Study of A Novel Predictable Poisson Method for Traversing Symmetric NAT

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Abstract. Network Address Translators (NATs) traversal techniques are applied in Peer-to-Peer (P2P) communication to improve network quality of service. The existing solutions to traverse NATs are including STUN, TURN and ICE. However, these solutions relay packets instead of traversing symmetric NATs directly. To solve these problems, this paper proposes a novel Predictable Poisson Method (PPM). The proposed Network Traffic Model (NTM) calculates the parameter λ of the Poisson process and the proposed Expected Value Method (EVM) and Poisson Sampling Method (PSM) are used to predict ports allocated by NATs. The proposed NAT Traversal Algorithm (NAT-TA) is designed to traverse symmetric NATs. Experimental results show the proposed EVM and PSM perform better on precision and efficiency than traditional methods.

Keywords: Symmetric NAT Traversal; P2P; Poisson Process; Port Prediction; UDP.

1. Introduction

NAT devices are deployed ubiquitous so that peer nodes are compulsory to establish P2P communication by traversing NATs. Mainly existing solutions are proposed to traverse non-symmetric NATs rather than traverse symmetric NATs directly. This paper focuses on the traversal of symmetric NATs. This paper establishes Network Traffic Model (NTM) by collecting the network traffic, and designs NAT Traversal Algorithm (NAT-TA) to traverse symmetric NATs by sending multiple prediction packets. Expected Value Method (EVM) and Poisson Sampling Method (PSM) predict ports allocated respectively based on NTM established by analyzing traffic. NAT-TA receives predicted ports from EVM or PSM, and makes peer nodes sending packets to predicted ports. The structure of this paper is: the next section introduces existing NAT traversal solutions. The section 3 introduces the design of Predictable Poisson Method (PPM) in detail. The section 4 tests the proposed EVM and PSM and traditional methods and evaluate the experimental results. The section 5 concludes the whole paper.

2. Background

STUN, TURN and ICE are existing NAT traversal solutions. Rosenberg et al. [1] proposed STUN solution which solved all non-symmetric NATs traversal problem by pre-establishing mapping information on the NAT, but STUN couldn't traverse symmetric NAT. Mahy et al. [2] proposed TURN solution which relayed packets to traverse NATs. Rosenberg et al. [3] proposed ICE solution which combined STUN and TURN, and traversed NATs by collecting candidate addresses and checking the connectivity of candidate addresses pairs. ICE and TURN traversed symmetric NATs rely on the relay server with additional transmission overhead which leaded to lower bandwidth and higher latency.

The existing methods to traverse symmetric NATs are as follows. Wang et al. [4] proposed to change source ports of peer nodes behind symmetric NATs, while the source ports are constant in practical applications. Wei et al. [5] proposed to limit the size of TTL (Time-to-Live) for controlling the number of ports allocated by NAT, while the operation of changing TTL required the root privileges of the operating system. Olofsson et al. [6] proposed to match the unique identifier associated with the source node with a unique identifier known to the destination node for traversing, while the method was not feasible all the time. Diffie W et al. [7] proposed to relay packets via a non-symmetric NAT that increased traversal success rate, while it cost more and leaded to higher latency.

3. The Proposed Predictable Poisson Method (PMM)

Considering network traffic changes at all times, the proposed PPM includes two parts: a network traffic model (NTM), and a NAT traversal algorithm (NAT-TA). NTM is established by collecting and analyzing traffic. Meanwhile, EVM and PSM are used to predict ports allocated based on NTM. NAT-TA makes peer nodes sending packets to predicted ports for traversing symmetric NATs.

3.1 Network Traffic Model (NTM)

Network traffic affects to traverse incremental symmetric NAT. The traffic from internal NAT to external NAT are mapped on NATs. NAT allocates more mapped port so that the port prediction is difficult. The intranet peer node can choose to access the external network or choose not to access the external network. When the time t changes, the statistical rules of the accumulation of network access events in $[t, t+\triangle t]$ obey the Poisson process. It can be demonstrated according the traffic capture on the server in the public network.

As shown in Fig. 1, the probability curve of network traffic obeys the Poisson distribution, and the average network traffic is 5.85. It indicates that network traffic is a time-period Poisson process, and traffic is 5.85 per 10 milliseconds. λ is defined as the average network traffic per millisecond.

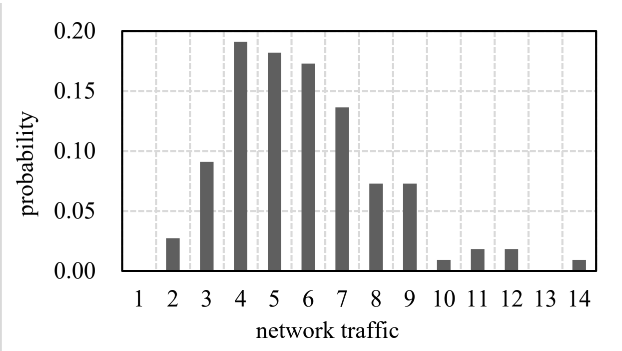

Fig. 1 Network traffic distribution, $\lambda = 0.5$

Network traffic probability distribution function can be expressed as:

$$P(A(t+\triangle t) - A(t) = n) = \frac{(\lambda \triangle t)^n}{n!} \cdot e^{-\lambda \triangle t} \tag{1}$$

The calculation of the parameter λ is based on the port's differences set by collecting packets on the server and analyzing data using the maximum likelihood method. There are two ways to estimate the network traffic within $[t, t+\triangle t]$ based on the parameter λ.

Expected Value Method (EVM)

$$E(A(t+\triangle t) - A(t)) = \lambda \triangle t \tag{2}$$

Formula (2) calculates network traffic within $[t, t+\triangle t]$ and the value is $\lambda \triangle t$.

Poisson Sampling Method (PSM)

$T = \triangle t$ is defined as the time interval and *n* is defined as the network traffic within $[t, t + \triangle t]$. The PSM pseudo code is shown in Table 1.

Table 1. Poisson Sampling Method pseudo code

```
Procedure PoissonSampling( λ , T )
    t ← 0, n ← 0;
    while t <= T
        u ← random();
        t ← 1/λ · log(u);
        if t <= T then
            do n ← n + 1;
        else
            do return n;
        end if
    end while
```

Therefore, predicted ports can be calculated respectively as:

Expected Value Method (EVM)

$$prePORT_s = natPORT + s + s \cdot \lambda(T + t_s) \tag{3}$$

Poisson Sampling Method (PSM)

$$prePORT_s = natPORT + \sum_{i=0}^{s} n_i + s \cdot \lambda t_s \tag{4}$$

3.2 NAT Traversal Algorithm (NAT-AT)

NAT-TA is based on port prediction. Peer nodes send a packet to every predicted port until they receive a packet from remote.

F1: The Node (Node A, Node B) sends a packet to the Server which located on the public network. The Server analyses the address mapped by NAT.

F2: The Server conveys the address mapped to the node.

F3: The Node A sends a packet includes the request to communicate with the Node B. The Server queries the address mapped of the Node B, and calls EVM or PSM to predict the port allocated by NAT B. Also, the Server predicts the ports allocated by NAT A by the same way.

F4: The Server sends a packet containing the all predicted ports numbers and the mapped IP of the Node B to the Node A. (If the prediction times is s, number of total predicted ports is *s*.)

F5: The Server sends a packet containing all the predicted ports numbers and the mapped IP of the Node A to the Node B.

F6: Based on this information, the Node A sends a large number of packets to the Node B. The destination of every packet is different including the *sth* predicted port. The send process continues until the Node A receives a packet from the Node B.

F7: Based on this information, the Node B sends a large number of packets to the Node A. The destination of every packet is different including the *sth* predicted port. The send process continues until the Node B receives a packet from the Node A.

F8: After receiving a packet from the node B, the Node A replies a packet to the Node B.

F9: After receiving a packet from the node A, the Node B replies a packet to the Node A.

When the Node A and the Node B both receive a reply packet from remote, a P2P connection between the Node A and the Node B has been established. It traverses the symmetric NAT successfully.

4. Experiments and Evaluations

The experimental environment is including two internal hosts (192.168.1.100, 192.168.2.100), two NAT devices (10.0.1.1, 10.0.2.1) and a server with a public IP (10.0.0.1). Mininet [8] and D-ITG [9] are used respectively to construct virtual network topology and generate random network traffic.

To test the success rate of the PPM, different network traffic and prediction interval are configured. The experiments test the EVM and PSM, and the traditional method the Change Source Port Method (CSPM) and the Linear Scanning Method (LSM).

Fig. 2(a, b) show the changes of success rate of four different method, along with the changes of the network access and prediction interval. Fig. 2(c) shows that the difference between the predicted port number and the actual port number. Fig. 2(d) shows the average prediction steps of the symmetric NAT traversal based on four different method.

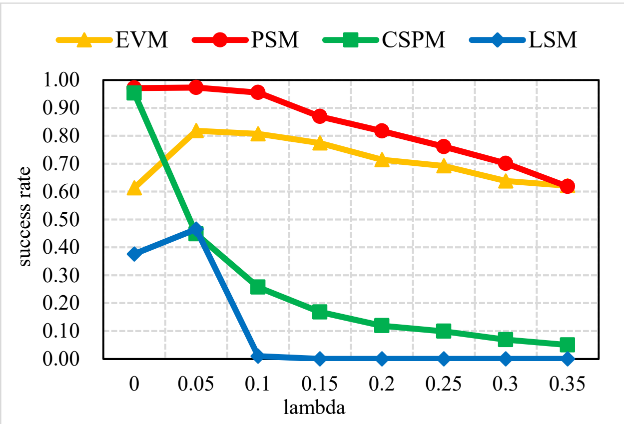

Fig. 2(a) Success rate

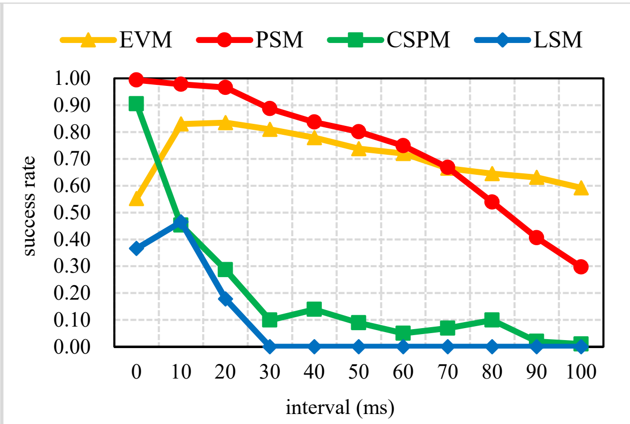

Fig. 2(b) Success rate

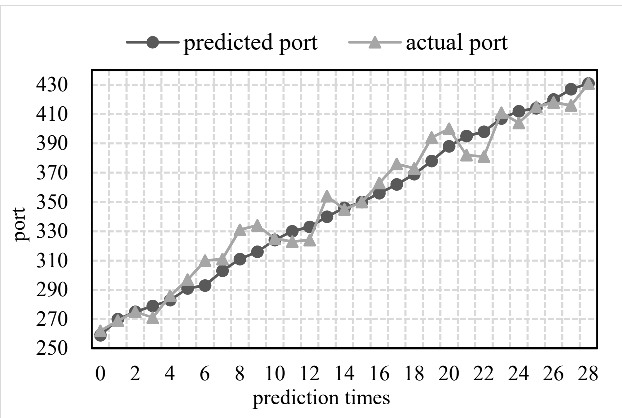

Fig. 2(c) Predicted ports differences

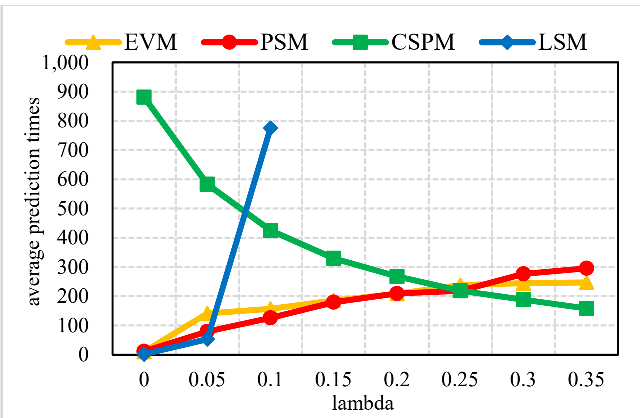

Fig. 2(d) Average prediction times

Comparing with the traditional method, the proposed EVM and PSM have higher traversal rate. Meanwhile, the traversal success rate decreases more slowly with the change of the network access and the prediction interval. Moreover, the EVM and the PSM have lower average prediction steps than the traditional method. In particular, when network traffic is less than 50 times per second and prediction interval is set as 10 millisecond, the success rate of PSM is over 95%, and the predicted port value deviates from the actual port value is less than 30, which means that the method add to up to 1 second delay during packets transmission. Therefore, the traversal of incremental symmetric NAT can be effectively implementation under low traffic in a short time.

5. Summary

This paper studies UDP traversal method of incremental symmetric NAT, analyses the traditional symmetric NAT traversal solution, and proposes a novel Predictable Poisson Method (PPM) to traverse symmetric NATs. Network Traffic Model (NTM) is established by collecting and analyzing the network traffic. Based on the NTM, this paper proposes the Expected Value Method (EVM) and Poisson Sampling Method (PSM) respectively to estimate network access and predicate ports allocated. NAT Traversal Algorithm (NAT-TA) makes peer nodes sending a packet to every predicted port. The experimental results show that the EVM and PSM outperform on predicting accurate prediction ports. Meanwhile, better traversal effect and lower traversal cost are achieved compared to traditional methods.

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