

## A Statistical Study of ANY Resource Record Based DNS Query Request Packet Traffic

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### Abstract

We statistically investigated the total ANY resource record (RR) based DNS query request packet traffic from the Internet to the top domain DNS server in a university campus network through January 1st, 2011 to December 31st, 2012. The obtained results are: (1) We found a significant increase in the inbound ANY RR based DNS query request traffic at November 28th, 2011. (2) In the DNS query request packet traffic, we observed only a query keyword of the campus domain name. (3) We found a correlation between the total inbound DNS query request packet traffic and the DNS query request packet traffic including the query keyword. (4) Also, we found that the source IP addresses were distributed in the ANY RR based DNS query request packet traffic. These results indicate that the ANY RR based DNS request packet traffic is strange. Therefore, we should pay much attention to the ANY RR based DNS query request traffic including the single domain name.

**Keywords:** DNS ANY Request Cannon, DNS ANY traffic bumps, DDoS

### 1. Introduction

It is of considerable importance to protect the domain name system (DNS) services and/or servers in the Internet, since they are very important components of the Internet infrastructures. If the DNS services stop, the almost the network applications or services will crash.

Recently, we observed interesting traffic bumps of the ANY resource record (RR) based DNS query request packet access to the top DNS (tDNS) server in a university campus network continuously since November 28th, 2011. The traffic bumps have been also reported in the several Weblog sites [1, 2]. This is probably because the DNS ANY RR based DNS query request packet access can perform or induce the DNS amplification attack employing the source IP address spoofing technology [3-5]. Therefore, it is very important to detect the ANY RR based DNS query request packet access to the DNS servers.

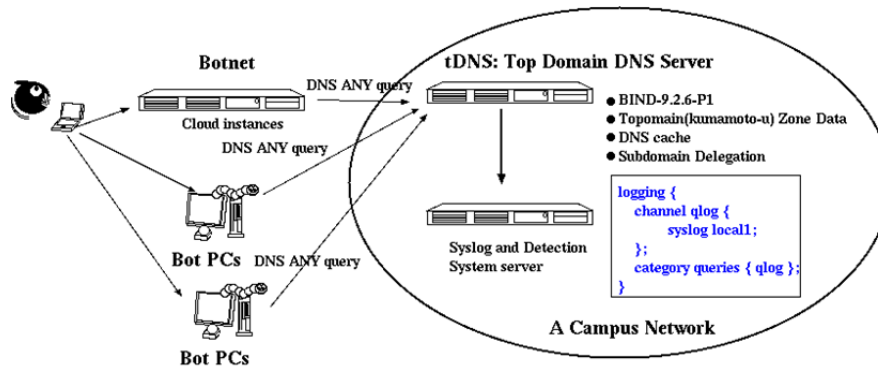
Previously, we reported development and evaluation of the restricted Damerau-Levenshtein [6, 7] distance based detection model of the Kaminsky DNS cache poisoning attack in the total inbound A RR based DNS query request packet traffic to the campus tDNS server through January 1st to December 31st, 2010 [8], and it can be also useful for detecting the ANY RR based DNS query request packet access.

In this paper, (1) we carried out restricted Damerau-Levenshtein distance based analysis on the total ANY resource record (RR) based DNS query request packet traffic from the Internet through January 1st, 2011 to December 31st, 2012, and (2) we assessed the results for the query keywords in the ANY-RR based DNS query request packet traffic.

### 2. Observations

#### 2.1 Network Systems and DNS Query Request Packet Capturing

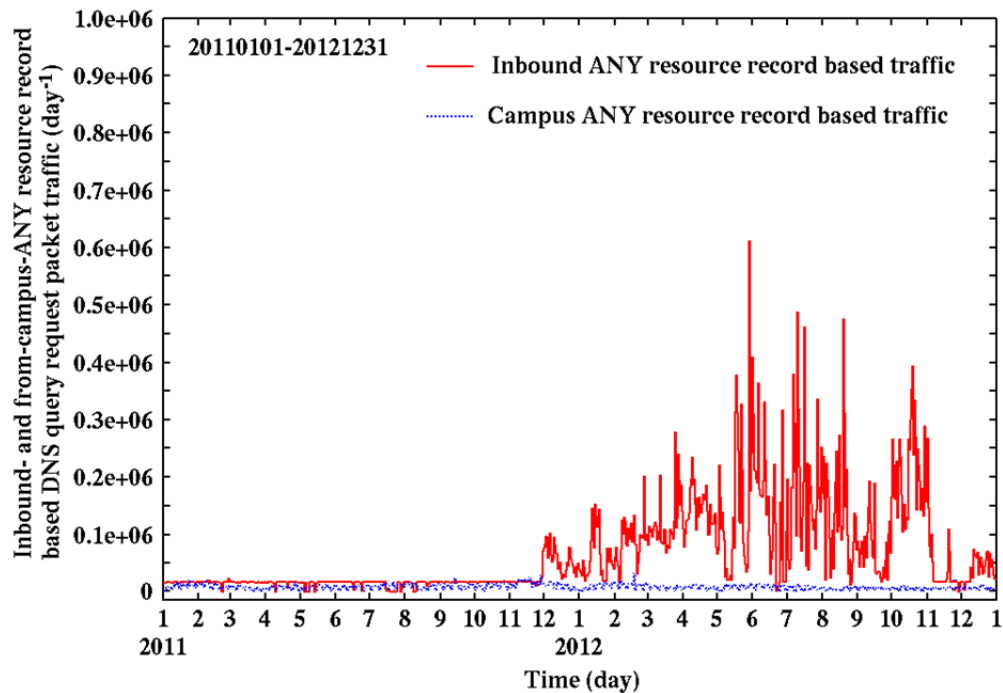
We investigated on the DNS query request packet traffic between the top domain DNS (tDNS) server and the DNS clients. Figure 1 shows an observed network system in the



**Figure 1.** A schematic diagram of an observed network in the present study.

present study, which consists of the tDNS server and the PC clients as bots like DDoS bots in the campus or cloud instances, and the victim hosts like the DNS servers on the campus network. The tDNS server is one of the top level domain name (kumamoto-u) system servers and plays an important role of domain name resolution including DNS cache function, and subdomain name delegation services for many PC clients and the subdomain network servers, respectively, and the operating system is Linux OS (CentOS 5.5 Final) in which the kernel-2.6.18 is currently employed with the Intel Xeon X5660 2.8 GHz 6 Cores dual node system, the 16GB core memory, and Intel Corporation EthernetPro 82575EB Gigabit Ethernet Controller.

In the tDNS server, the BIND-9.3.6-P1 program package has been employed as a DNS server daemon [9]. The DNS query request packets and their query keywords have been captured and decoded by a query logging option (see Figure 1 and the named.conf manual of the BIND program in more detail). The log of DNS query request packet access has been recorded in the syslog files. All of the syslog files are daily updated by the cron system. The line of syslog message consists of the contents in the DNS query request packet like a time, a source IP address of the DNS client, a query keyword, a type of resource record (A, AAAA, ANY, PTR, MX, or TXT).



**Figure 2.** Changes in the ANY resource record based DNS request packet traffic from the campus network and the Internet through January 1st, 2011 to December 31st, 2012.

## 2.2 Observed ANY Resource Record based DNS Query Request Packet Traffic

Firstly, we demonstrate the observed ANY resource record (RR) based DNS query request packet traffic from the campus network and the Internet to the top DNS (tDNS) server through January 1st, 2011 to December 31st, 2012, in Figure 2.

In Figure 2, we can observe that the both traffic curves change in a mild manner (the inbound traffic:  $18,000 \text{ day}^{-1}$ , the traffic from the campus:  $7,000 \text{ day}^{-1}$ ). However, we can see that the inbound ANY RR based DNS query request packet traffic drastically changes after November 28th, 2011. Daly reported the same bumps in the ANY RR based DNS query request packet traffic [1] and Shortt also called the traffic bumps a DNS ANY Request Cannon [2].

We also investigated the query keyword change in the ANY RR based DNS query request packet traffic through November 28th, 2011, and the results are shown in Figure 3. In Figure 3, we can observe a continuously repeated sequence of the same query keyword “kumamoto-u.ac.jp”. This feature shows that there can be a possibility to detect the inbound ANY RR based DNS query request packet traffic bumps more efficiently.

```
Nov 28 21:50:46 kun named[6346]: client ***.***.***.8.31#57407: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:46 kun named[6346]: client ***.***.***.8.31#21270: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:46 kun named[6346]: client ***.***.***.8.31#32864: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:46 kun named[6346]: client ***.***.***.8.31#65298: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:46 kun named[6346]: client ***.***.***.8.31#22967: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:46 kun named[6346]: client ***.***.***.8.31#49808: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:47 kun named[6346]: client ***.***.***.8.31#31785: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:47 kun named[6346]: client ***.***.***.8.31#56279: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:47 kun named[6346]: client ***.***.***.8.31#55271: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:48 kun named[6346]: client ***.***.***.8.31#49815: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:48 kun named[6346]: client ***.***.***.8.31#49815: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:48 kun named[6346]: client ***.***.***.8.31#14289: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:48 kun named[6346]: client ***.***.***.8.31#37016: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:48 kun named[6346]: client ***.***.***.8.31#63239: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:48 kun named[6346]: client ***.***.***.8.31#45132: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:49 kun named[6346]: client ***.***.***.8.31#58199: query: kumamoto-u.ac.jp IN ANY +
Nov 28 21:50:49 kun named[6346]: client ***.***.***.8.31#34610: query: kumamoto-u.ac.jp IN ANY +
```

**Figure 3.** Changes in the query keywords in the inbound ANY-resource record based DNS query request packet traffic to the top domain DNS (tDNS) server at November 30th, 2011.

## 2.3 Detection Model for DNS ANY Request Cannon

We define here a detection model of the DNS ANY Request Cannon [2] or a traffic bump in the ANY RR based DNS query request packet access.

— *A detection model* — the DNS ANY Request Cannon (DARC) activity can be mainly carried out by a small number of IP hosts on the Internet or like the bot compromised PCs or the public cloud instances. Since these IP hosts send a lot of the ANY RR based DNS query request packets to the tDNS server, the traffic can be detected by calculating the Euclidian distance between the source IP addresses. Then, we suggest hereafter the restricted Damerau-Levenshtein (edit) distance [6, 7] based detection system of the DARC activity, since the DARC activity causes the continuously repeated sequence of the same query keyword (Figure 3). Here, we should also define thresholds for detecting the DARC activity, as setting to 10 packets  $\text{day}^{-1}$  for the frequencies of the top unique source IP addresses and for the edit distance, respectively.

## 2.4 Euclidean-Distance of source IP addresses

The Euclidean distances,  $\text{ed}(sIP_i, sIP_{i-1})$ , are calculated, as

$$d(sIP_i, sIP_{i-1}) = \sqrt{\sum_{j=1}^4 (x_{i,j} - x_{i-1,j})^2} \quad (1)$$

where both  $IP_i$  and  $IP_{i-1}$  are the current source IP address  $i$  and the last source IP address  $i-1$  respectively, and where  $x_{i,1}$ ,  $x_{i,2}$ ,  $x_{i,3}$ , and  $x_{i,4}$  correspond to an IPv4 address like A.B.C.D, respectively. For instance, if an IP address is 192.168.1.1, the vector  $(x_{i,1}, x_{i,2}, x_{i,3}, x_{i,4})^T$  can be represented as  $(192.0, 168.0, 1.0, 1.0)^T$ . If the DARC activity model follows a single or distributed source IP address based model i.e. we define the DARC activity, the detection is decided by thresholds  $sd_{min}=sd_{max}=0.0$  or  $sd_{min}=1.0, sd_{max}=5.0$  [10], as

$$\begin{aligned} sd_{min} (= 0.0) \leq ed(sIP_i, sIP_{i-1}) \leq sd_{max} (= 0.0) \text{ or} \\ sd_{min} (= 1.0) \leq ed(sIP_i, sIP_{i-1}) \leq sd_{max} (= 5.0) \end{aligned} \quad (2)$$

## 2.5 Estimation of restricted Damerau-Levenshtein Distance between Domain Names as Query Keywords

The Levenshtein distance, LD (X, Y), is calculated, as

$$LD[x, y] = \min (LD[x - 1][y] + 1, LD[x][y - 1] + 1, LD[x - 1][y - 1] + cost) \quad (3)$$

where both  $x$  and  $y$  are lengths of the strings  $X$  and  $Y$ , and the  $X$  and the  $Y$  are strings of the current domain name (DN)  $i$  and the last DN  $i-1$  of the DNS query keywords, respectively. For instance, if the DNs are  $X = "a001.example.com"$  and  $Y = "a002.example.com"$ , the Levenshtein distance LD (X,Y) is calculated to be 1, since the Levenshtein distance counts the number of edit operations like "insertion," "deletion," and "substitution" [6]. Furthermore, the restricted Damerau- Levenshtein distance takes into consideration the operation "transposition" in order to suppress the overestimation [7]. The detection of the DARC activity is decided by thresholds  $dl_{min}=dl_{max}=0$ , as

$$dl_{min} \leq LD(DN_i, DN_{i-1}) \leq dl_{max} \quad (4)$$

This is because the DARC activity causes the continuously repeated sequence of the same query keyword (See Figure 3).

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```

1  #!/bin/tcsh -f
2  set Threshold=10
3  # Step 1 Learning to produce a low-dimensional
4  cat /var/log/querylog | clgrep -v -cclients.conf | \
5  grep "IN ANY +" | \
6  sdis 0.0 0.0 1.0 5.0 | dlevens 0 0 | tr '#' ' ' | \
7  awk '{print $7}' | sort -r | uniq -c | sort -r | \
8  awk '{printf("%s\t%s\n", $2, $1);}' | \
9  qdos Threshold >tmpfile
10 # Step 2 Detection
11 cat /var/log/querlog | clgrep -ctmpfile | \
12 grep "IN ANY +" >ANYActDet.log
13 # Step 3 Scoring
14 cat ANYActDet.log | wc -l >>ANYActDetScore.txt
15 exit 0

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Figure 4. DNS ANY Request Cannon (DARC) Activity Detection Algorithm.

## 2.6 Detection Algorithm for DARC Activity

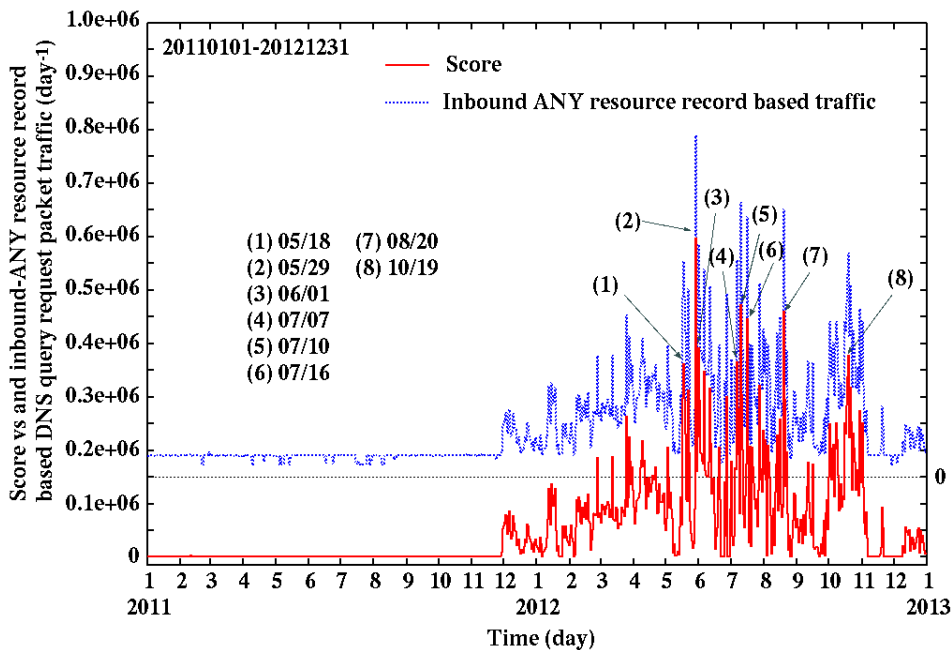
We suggest the following detection algorithm of the DNS ANY Request Cannon (DARC) activity and we show a prototype program (see Figure 4):

— **Step 1 Learning to produce a low-dimensional**—In this step, the **clgrep**, **cngrep**, and **grep** commands extract inbound ANY RR based DNS query request packet messages from the DNS query log file (*/var/log/querylog*) with discarding case-insensitively keywords *local*

and *kumamoto-u*, the **sdis** command prints out a syslog message if the Euclidean distance of two source IP addresses is calculated to be zero or to take a range of 1.0-5.0 [10], the **dleven** command prints out the syslog message if the restricted Damerau-Levenshtein distance  $LD(DN_i, DN_{i-1})$  takes a zero value (as discussed in the Section 2.5), and the **awk**, **sort**, **uniq**, and **qdos** commands (lines 7 to 9 in Figure 4) compute and check the frequencies of the restricted Damerau-Levenshtein distance  $LD(DN_i, DN_{i-1})$  and if the frequency exceeds a threshold value ( $Threshold=10$ ), they write out the candidate IP addresses into a *tmpfile* as training data.

— **Step 2 Detection** —In the next step, the **cgrep** and **grep** commands extract the DARC activity related messages in the DNS query log file (*/var/log/querylog*), using the training data (*tmpfile*) and they generate only a DARC activity related DNS query log file (*ANYActDet.log*).

— **Step 3 Scoring** —In the final step, the **wc** command calculates the score for the detection of the DARC activity in the file *ANYActDet.log*, and it writes out the detection score into a score file (*ANYActDetScore.txt*) in an appending manner.



**Figure 5.** Changes in score of the DNS ANY Request Cannon (DARC) activity (solid curve) and the inbound ANY resource records (RR) based DNS query request packet traffic to the top DNS (tDNS) server (dotted curve) through January 1st, 2011 to December 31st, 2012 ( $\text{day}^{-1}$  unit).

### 3. Results and Discussion

#### 3.1 Score of DNS ANY Request Cannon Activity and Inbound ANY RR Based DNS Query Request Packet Traffic

We illustrate the calculated score of the DNS Query Request Cannon (DARC) activity using restricted Damerau-Levenshtein distance based detection model ( $LD(DN_i, DN_{i-1}) = 0$ ) between the current domain name  $DN_i$  and the last domain name  $DN_{i-1}$ , as the DNS query keywords in the ANY resource record (RR) based DNS query request packet traffic from the Internet to the top DNS (tDNS) server through January 1st, 2011 to December 31st, 2012, as shown in Figure 5.

In Figure 5, we can observe that the DARC activity score curve takes a zero value and it starts to change drastically after November 28th, 2011. Also, we can observe that the inbound ANY RR based DNS query request packet traffic curve changes in a mild manner before November 28th, 2011, however, the both curves change in almost the same manner after November 28th, 2011. This feature indicates that the DARC activity score significantly is

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May 29 23:58:19 kun named[5595]: client **4.**8.**8.**30#61617: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:19 kun named[5595]: client **8.**8.20.**8#54839: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:19 kun named[5595]: client **4.**8.**8.**30#7805: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:20 kun named[5595]: client 2**.**8.**4.**7#54431: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:21 kun named[5595]: client **8.**8.20.**8#64503: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:21 kun named[5595]: client 2**.**8.**4.**7#45380: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:22 kun named[5595]: client 1**.1**.**.#4#47365: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:22 kun named[5595]: client **8.**8.20.**8#62936: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:23 kun named[5595]: client **4.**8.**8.**30#54618: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:24 kun named[5595]: client 2**.**8.**4.**7#32481: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:24 kun named[5595]: client **4.**8.**8.**30#806: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:24 kun named[5595]: client 2**.**8.**4.**7#3926: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:25 kun named[5595]: client **8.**8.20.**8#56393: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:25 kun named[5595]: client **8.**8.20.**8#60067: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:25 kun named[5595]: client 1**.1**.**.#22420: query: kumamoto-u.ac.jp IN ANY +
May 29 23:58:25 kun named[5595]: client 1**.1**.**.#3146: query: kumamoto-u.ac.jp IN ANY +

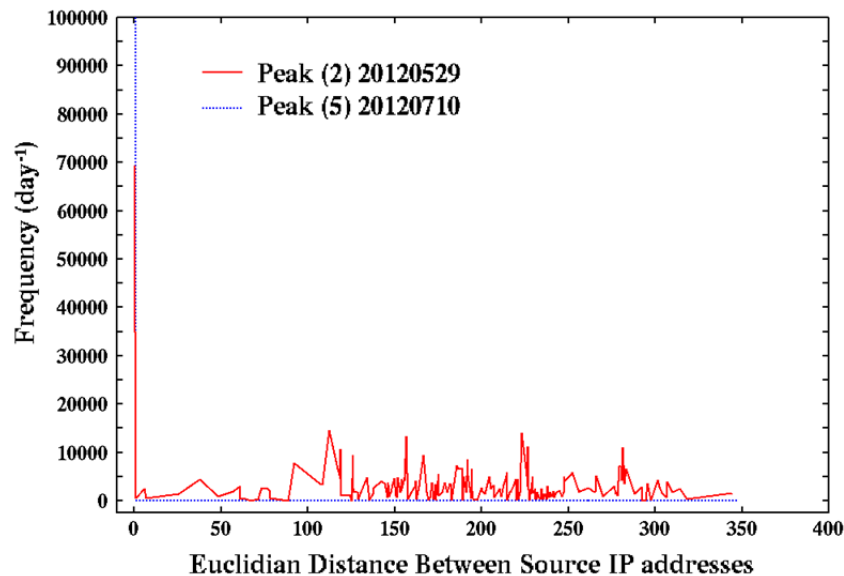
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**Figure 6.** Changes in the source IP address in the total ANY-resource records (RR) based DNS query request packet traffic from the Internet to the top domain DNS (tDNS) server at May 29th, 2012.

correlated with the traffic value of the inbound ANY RR based DNS query request packet access.

In the score curve for the DARC activity, we can observe nine significant peaks (1)-(8), exceeding more than a score value of  $35,000\text{day}^{-1}$  and being allocated to (1) May 18th, (2) 29th, (3) June 1st, (4) July 7th, (5) 10th, (6) 16th, (7) August 20th, and (8) October 19th, 2012, respectively. In the peaks, the peak (2) is the top score ( $=597,977\text{day}^{-1}$ ), and we also investigated the source IP address-changes in the ANY RR based DNS query request packet traffic through May 29th, 2012, and the results are shown in Figure 6.

Interestingly, in Figure 6, we can view scenery that the source IP addresses change periodically, showing that the DARC activity is carried out in a source IP address distributed manner.



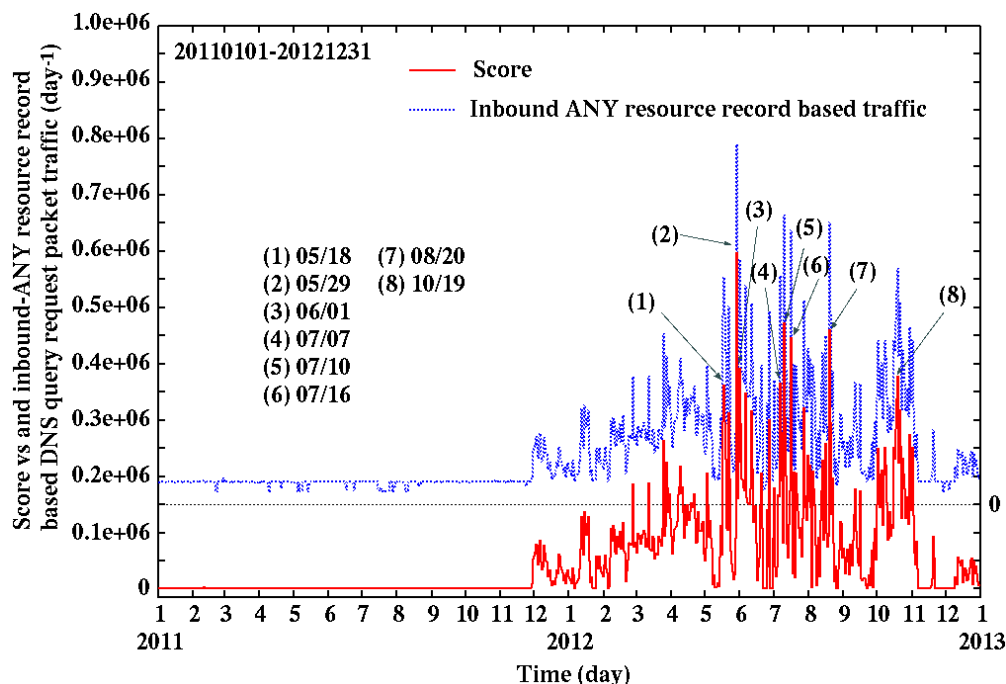
**Figure 7.** Frequency distributions of the Euclidian distance between the source IP addresses at May 29th and July 10th, 2011 ( $\text{day}^{-1}$  unit).

### 3.2 Frequency Distributions of Euclidian distance in Source IP addresses

We calculated frequency distributions of the Euclidian distance for the two peaks (2) May 29th and (5) July 10th, 2012, as shown in Figure 7. In Figure 7, the frequency distribution of the peak (2) has a significant peak at zero value and the other one (10) has also a peak at zero

but several peaks taking a range of 0.0-350.0 in a broad manner. This feature indicates that there are two types of DARC activity, the one is a source IP address non-distributed activity and the other one is a source IP address distributed activity.

Interestingly, however, the source IP address distributed activity was also reported in the host search (HS) activity [10] and the frequency distributions in the HS activity takes a frequency range of 1.0-5.0. This difference shows that the source IP address distributed DARC activity does not resemble well with the source IP address distributed HS one.



**Figure 8.** Changes in score of the DNS ANY Request Cannon (DARC) activity (solid curve) and the number of the unique source IP address in the DARC activity (dotted curve) through January 1st, 2011 to December 31st, 2012 (day<sup>-1</sup> unit).

### 3.3 Change in Number of Unique Source IP address

We calculated changes in the number of the unique source IP address in the DARC activity traffic through January 1st, 2011 to December 31st, 2012 (Figure 8).

In Figure 8, we can observe new seven peaks (9)-(16), assigned to (9) February 9th, (10) February 26th-April 28th, (11) May 17th, (12) 31st, (13) August 15th, (14) 22nd, (15) September 16th, and (16) October 28th, 2012, respectively. Unexpectedly, we, however, can observe a weak correlation between the peaks in the score and the unique number curves.

## 4. Conclusions

We developed and evaluated the restricted Damerau-Levenshtein (DL) edit distance based detection model of the DNS ANY Request Cannon (DARC) traffic in the inbound ANY resource record (RR) DNS request packet traffic through January 1st, 2011 to December 31st, 2012. The following interesting results are found: (1) we observed that the detection score of the DARC traffic was significantly correlated with the inbound ANY RR DNS query request packet traffic since after November 28th, 2011, (2) we observed that the DARC traffic was generated in a source IP address distributed manner, (3) we found that there were a lot of peaks in the frequency distribution of the DARC traffic, taking a range of 0.0-350.0, and (4) we also found a weak correlation between the detection score and the unique number of the source IP addresses of the DARC traffic. These results show that the DARC activity carried out in a source IP address distributed manner that is different from the HS activity previously reported [8].

We continue further investigation and development of the DARC detection technology near future.

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