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On the Identification Protocols of Versions 4 and 6

Mustafa A. Salman
Ajman University of Science and Technology

ABSTRACT: *In this paper, a new method for assigning addresses for the Identification Protocols of version 4 and version 6 have been introduced which makes the addresses space compact and the generation of a new address by a host is direct with no need for algorithm to check the uniqueness of the new address. The method of representing addresses of the Identification Protocol of Version 6 is presented to be compatible to that been used for version 4 which makes it convenient to define a 1-1 injective function from IPv4 space to IPv6 space and a direct consequence of that the IPv4 space becomes isomorphic to a subspace of the IPv6 space. This means there is no need for exchange process of addresses between the two versions that is no need for Gateway Algorithm or any other translation algorithm. The output of these processes is a reduction of the number of used algorithms by omitting the Duplicate Address Detection Algorithm and the translation technology algorithms and eases the process of generating new addresses, using a minimum number of bits, to satisfy future demands for internet devices or objects.*

KEY WORDS*: object; IPv4; IPv6; identification protocol; Duplicate Address Detection Algorithm; exchange addresses; 1-1 invertible function.*

I. INTRODUCTION

The two Identification Protocols of version 4 (IPv4) and version 6 (IPv6) are the recent protocols that have been used for the Internet of Things (IoT) and for any network. Identification Protocol (IP) is a communication protocol that deals with the identification and location of a device or object in the internet or in a network and a thing in the IoT is an object that is capable of sensing, communicating, and interacting with the environment (sensor, computer, source, … etc). The work with The IoT is directed toward having a smart society that is a society on which every things senses, communicates, and interacts with the environment such as homes, cars, road, air, science, education, business, communication, … etc [1, 2]. An internet or network that connect all objects in the world certainly needs a unique address for each object together with other needs such as privacy, security, coding, ... , etc . Billions of objects exchanging and storing data between them is carried out by both identification protocols IPv4 and IPv6 although till yet majority of objects deal with the IPv4 but IPv6 is the identification protocol of the future because of the large capacity that has for addresses. Deployment of IPv4 and IPv6 in IoT faces many challenges, among them, the limited addresses space of IPv4, (32 – dimensional vector space), while the number of users of the internet and objects connected to the internet is growing rapidly in billions which is expected to be out of the addresses space of IPv4 soon. Also the generation of new addresses needs a check for uniqueness which is performed by an algorithm (Duplicate Address Detection Algorithm) and the addresses exchange between IPv4 and IPv6 identification protocols, needs some translation algorithms since the recent identification protocols IPv4 and IPv6 are not simultaneously compatible.

II. THE IDENTIFICATION PROTOCOL IPV4

IPv4 was the first identification protocol used, worldwide, in the internet. In September 1981, a version of IPv4 published to replace earlier one. On May 2014, the IPv4 was responsible for 96% of traffic of internet worldwide [1, 2, 3], but with the highly increased number of new objects to be connected to the internet, the IPv4 seemed to be not capable of satisfying all future demands for new objects, since every object must have an IP address for identification and location.Mathematically, IPv4 can be regarded as a 32-dimensional vector space over a binary field GF(2). It consists of 32-bit binary sequences, so the number of available addresses will be (2^{32}) which provides approximately 4.3 Billion addresses for objects to be connected to the internet. The 32-bit sequences of IPv4 is partitioned to four octets, each octet is a binary sequence of eight bits, which is represented by a decimal number ranging from 0 to 255. An example of such address could be

10011100 01010001 00110000 00001111 which is represented by
156 81 48 15

That is a binary number 10011100 = 156 decimal number and 01010001 = 81 decimal number and so on.

IPv4 addresses space is embedded in IPv6 space in a natural function in which the first 32 bit (least significant bit) will be IPv4 address then followed by a 16 bit of one's and the remaining 80 bit all set to zeroes and that sum up to 128 bit, the length of the binary sequence in the IPv6 addresses space. The problem of this injection is the non-uniform set of sequences of the addresses of IPv4. IPv4 space has two kinds of addresses local and global, which put more difficulty on exchanging addresses and generating new address because the possibility of having duplicate addresses.

III. THE IDENTIFICATION PROTOCOL IPV6

The IPv6 was defined by1996, and formally published on December 1998, [8]. IPv6 is a 128-dimensional vector space over a binary field GF(2). It consists of 128-bit binary sequences, which provide 2^{128} address of the 128-dimensional space of addresses. Since $2^{10} = 1024 > 10^3$ then this huge number 2^{128} is approximately (3.4×10^{38}). That is, IPv6 provides this amount of addresses for objects connected to the internet. The method of representation of addresses in IPv6 is different than, that used for IPv4.The 128-bit sequence of the identification protocol, IPv6 is partitioned to eight groups of four hexadecimal digits (128 = 8 x 16). For example,

2211: 02ab: 00ef: 85a1: 1000: 39cd: 0274: 2160

is one of the representation of 128-bit sequence (address) of IPv6.

In the above representation, each digit is a hexadecimal (4 bits) that is a hexadecimal number "02ab", represents " 0000 0010 1010 1011" binary number (sequence), and the hexadecimal number " 39cd " is represented by the binary number "0011 1001 1100 1101, [4, 5, 6]. In general

0 → 0000, 1 → 0001, 2 → 0010, … , 9 → 1001, a → 1010, b → 1011, … , f → 1111.

The identification protocol, IPv6 has features not present in IPv4. Some of these, the host identifier portion of the 128 bit address is fixed by 64 bit, provide source to destination data transmission across multiple IP network in a single operation, security was considered in the design, and hosts can configure themselves automatically when connected to an IPv6 network, and so on [7, 8].

In IPv6, a packet has two parts, a header and payload. The header consists of a fixed portion with minimum number of functions required for all packets. It contains a source address, destination address, traffic classification options and the type of payload follows the header, [7, 9, 10].

The headers of IPv4 packets and IPv6 packets are different because the two protocols are not compatible. To exchange traffic between IPv4 and IPv6, a gateway or translation technology is required such as tunneling protocol, [4].This is one of the problems that this paper is dealing with.

IPv6 permits any host to generate an IP address and check whether it is unique or not. Checking the uniqueness of an address is performed by, the Duplicate Address Detection Algorithm. In these processes, the host will send a message asking for the Link-Layer address of the assumed new IP address. If there is another host using that address then it will respond, otherwise it will be regarded new IP address, [7, 9, 10]. That is, another problem, this paper is dealing with.

IV. NEW METHOD FOR ASSIGNING ADDRESSES FOR IPV4 SPACE

As indicated in the above section, generating new address by a host needs to run the Duplicate Address Detection Algorithm since the set of the IP addresses of the IPv4 is not a compact set. By a uniform set, in this paper, it meant a set of ascending sequences on which each term is more than the previous one. In other word, it is a set of increasing sequences. A compact set of sequences, in this paper, means a uniform sequence on which each term is more than the previous term by 1.

Let A be the set of all the recent addresses of the IPv4, and let (n +1) be the number of these addresses.

Clearly $n < 2^{32}$

Hence $A = \{ v_i : v_i = (a_{31}\, a_{30} \ldots a_1\, a_0) \}$, where $a_j \, \varepsilon \, \{0,1\}$, $i = 0, 1, \ldots , n$.

Re-order the elements (32-bit binary sequence) in A, to have a set of ascending elements with respect to the decimal value of the 32-bit binary numbers of the elements (addresses).

Let B be the produced set of addresses after re-ordering the elements of A in ascending order.

Then $B = \{ u_i : u_i = (b_{31}\, b_{30} \ldots b_1\, b_0) \}$, where $b_j \, \varepsilon \, \{0,1\}$, $i = 0, 1, \ldots , n$

Clearly, as binary numbers $u_i \leq u_{i+1}$ since IPv4 have local and global addresses which may suggest a possibility of repeated addresses.

Assign to each 32-bit binary number, the equivalent decimal number as shown below:

00000000 00000000 00000000 00000000 → 0
00000000 00000000 00000000 00000001 → 1
00000000 00000000 00000000 00000010 → 2
00000000 00000000 00000000 00000011 → 3
.
.
11111111 11111111 11111111 11111111 → $2^{32} - 1$

Transform the addresses in B to new distinct addresses as follows:

$u_i \rightarrow$ i decimal = 32-bit binary sequence w_i . That is

$u_0 \rightarrow$ 0 decimal = 32-bit binary sequence w_0 , where

w_0 = 00000000 00000000 00000000 00000000

$u_1 \rightarrow$ 1 decimal = 32-bit binary number (sequence) w_1, where

w_1 = 00000000 00000000 00000000 00000001

$u_2 \rightarrow$ 2 decimal = 32-bit binary sequence w_2, where

w_2 = 00000000 00000000 00000000 00000010

.

.

$u_n \rightarrow$ n decimal = 32-bit binary sequence w_n .

Then the new addresses set W = { w_i : i = 0, 1, 2, … , n } is a compact set consists of ascending binary sequences whose numerical values from 0 to n and $w_{i+1} = w_i + 1$.

Hence, the set, A, of the recent addresses of the IPv4, has been transformed, to the compact set W.

Since new addresses as binary numbers range from 0 to n as decimal numbers then a new address generated by host will be the 32-bit sequence whose decimal value, is (n + 1) with no need to check for duplication.

These processes of assigning new addresses, for the recent addresses of the IPv4, done one times only. The output will be having a compact uniform set of addresses that makes it possible to generate new addresses easily, without checking for duplication, and all addresses will be global, since all new addresses been given different addresses in the compact set. Unless IPv4 has exhausted more than half of the space capacity of the IPv4, the most significant bits will be zeroes.

V. EMBEDDING THE IDENTIFICATION PROTOCOLS IPV4 IN IPV6

The recent representation of IPv6, as mentioned in section 3, is an eight group of four hexadecimal. This means the 132 bit of the addresses of the IPv6 is partitioned to 8 parts, each part consists of 4 digits and each digit consists of 4 bits. This is not convenient for compatibility with IPv4.

Since 128 = (8 x (4 x 4)) = (8 x 16) = (16 x 8)

Then, the 132- bit of the IPv6, could be partitioned to 16 octets similar to that used for IPv4. The four least significant octets will be left for addresses of the IPV4, which will be done by a natural 1 – 1 injective function as shown below:

Let w_i be an address in the compact space of IPv4.

Then $w_i = c_3\, c_2\, c_1\, c_0$, where c_i is an octet of number i .

Define an injective function f: IPv4 space $\rightarrow$ IPv6 space such that

$f(w_i) = 0_{15}\, 0_{14}\, 0_{13}\, 0_{12}\, 0_{11}\, 0_{10}\, 0_9\, 0_8\, 0_7\, 0_6\, 0_5\, 0_4\, c_3\, c_2\, c_1\, c_0$ where 0_i is an octet of zeroes.

This is a natural embedding function of IPv4 addresses into IPv6 space. Clearly, the addresses of the IPv4 occupy 32 bit or less and the rest bits will be zero, which suggests that the addresses of IPv6 occupy the complement of these addresses. This means IP6 may have new 128- bit addresses in the same way of the addresses of IPv4 but starting from the address whose numerical value is 2^{32} and the second will have the numerical value $2^{32} + 1$ and so on. Considering the numerical value of addresses of IPv6, the first address h_0 will have 1 in the 33[rd] bit and the rest bits will be zero, $h_1 = h_0 +1$, $h_2 = h_1 +1$, . . . , $h_{i+1} = h_i +1$, . . . , $h_{m+1} = h_m + 1$, where m+2 is the number of addresses of IPv6. Clearly IPv6 addresses set will be compact and this method of assigning addresses to both IPv4 and IPv6 will divide them to two portion one for addresses whose numerical value less than 2^{32} for IPv4 addresses and the other for addresses whose numerical value more than or equal 2^{32} for IPv6 addresses. This results that IPv4 space is an isomorphic to a subspace of the vector space IPv6. That is the IPv4 subspace, is embedded in the IPv6 space, and then having same pattern. The differentiation between them depends on the numerical value of the addresses. Hence, the IPv6 will start having addresses starting from h_0 that represents a binary number of 128 bit of zeroes except the 33[rd] bit is one as shown below:

$0_{15}\ 0_{14}\ 0_{13}\ 0_{12}\ 0_{11}\ 0_{10}\ 0_9\ 0_8\ 0_7\ 0_6\ 0_5$ (0000 0001) $0_3\ 0_2\ 0_1\ 0_0$

The successor $h_1 = h_0 + 1$ will be

$0_{15}\ 0_{14}\ 0_{13}\ 0_{12}\ 0_{11}\ 0_{10}\ 0_9\ 0_8\ 0_7\ 0_6\ 0_5$ (0000 0010) $0_3\ 0_2\ 0_1\ 0_0$

And so on.

Clearly, the above embedding function and the new addresses for both IPv4 and IPv6 will results that there will be no need for exchanges traffic between IPv4 and IPv6 since IPv4 became a subspace of IPv6 space. Also no need for gateway, tunneling protocol, or any other exchange algorithms. Addresses of the IPv6, will have some non- zero bits in the fifth octets or successors of the fifth, while addresses of IPv4 will be limited to the 32 or less least significant bits. If IPv4 is not exhausted, then a new addresses will be assigned as $f(w_{n+1})$ which is the successor of the last one $f(w_n)$ otherwise a new address will be assigned h_{m+2} and so on. Having compact spaces for both IPv4 and IPv6 will reduces the number of bits that used for addresses. In [11, 12], the eight least significant octets (64 bit) left for addresses of IPv6 is shown too much and a 51-bit sequence is sufficient for all addresses needed in future, in the most exaggeration case, up to year 2100. Regarding this, a 51- bit is more than enough, for addresses up to year 2100, and this will leave 51 – 32 = 19 bit for recent and new addresses of IPv6. Also a 64 – 51 = 13 bit left for error detection and error correction codes or any other requirement for addresses sequences.

VI. CONCLUSION

This paper studied the recent identity protocols IPv4 and IPv6 and suggested a new method for assigning addresses for both IPv4 and IPv6 in such a way that, a new address, directly produced with no requirement of checking for duplication. This is because the produced sets of addresses of both IPv4 space and IPv6 space are compact and this will ease these processes. A different method of representation of addresses of IPv6, convenient to the representation of addresses of IPv4 was introduced which suggest a direct invertible 1 – 1 injective function from IPv4 space into the IPv6 space. The output of this is a direct generation of addresses with no need for Duplicate Address Detection Algorithm and no need for exchanging traffic between IPv4 and IPv6 since IPv4 will be a subspace of IPv6 space. It means no need for Gateway, or translation technology such as tunneling algorithms or others. Also the new method for assigning addresses will produce, a compact sets of addresses for both IPv4 and IPv6 that occupy no more than 51 bit up to the year 2100 which leave at least 13 bit for other uses such as error correction or detection codes.

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