats
Sept, 2007	1,245 millions	18.9 %	Internet World Stats
Dec, 2007	1,319 millions	20.0 %	Internet World Stats
Mar, 2008	1,407 millions	21.1 %	Internet World Stats
June, 2008	1,463 millions	21.9 %	Internet World Stats
Sept, 2008	1,504 millions	22.5 %	Internet World Stats
Dec, 2008	1,574 millions	23.5 %	Internet World Stats
Mar, 2009	1,596 millions	23.8 %	Internet World Stats
June, 2009	1,669 millions	24.7 %	Internet World Stats
Sept, 2009	1,734 millions	25.6 %	Internet World Stats
Dec, 2009	1,802 millions	26.6 %	Internet World Stats
June, 2010	1,966 millions	28.7 %	Internet World Stats
Sept, 2010	1,971 millions	28.8 %	Internet World Stats
Mar, 2011	2,095 millions	30.2 %	Internet World Stats
Jun, 2011	2,110 millions	30.4 %	Internet World Stats
Sept, 2011	2,180 millions	31.5 %	Internet World Stats
Dec, 2011	2,267 millions	32.7 %	Internet World Stats
Mar, 2012	2,336 millions	33.3 %	Internet World Stats
June, 2012	**2,405 millions**	**34.3 %**	Internet World Stats

2.3 World Population Growth

Based on U.S. Census Bureau, now we have 7 billion people on earth, and still rising.

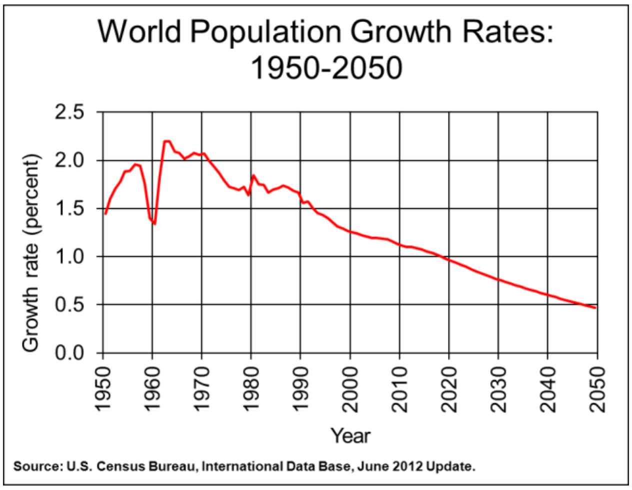

Fig. 2.3.1. World Population Growth Rates

From the picture above, we can see the world population growth rate. If we take the average, the growth rate is 1,10% per year.

III. Application

From the table above, we can calculate the average world international growth. First we calculate per-year average:

1995 : 0.4% world population
1996 : 0.9% (rise 0.5%)
1997 : 1.7% (rise 0.8%)
1998 : 3.6% (rise 1.9%)
1999 : 4.1% (rise 0.5%)

Q1 2000 : 5.0%
Q2 2000 : 5.9%
Q3 2000 : 5.8%
Average 2000 : 5.56% (rise 1.46%)

Q1 2001 : 7.6%
Q2 2001 : 7.9%
Q3 2001 : 8.6%
Average 2001 : 8.03 (rise 2.47%)

Q1 2002 : 8.6%
Q2 2002 : 9.1%
Q3 2002 : 9.4%
Average 2002 : 9.03% (rise 1%)

Q1 2003 : 9.7%
Q2 2003 : 10.6%
Q3 2003 : 11.1%
Average 2003 : 10.46% (rise 1.43%)

Q1 2004 : 11.5%
Q2 2004 : 11.7%
Q3 2004 : 12.7%
Average 2004 : 11.96% (rise 1.5%)

March 2005 : 13.9%
June 2005 : 14.6%
September 2005 : 14.9%
November 2005 : 15.2%
Desember 2005 : 15.7%
Average 2005 : 14.86 (rise 2.9%)

Q1 2006 : 15.7%
Q2 2006 : 16.0%
Q3 2006 : 16.7%
Average 2006 : 16.13 (rise 1.27%)

March 2007 : 17.2%
June 2007 : 17.8%
September 2007 : 18.9%
Desember 2007 : 20.0%
Average 2007 : 18.47 (rise 2.34%)

March 2008 : 21.1%
June 2008 : 21.9%
September 2008 : 22.5%
Desember 2008 : 23.5%
Average 2008 : 22.25% (rise 3.78%)

Q1 2009 : 24.7%
Q2 2009 : 25.6%
Q3 2009 : 26.6%
Average 2009 : 25.63% (rise 3.38%)

June 2010 : 28.7%
September 2010 : 28.8%
Average 2010 : 28.75% (rise 3.12%)

March 2011 : 30.2%
June 2011 : 30.4%
September 2011 : 31.5%
Desember 2011 : 32.7%
Average 2011 : 31.2% (rise 2.48%)

March 2012 : 33.3%
June 2011 : 34.3%
Average 2012 : 33.8% (rise 2.6%)

From this calculation, we obtained that the user of internet has risen 1.96% per year (assuming that the world population are 7 billion)

If we assume that the average increase rate of internet users will always be 1.96% of world population per year, then we have approximately 51 years from 1995 to give all world population an internet access. That's year 2046.

Now that IPv6 has 2^{128} addresses, that gives 340,282,366,920,938,463,463,374,607,431,768,211,456 addresses, or 3.4×10^{38}. If the world population are 7×10^9, by 2046, every people in the world has $3.4 \times 10^{38} / 7 \times 10^9$ addresses or 4.85×10^{28}. That's plenty.

If we want to calculate, when will 1 person only have 1 address, then the population of the world must be 3.4×10^{38}. Based on the average world population growth rates (1,10% per year), the world population will reach 3.4×10^{38} on 4.85×10^{30} years from now.

IV. Conclusion

The world now mostly depends on internet because it's the fastest and most efficient way to share information. Devices connect to the internet using an IP address to ensure that the information is sent to correct requester.

But, we once 'fail' to predict the demand of the IP address, the IPv4. Now that the IPv6 officially launched to public, we have to ensure that the IPv6 will be enough to maintain the demand of the internet users. Therefore, we use the combinatorial theorem to ensure that IPv6 can be used for a long time.

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PERNYATAAN

Dengan ini saya menyatakan bahwa makalah yang saya tulis ini adalah tulisan saya sendiri, bukan saduran, atau terjemahan dari makalah orang lain, dan bukan plagiasi.

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Reno Rasyad (13511045)