Providing the IPv4 Addresses Utilization to RPX

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Abstract – As the limited IPv4 address space has made the cellular industry that decided to start using IPv6 for the mobile users in 3G-network. However, there is a potential threat to the success of 3G-network deployment, as the success will depend on the services offering to the end users. These services all reside in the current IPv4 address space, which make them inaccessible to the users that will reside in the IPv6 address space. Previous studies on network address translation have shown that the REBEKAH-IP with Port Extension, RPX is promising in that it provides excellent scalability and also supports all types of services without limitation for the mobile users in cellular network.

In this paper, we propose a method that enables to evaluate the performance of RPX scheme in terms of scalability and number of public IPv4 addresses utilization. We provide a mathematical model as a guideline to determine the range of public IPv4 addresses allocated to an RPX gateway in a cellular network. In addition, we present all results on the practical scalability of RPX through the mathematical analysis and simulations.

Keywords – IPv4, IPv6, Mobile terminals

I. INTRODUCTION

The cellular industry has decided to use the next generation IP, IP version 6 [1], since the current version of IP, IP version 4, has a limited address space [2] with the growth of the number of IP enable devices. However, it has been shown that IPv6 will not solve the immediate problem because these terminals will not be able to directly communicate with IPv4 terminals and access fixed Internet services, which reside in the IPv4 address space. Therefore, there have been numerous proposals for translating and providing connectivity between the two protocols until IPv6 has been widely deployed in the fixed Internet.

One of these proposals called Realm Base Kluge Address Heuristic-IP. REBEKAH-IP [3, 4] has been shown great potential that it is scalable and does not limit the services that can be offered to IPv6 terminals from the public Internet. Furthermore, REBEKAH-IP with Port Extensions, RPX [5-7] was introduced to improve REBEKAH-IP in terms of scalability and then can be eliminated the problem of call blocking from the initial REBEKAH-IP. RPX scheme proposed to incorporate centralized management of both IP addresses and port numbers for the IPv6 terminals to use for the socket. Once, it has been shown the RPX is promising in that it provides excellent scalability and also meets some demands of cellular network.

However, the scalability of RPX will depend on a set of number of publicly available IPv4 addresses to RPX server. Therefore, this paper presents a mathematical model that allocates the expected number of IPv4 addresses utilization to RPX server in cellular network. This utilization is computed in terms of the probability of socket open requests from mobile terminals, the probability of call blocking and the estimated number of mobile terminals at the network initialization phase.

The rest of the paper is organized as follows. Section II details the original REBEKAH-IP proposal and the extension in RPX. Then, we provide the mathematical model used to determine the expected number of public IPv4 addresses utilization in the network together with simulation results in Section III. Finally, the conclusion is presented in Section IV.

II. OVERVIEW OF REBEKAH-IP

REBEKAH-IP server (RS) [3, 4] illustrated in Fig. 1, is provided the mechanism from two existing NAT proposals, RSIP and Bi-directional NAT [8], and extends the combination of Layer 3 and Layer 4 switching functions. The scalability of REBEKAH-IP far surpasses those of previous NAT proposals since rather than switching traffic based on only a parameter pair (destination IP address and sender port number), it uses a four-tuple (sender and receiver IP address and port numbers). Therefore, in this scheme a pool of public IPv4 addresses is used to configure private terminals while allowing the public IPv4 addresses to be reused as long as the combination is unique as the identifier for a single flow.

Consider the following operational scenario, terminal A/RC connects to a REBEKAH-IP server and request to be assigned a public IPv4 address. The server obtains address x.x.x.x from the DNS function and assigns it to

A/RC. The selection process is simple. The DNS has a pool of public IPv4 addresses and it selects addresses from this pool in a round-robin fashion. When terminal B/RC requests a public IPv4 address, the DNS function is able to pick and assign the same address x.x.x.x to B/RC. Therefore, more than one private terminal can be configured with a single public address simultaneously. The scheme takes into account the four socket parameters (source and destination IP addresses and port numbers) rather than only IPv4 addresses for routing purposes.

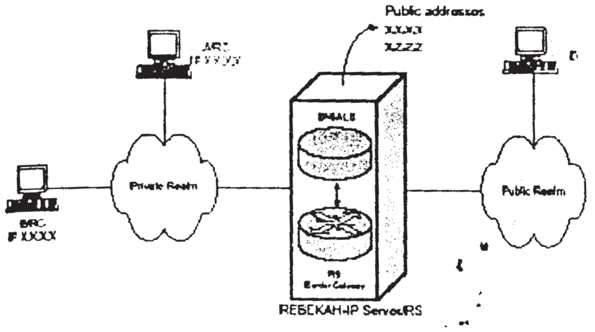

Figure 1: All components of REBEKAH-IP Server.

REBEKAH-IP with Port Extension (RPX) [5] was proposed to incorporate centralized management of both IPv4 addresses and port numbers, that is solved the problem with of the original REBEKAH-IP scheme from the usage of ephemeral ports when applications open sockets. Since there is no control over the port allocation, it is impossible for REBEKAH-IP to predict the sender port a terminal will use for a certain flow. The RPX eliminates the ambiguity problem from the initial REBEKAH-IP scheme and unambiguously support a maximum of $(2^{16} - 1024) \times N_{IP} \times (2^{32} - N_{IP}) \times (2^{16} - 1024)$ simultaneous flows, where, N_{IP} is the number of public IPv4 addresses available to the RPX server. The reader is referred to [3-5] for additional details on REBEKAH-IP and RPX.

III. System Description And Design

In order to evaluate the performance of RPX scheme in terms of scalability [5], it can be seen that the scalability of the RPX will depend on the number of public IPv4 addresses (N_{IP}) that are allocated to the RPX DNS. Therefore, the purpose of this section is to determine the range of public IPv4 address utilized by an RPX server in a cellular network. This utilization is computed in terms of the probability of socket open requests from mobile terminals, the probability of call blocking and the estimated number of mobile terminals at the network initialization phase as the main factors to estimates IPv4 addresses utilization. In addition, the results are presented through a set of simulations.

A. Providing the number of public IPv4 addresses utilization

In our model, there are two different areas, namely connected area and disconnected area. In the connected area, it has wireless infrastructure that mobile terminals are able to access the network service under its coverage area. It also has a dedicated RPX server (RS) acting as border gateway. The disconnected area does not have any wireless coverage for mobile terminals. We assumed that mobile terminals are free to move between different areas. Finally, we assumed that all connected areas are analogous to sub-networks in IP terminology and also belong to a common administrative domain as shown in Fig. 2.

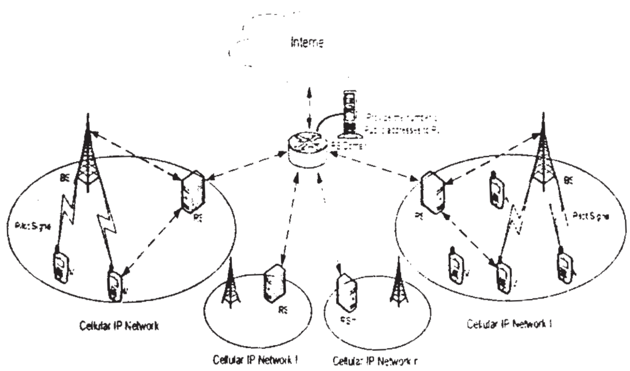

Figure 2: System design for distributing RPX servers

As the RPX servers are distributed among the sub-networks, the operator needs to manage and allocate a subset of the publicly available IPv4 address pool to each server in each sub-network. The allocation method depends on the probability of requests, the probability of call blocking and the estimated number of mobile terminals within the sub-network.

Assume there are a total of N mobile terminals in the network domain and let N_j be the total number of mobile terminals within sub-network j with the condition $1 \leq N_j \leq N$. The handoff frequency for a new terminal and the probability of the mobile terminal moving out of the network are assumed equal at the network initialization phase. Therefore, we only need to calculate the expected public IPv4 addresses utilization for network j by considering the estimated number of existing terminals within the area. Given that the probability of requests for assigning addresses and port numbers, $P_{r,j}$ is equal among all mobile terminals so that the probability of call blocking, $P_{B,j}$ is given by:

$$P_{B,j} = \begin{cases} 1 - \dfrac{N_A}{N_R} & , for\ N_R > N_A \\ 0 & , otherwise \end{cases} \quad (1)$$

Where N_A is the maximum number of unambiguously supported flows by the RPX scheme and N_R is the total number of requests from the mobile terminals in the network j.

We express the number of public IPv4 addresses a sub-network j utilizes as follows. Let the average rate for opening new sockets be λ, the average socket holding time be t and the port range for each public IPv4 address be m.

Equation (1) then could be written as a function of the expected public IPv4 addresses utilization as follows:

$$N_{IP,j} = \frac{K \cdot N_j}{2^{32} \cdot m^2} \cdot \left(1 - P_{B,j}\right) \qquad (2)$$

Where N_{IPj} is the expected public IPv4 addresses utilization for network j and $K = \lambda t P_{r,j}$.

In addition, if number of connections would be made to the same server process (and the server can handle an unlimited number if connections), then the equation as in (2) would be become:

$$N_{IP,j} = \frac{K \cdot N_j}{m} \cdot \left(1 - P_{B,j}\right) \qquad (3)$$

In reality, the expected public IPv4 addresses utilization for sub-network j will be varied in-between the two equations, as in (2) and (3). Thus, these equations provide the upper and lower bounds of the expected number of public IPv4 addresses that the network operator will assign to each RPX server to support mobile terminals in each sub-network.

B. Simulation results

In order to obtain realistic input values to the mathematical model, we examined traffic using parameters from previous work [3]. The average number of sockets opened per second and the average socket holding time for a mobile terminal were 0.015 and 17 seconds respectively. In addition, the available number of ports for each IPv4 address was $2^{16} - 1024$ as specified in [9].

Fig. 3 shows the number of utilized public IPv4 address ($N_{IP,j}$) versus the number of mobile terminals (N_j) when using different probabilities of call blocking ($P_{B,j}$). The probability of socket open requests from the number of terminals ($P_{r,j}$) was set to one in the network. The results show that the public IPv4 address utilized increases with the increasing number of mobile terminals that can be supported by RPX in the network, as expected. However, the address utilization can also be contained by varying the probability of the call blocking. This figure illustrates the utilization with a blocking probability of 0%, 5% and 10% respectively.

Fig. 4 shows the public IPv4 addresses (N_{IPj}) utilization versus the number of mobile terminals (N_j) when the probability of socket open requests from the number of terminals ($P_{r,j}$) is varied. The call blocking probability was set to a constant of 5% in the simulation. The figure illustrates how the number of utilized public IPv4 addresses will be reduced as the probability of request decreases since the call blocking probability ($P_{B,j}$) is dependent on the probability of socket open requests from the mobile terminals ($P_{r,j}$) with the condition $P_{B,j} \alpha P_{r,j}$. Furthermore, we can see that the number of terminals that the RPX server can support increases as the probability of socket open requests decreases with a fixed public IPv4 addresses utilization.

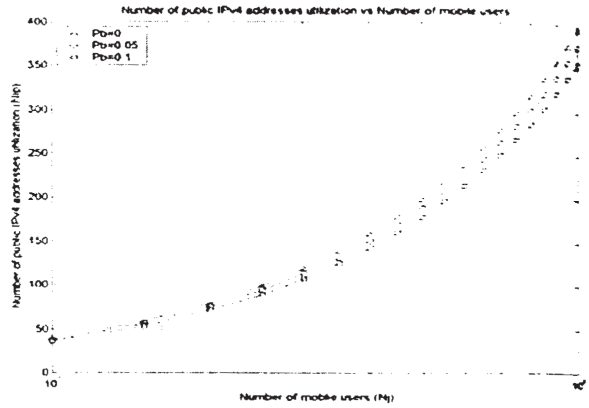

Figure 3: Public IPv4 address utilization and number of mobile terminals with $P_{r,j} = 1$.

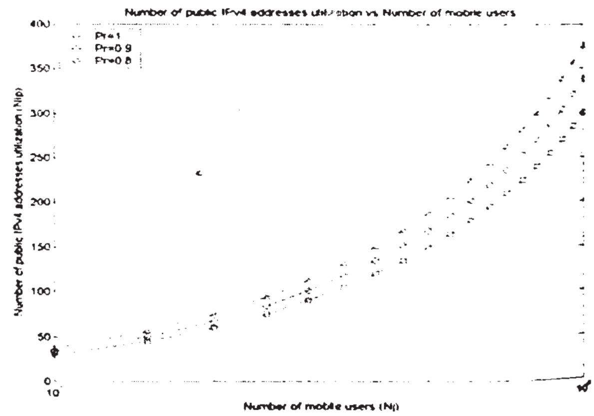

Figure 4: Public IPv4 addresses utilization and number of mobile terminals with $P_B = 5\%$.

In this section, the results from our simulations allow us to draw some conclusions regarding the number of public IPv4 addresses utilized by the RPX scheme as follows:

Firstly, the results in Fig. 3 and 4 were obtained with the assumption that all connections were opened up to the same server process in the public Internet as simplified in equation (3). Therefore, the results illustrate the maximum number of public IPv4 addresses utilized, while scaling the expected number of mobile terminals in the network from ten to one hundred million terminals under the assumed conditions of call blocking probability and number of sockets of each terminal. From the results above it can be seen that RPX can provide excellent scalability in terms of supporting a large number of private terminals, while only utilizing a small number of public IPv4 addresses, meaning that cellular 3G operators may operate with a realistic value of 1000 IPv4 addresses available for allocation.

Secondly, the formulas used in the simulations above enable us to give a good estimation of the number of IPv4 addresses utilized in order to achieve reasonable estimates of RPX in actual deployment, and indicate that the scalability of RPX is very promising.

VI. Conclusion

In previous work, it has shown that RPX provides excellent scalability in terms of the supported number of IPv6 terminals. However, the scalability of RPX will depend on a set of number of publicly available IPv4 addresses to RPX server. In this paper, we have presented mathematical model that an operator can use to determine the expected number of available public IPv4 addresses utilization of an RPX system. In addition, our experimental results also give a good indication on the scalability of RPX that is unexpected from the theoretical scalability according to the call blocking probability.

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