# Study of Dynamic Timeout Strategy based on Flow Rate Metrics in High-Speed Networks

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*Abstract*—**The measurements based on flow characteristics are playing more and more important roles in the analysis of Network Behavior. As a main method for flow recognition, the timeout strategies have a significant impact on correctness and performance of flow measurement. This paper discusses the state-of-art of flow timeout strategies, and explains where they are applicable and their shortcomings. To deal with short flows that take a large part of the total flows in the networks, the paper proposes the Dynamic Timeout Strategy (DToS) to analyze flows distribution and flow rate metrics in detail. The studies show that this method can improve the performances of network measurement and the efficiency of the resource usage by using different timeout strategies to deal with flows that have different rate features based on integrated usage analysis of target network. It can also apperceive network abnormal behavior efficiently, and then take emergent measures to ensure the safety of measurement system. Some experiments have been carried out to show the rationality of DToS strategy. The applicable area of the strategy is also analyzed in the end of this paper.**

*Key words*—***High-Speed Networks; Network Flow; Flow Rate Characteristics; Dynamic Timeout Strategy (DToS)***

## I. Introduction

As the development of Internet, the number of users is expanding rapidly and so are new network applications, which make the Internet traffic aggrandized continually and the network behaviors been more and more sophisticated. It is especially important for promoting network quality of service based on the existing network infrastructures through the analysis of network behaviors, which can find out Macro and/or Micro changing rules behind on those behaviors and make use of those rules appropriately. Traditional network measurements mainly focus on packet level, but these applications can't satisfy the needs of network optimization and management because they anatomize every packet relative equally, which causes the lack of information that hides among packets and higher level.

Network behavior analyzing based on flow fetches up many disadvantages of packet level study. A flow is defined as a stream of packets subject to flow specification and timeout[1].The study based on network flow analyzes the packet set which belongs to special flow, which can obtain the network behavior at higher level and support network applications with more information. It can also use different flow specification and/or timeout strategies to fit the needs of different applications. And so the Qos and performance of network can get benefits from flows' analysis and profiling. Now the widely used flow specifications are 5-tuple, destination address and OD flow etc[1][10][11], in which 5-tuple specification is applied more frequently[1][2][3][8]. ***Timeout*** is used to terminate the flow when it has no packet coming in a special time. Measurement systems' resource can be used more efficiently by using this way. And the ended flow can fit the need of further flow analysis. Thus to say, flow timeout strategies can deeply influent the precision of flow measurement and systems' resource usage.

***Network flow rate metric*** is a guideline that describes the packet-incoming rate of special flow in the network. It can be depicted as number of arriving packets in special flows at an observation point (usually in edge or core router). The parameters of flow rate metric are including flow rate, flow length distribution, flow inter-arrival time, etc. The data from different networks and different time indicate that flow length of networks is obeyed distribution of heavy tail[2][3][5][6], and this characteristic can't change if the network is in the situation of normal. But the flow rate and flow inter-arrival time are fluctuating with load of network traffic. And so different timeout strategies can affect the precision of flow recognition when the load of network changing, they can also affect the resource usage of measurement system.

This paper studies the precision of flow recognition and resource usage of system when using different timeout strategies on the flow specification of 5-tuple, and presents a new timeout strategy: Dynamic Timeout Strategy Based on Flow Rate Metrics (DToS). This timeout strategy uses different timeout values aiming at flows with different flow rate features, which can improve the performance of flow measurement and enhance the resource usage of measurement system. And it can also apperceive network abnormal and trigger emergency response action to make the measurement system safety. The second section of this paper analyzes the existing timeout strategies introduced by Claffy K.C.[2], Ryu B.[1] and others in detail, and then points out their fitness and shortages. In Section 3, flow rate metric in high-speed network is analyzed using the trace from CERNET. And based on the results of Section 3, this paper describes the DToS timeout strategy in

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Section 4 and anatomizes the performance, error ratio and applicability of this strategy. In Section 5, experiments are employed to verify efficiency and effectiveness of DToS strategy comparing with the other timeout strategy. Conclusion and future work are expressed at last.

## II. Timeout Strategies

Timeout is one of most important features of flow recognition, and different timeout strategy influences the usage of resources and the results of flow statistics dramatically. The terminated flow will be kept in the memory for a long time if timeout is set too long which will burden the detect and control systems, while too short timeout will shorten long flow to several short flows which will cause too excessively frequent termination and creation of flows called thrashing. The direction of most recent researches is finding out the best balance of performance and consuming according to the characteristics of network flows.

Claffy K. C.[1] presented the method of using fixed timeout, and proved its fitness through several experiments. These results of experiments were admitted broadly and adopted vastly. But there were still some questions in fixed timeout strategy: (1) fixed timeout distinguished flows with different packets inter-arrival time, and this would store ended flows too long time which mean more memory had been used; (2) too short fixed timeout would cause shortening and thrashing, while if fixed timeout was too long, terminated flows would be kept ended flows in the memory too long. What people could do is only to find out a tradeoff between long and short; (3) Claffy promoted and verified 64 fixed timeout was working well when network traffic was at normal situation, but wrong results would be induced when traffic was under abnormal.

Rye B., Cheney D., et al adopted a new adaptive timeout approach called MBET which held an independence timeout value for every flow, and reduced or kept this value unchanging according to the flow throughput. In this algorithm, enough large and same timeout threshold values were set when new flows were established. These values would be unchanged or reduced as 2-exponential and could reduce the long flow holding time dramatically without introducing shortening and thrashing. But there were still some problems unsolved in this algorithm: (1) it just used the single fitness timeout mechanism without taking advantages of the characteristics of measured objects enough, and this would lead to inaccuracy and inefficiency. (2) The setting of parameters influenced the measurement precision badly, and the immoderate parameters will cause the extraordinary diversities between the measure results and the facts.

Based on this, Hohn N., Veitch D. [7] introduced new methods to terminate flows such as protocols(FIN packets sent by TCP, etc) and memory management(flow was terminated to free resources for new flows). But they did not analyze those in detail. These timeout strategies, especially the memory management strategy, must integrate with special network measure ways, and sacrifice its correctness to fit the measure performance if it was necessary.

Experiment data in [1][2][3] expressed that there were lots of short flows (the percent of flows which's packet number smaller than 6 is above 95%) in different networks, and it is also proved by the measurement in CERNET backbone. Analysis result of CERNET backbone flows distribution in different time shows that the number of short flows is 90 percents of the total. Those short flows have very important influence in the flow distribution and flow characteristics, and also they take up most resource in flow measurement systems. Reducing the resource used by short flows can save total resource of systems effectively. Unfortunately, recent timeout strategies do not optimize the short flows but treat them equally with the other flows. In the MBET strategy, the short flows occupy more resources because their timeout values will keep in the threshold timeout values for not so many packets arriving. When abnormal traffic appears in the network (DDOS attack, worm burst, et al.), the ratio of short flows will increase dramatically, and so the resource they take. The measurement resources will be exhausted or the results will be wrong if optimization is not employed on those short flows.

All kinds of timeout strategies are aiming at the coordinating correctness of flow distribution description and resource usage, finding out the balance, and reducing resources consummation with relative correctness. Recent methods of flow recognition always use simplex timeout mechanism [1][2][3][5][8][11]. Those mechanisms have their own advantages in flow recognition precision and measurement system performance, but they can't reach the perfect balance in two directions. And so it is necessary to provide a new flow timeout strategy that uses system resources more efficiently without losing the correctness of flow recognition.

## III. Flow Rate Metrics Analysis in High-speed Networks

Flow rate metric is a guideline that describes the packet-incoming rate of special flow in the network, and then flows can be classified according to flow rate metric: fast and slow. Fast flow is defined as a flow with its mean value of inter-arrival packet time smaller than 0.1 seconds. This paper described the flow rate metric from several dimensions: random packet arrival rate, mean of packet arrival rate in special flow, flow rate stability.

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### *A. Features of Flow Rate Metrics*

The heavy tail distribution of flow length was expressed in detail at former papers [2][3][5][6], it was also proved by experiments on CERNET. And that means overwhelming majority of flows are short flows, and long flows number is very small. But those long flows take most payloads of network actually, while short flows affect the performance of network equipments by their number. This paper used threshold-based scheme to define flows in flow size dimensions: short flow and long flow. The flows whose packet number equates or less than 5 are defined as short flows, and the others are long flows. The reasons of using 5 packets as the threshold is: (1) TCP flows is the main body of flows because they take above 97% of total flows[10][11][12]; (2) the normal

TCP connect needs 6 packets at least(the flow described in this paper is bi-directional)[13],thus means the TCP flow whose packet number less than 6 is useless or illegal connection. And so it is very important for improving the performance of systems to identify those useless or illegal short flows as soon as quickly without impacting the efficiency of flow recognition.

Fig.1. describes the random(Up) and special flows'(Down) packet inter-arrival time distributions. The data are gotten from Northeast network center of CERNET backbone in different time on someday. The former catches packet inter-arrival time from different flows by random sampling, and the latter catches the all packet inter-arrival time of special flows by flow sampling and then calculates their mean value. This figure indicates that both of curves are obeyed to the distribution of heavy tail. The left of Fig.1 denotes most packet inter-arrival time is very little, and the right shows most flows are fast whose mean packet inter-arrival time is far less than 1 seconds. But the mean value of total packet inter-arrival time in all special flows is 1.88 seconds which indicates very few slow flows impact the mean value of flow rate heavily.

Flow rate stability describes the burst probability of flows. This paper amortizes the flow rate stability of high-speed networks through variations analysis of packet inter-arrival time. The variation of packet inter-arrival time of same flow can describes the stability of this flow in someway, and the bigger value means the poorer stability. But if the mean value is very small, small variation may not mean the packet inter-arrival time does not change heavily too because variation cannot gauge the ratio of values in someone set departure from its mean value. And so this paper introduces a new definition: ***coefficient of variation***.

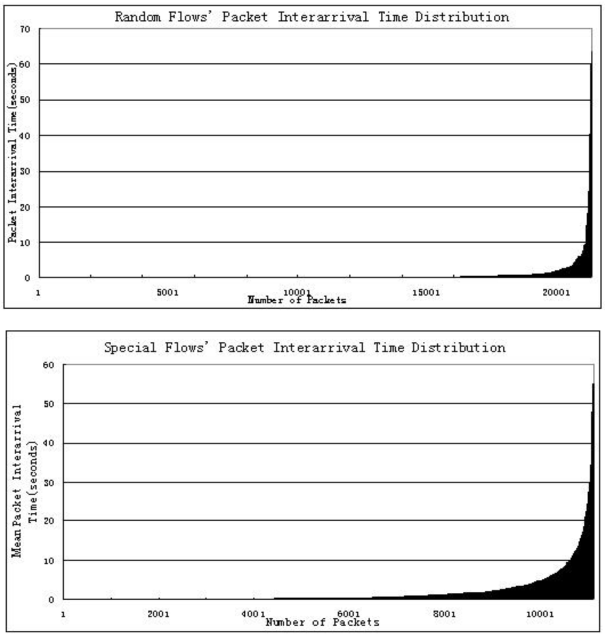


Figure 1. Random(Up) and special flows'(Down) packet inter-arrival time distributions

**Definition:** Every item in one set divided by the mean of this set is putted as a new item to another set, and calculating the variation of the new set, this variation is called coefficient of variation.

Coefficient of variation depicts the ratio of values in someone set departure from its mean value, and so it can be used to describe the stability of packet inter-arrival time in flows. It is illustrated in Fig. 2 that the packet inter-arrival time's distributions of means, variations and coefficient of variations which belong to 2065 different length flows from CERNET. Because flows are gathered at random, the distributions of sampling reflect the true distribution of total flows in the network.

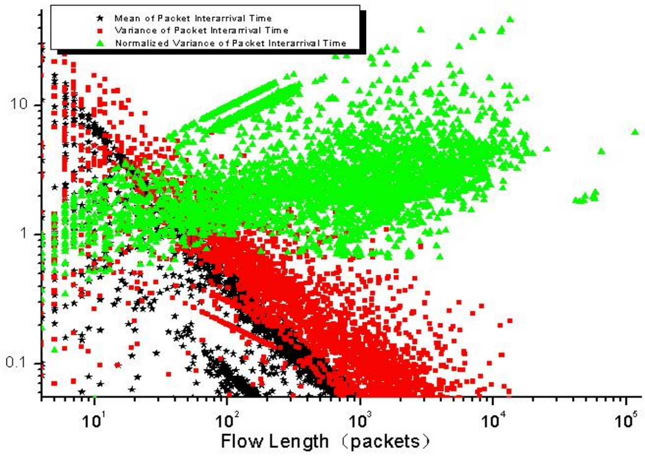


Figure 2. Analysis of Flow rate stability based on variation of packet inter-arrival time in flows

The distribution of pentagrams in Fig. 2 indicates that the means of inter-arrival time are decreasing when the flow length are increasing. And this means short flows are more possible slow flows while most long flows are fast flows. The variations whose distribution is described by the rectangles also have same trend with the means. That is to say fast flows have smaller variations than slow flows generally. The normalized variations which is illustrated by the triangles show absolutely different trend in the distribution with the former two. They are increasing with as the flow length increasing. That means the burstiness of long flows is much heavier than short flows, in other words, the flow rate stability of short flows is better than fast flows in general. We call the interval between two bursts ***silence time***.

Then we can get some inferences about flow rate metric:

- The packet inter-arrival time of special flows is obey the heavy tail distribution, packet arrival rates of most flows are fast.
- The means of packet arrival rate is increasing with the flow length.
- The faster of a flow's packet arrival rate the more possibility of its instability in flow rate. That means the burstiness of fast flows is more serious. But for fast flows, the numbers of packets they passed in every burst are relative big in general.
- Packet arrival rate of slow flows is stable in all.

*B. Features of Short Flows and Long Flows' Head's Flow Rate Metrics*

Because short flows take a large proposition of total flows, it is very importance for timeout value setting in flow recognition to analysis rate characteristics of short flows. This paper reviews the rate metric of short flows in detail. Tab. 1 exhibits distributions of 2500000 short flows' durations (500000 flows in every time zone), which are sampled from CERNET in different time using 5-tuple specification and fixed 64-seconds timeout value (rows are time zones, columns are time slices). It can be seen that the distribution of short flows durations in every time slice is same in different time zones, and durations of most short flows (above 95%) are less than 16 seconds. The analysis results of the TRACEs from other network also indicate that most flows are short flows if using the specification of 5-tuple. The traditional flow recognition systems always use fixed timeout value, 64-second or 60-second [10][11], and the most resource of those systems is not used efficiently.

TABLE I. THE DISTRIBUTION OF SHORT FLOWS DURATION IN DIFFERENT TIME

| | t<2 | 2≤t<4 | 4≤t<8 | 8≤t<16 | t≥16 |
|---|---|---|---|---|---|
| 00:00 | 0.327 | 0.127 | 0.396 | 0.209 | 0.041 |
| 04:00 | 0.317 | 0.099 | 0.289 | 0.271 | 0.032 |
| 08:00 | 0.467 | 0.115 | 0.202 | 0.177 | 0.039 |
| 16:00 | 0.467 | 0.130 | 0.223 | 0.126 | 0.051 |
| 20:00 | 0.424 | 0.122 | 0.277 | 0.127 | 0.060 |

This paper also inspects the first N packets inter-arrival time distributions in 1000000 long flows coming from the same dataset. The results are shown in Tab. 2 (rows are time slices, columns are values that N is set). In general, the inter-arrival time changes a little among several time slices as N is increasing. Especially, the ratio of that bigger than 16 seconds is almost not changing with the value of N. The reason can be explained by conclusions in § 3.1: Packet arrival rate of long flows is rapid in general, and those flows also exist heavy-hitter burstiness. Only when long flows belong to slow flows or one or more silence times are in first N packets of long flows, the inter-arrival time of first N packets of long flows exceeds 16 seconds can appear.

TABLE II. THE INTER-ARRIVAL TIME OF FIRST N PACKETS IN LONG FLOWS

| | N = 2 | N = 3 | N = 4 | N = 5 |
|---|---|---|---|---|
| t<2 | 0.432 | 0.412 | 0.390 | 0.229 |
| 2≤t<4 | 0.385 | 0.320 | 0.262 | 0.288 |
| 4≤t<8 | 0.126 | 0.207 | 0.201 | 0.205 |
| 8≤t<16 | 0.040 | 0.028 | 0.106 | 0.133 |
| t≥16 | 0.017 | 0.033 | 0.041 | 0.045 |

From the analysis of short flows and first 5 packets of long flows, we get a very important conclution: most short flows duration and inter-arrival time of first 5 packets of long flows are very small, and fast flows take a large proportion of total flows. The researches of other networks also give the same results [10].

## IV. DYNAMIC TIMEOUT STRATEGY BASED ON FLOW RATE CHARACTERISTICS (DTOS)

The characteristics of flows are up to the specification and timeout strategy they take. It will get absolutely different results about flow characteristics when using different flow specification and/or timeout in the same dataset. But it is right that resource usage will be reduced dramatically without impacting efficiency of flow recognition by applying new timeout strategies under the same flow specification.

*A. Introduction of DToS*

This paper presents a new timeout strategy, DToS, according to packet arrival rate and flow length characteristics. It can improve the efficiency of resource usage dramatically without loss the precision of flow recognition by detecting and terminating the ended flows as soon as quickly based on the flow rate metric discovering. The system model of using DToS for flow measurement is illustrated in Fig. 3.

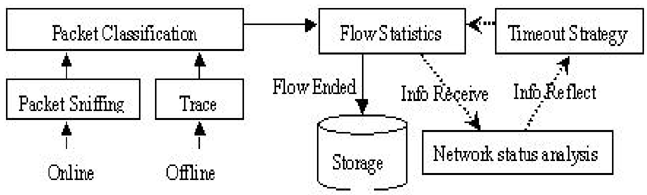


Figure 3. The system model of using DToS for traffic measurement.

- Firstly, some thresholds are set as following: short flow threshold *N*, short flow timeout threshold $T_S$, short flow duration threshold $T_D$, long flow timeout threshold $T_L$, threshold of the proportion of flows number and packets number $\xi$;
- When a packet is coming, the packet classifier will create a new flow or put the packet into existing flow in the flow statistical space according to the flow specification. For the long flows, protocols analysis method will be used to terminated the TCP flows with the fixed timeout value $T_L$, and MBET method is used for non-TCP flows, every flow will keep a dynamic timeout [1];
- $T_S$ is used as the scanning interval in the flow statistical space to find out the ended flows. A flow with length $\leqslant N$ and duration $\leqslant T_D$ will be terminated and driven out of the space if its last packet arrived $T_S$ ago. The flows that use MBET strategy are terminated by their own timeout values. And the TCP flows without getting the FIN packets for a long time will be terminated by the long flow threshold $T_L$;
- The module of network situation analysis will get new creating flows number *F* and incoming packets number

$P$ in unit time at scanning. If $F/P> \xi$, the value of threshold $T_S$ will change to $T_S/2$, and the information of traffic abnormal will be reported.

### B. Performance of DToS

DToS need more CPU time to calculate the length and timeout value of every flow. And it need establish algorithm's cost model to provide the rules for algorithm performance evaluation. The main parameters this algorithm involved are including: flow creating CPU time $C_{CF}$, CPU time of keeping a short flow in unit time $C_K$, scanning frequency $\alpha$, CPU time for detecting flow length $C_{FL}$, mean value of storage for keeping a flow in flow statistical space $S_F$, ratio of short flows in total flows $\mu$, short flow timeout threshold $T_S$, long flow timeout threshold $T_L$, fixed timeout threshold $T_L$.

The mean CPU time of creating and keeping a new flow using fixed timeout and DToS algorithm are (1) and (2):

$$F_{C1} = C_{CF} + \alpha \cdot T_L \cdot C_K \quad (1)$$

. $$F_{C2} = C_{CF} + C_{FL} + \mu \cdot \alpha \cdot T_S \cdot C_K + (1-\mu) \cdot \alpha \cdot T_L \cdot C_K \quad (2)$$

Because $T-T_S>0$ , the result can be deduced from（1）and（2）:

$$MAX(F_{C2} - F_{C1}) = C_{FL} \quad (3)$$

Computational complexity of estimating every flow's timeout value is O(1),and the CPU time of DToS does not increase distinctly than fixed timeout strategy. The experiment results in § 5 indicates only about more 5% CPU time should be added in DToS than fixed timeout strategy.

The mean resource usage of creating and keeping a new flow using fixed timeout and DToS algorithm are $T_L \cdot S_F$ and $\mu \cdot T_S S_F + (1-\mu) T_L S_F$, which can inference that saved resource in DToS is $\mu \cdot (T_L - T_S) \cdot S_F$. Because short flows' ratio is very big, that is to say the value μ of is close to 1. And $T_S$ is much smaller than $T_L$ in measurement system. It is can be concluded that the efficiency of resource usage in DToS is much better than traditional fixed timeout strategies.

Short flow duration $T_D$ is set for preventing slow flows from being shorten by system. And this method can assure the precision of flow recognition. The packet arrival rate and stability analysis of flows in Fig. 1 shows that slow flows' number is smaller than that of fast flows, but they are more stable than fast flow.

When the proportion of flows number to packets number expands suddenly and exceeds the threshold ξ, this means the number of short flows in the network increases dramatically. This phenomenon is the characteristic of network abnormal (i.e. DDOS and worm burst). There are no emergent measures to reply on rapid expanding of flows number in the network in fixed timeout strategy, MBET strategy and the strategies based on protocol and memory control etc. And it will cause the exhausting of resource in the measurement systems. DToS strategy carries out emergent measures to deal with the emergency by shortening the timeout values of short flows, detects and drives the ended flows as soon as quickly. This method will assure the safety of measurement system when network traffic is at abnormal with little influence of the precision of flow recognition.

### C. Error rate analysis of DToS

DToS algorithm saves large numbers of resource with little additional CPU time but it uses small timeout values to deal with most flows. The situation is inevitable that some flows are terminated though they are not ending actually. The following part of this paper will analyze the errors of DToS algorithm in flow recognition in detail.

We suppose that packet inter-arrival time X of different flows follows an independent and homogeneous distribution whose distribution function (***d.f***) is F(x) and probability density function (***p.d.f***) is f(x). We called it Y that the sum of first N packet inter-arrival time whose distribution function is F(y) and probability density function is f(y). then we can get the equations as following:

$$Y = \sum_{i=1}^{n-1} X_i \,(n = 1, 2, ....)$$

$$F(y) = F(\sum_{i=1}^{n-1} x_i) = \int_{-\infty}^{+\infty} f_y \, dy$$

By the theorem of multivariate distribution statistics, the ***p.d.f*** of multivariate added is equal with the convolution of ***p.d.f*** of every variable:

$$f(y) = f(x_1) * f(x_2) \cdots * f(x_n)$$

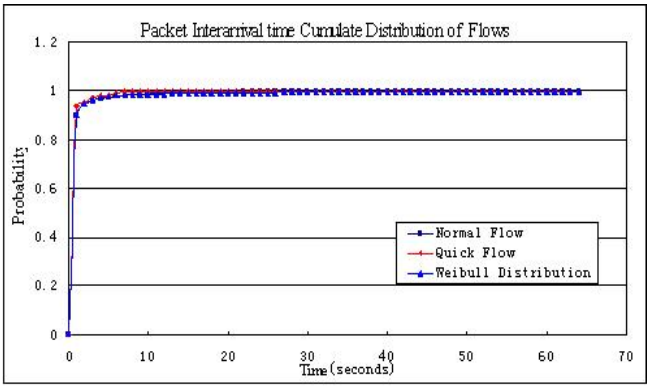


Figure 4. Packet inter-arrival time cumulate distribution of flows

And then we discover the type of distribution that the packet inter-arrival time follows. By the TRACE used in flow rate metric analysis in § 3, it is depicted that the packet inter-arrival time cumulate distributions of flows belong to two types in Fig. 4. Type I is the set of random sampled 20000 long flows (Normal Flow), Type II is the set of another random sampled 20000 long flows whose mean packet inter-arrival time is smaller than 0.1 second (Quick Flow). The analysis results of those curves show that the packet inter-arrival time follows Weibull distribution as following equation whose parameters are λ = 0.103, α = -0.93 when time is bigger than 1 seconds because the influence of the inter-arrival time less than 1 second can be omitted when $Ts$ is far bigger than 1 second.

$$f_{X_i}(x) = \begin{cases} \alpha\lambda x^{\alpha-1} e^{-\lambda x^{\alpha}}, x > 0 \\ 0, x \le 0 \end{cases} i = 1,2,...,n$$

And then we inspect the distribution of time needed by transferring first N packets of long flows. A simplified method is introduced for the complexity of calculating the value of $f_Y$. The theorem is obtained from the fact that the distribution of packet inter-arrival time bigger than 1 second follows Weibull distribution.

**Theorem 1:** As the increasing of time, the incoming packet number is decreasing in unit time, and so is the slope of the decreasing curve.

The suppose is brought forward in this paper according to Theorem 1.

**Supposition:**

The probability is smallest that the sum of first N packets' inter-arrival time is equal or less than T when these N packets inter-arrival time is same: $t_1=t_2=\ldots=t_{N-1}=T/(N-1)$.

**Proof :**

Let packets inter-arrival time as following: $t_1$, $t_2$, …, $t_{N-1}$. Because the sum of those values is irrelevant with their sequence, without the loss of generality, let $t_1 \leqslant t_2 \leqslant \ldots \leqslant t_{N-1}$. Let

T: the sum of first N packets inter-arrival time;

$P(t_i)$: the ratio of packets whose inter-arrival time is smaller than $t_i$;

$F(t_i)$: the distribution function in $t_i$, $P(t_i) = 1- F(t_i)$;

$P_N(T)$:the probability that the first N packet incoming time is smaller than T.

Then :$T = t_1+t_2+\ldots+t_{N-1}$

$$P_N(T) = \prod_{i=1}^{n} P(t_i) = \prod_{i=1}^{n} (1 - F(t_i))$$

It is known from Theorem 1 that

$F(t_1) \geqslant F(t_2) \geqslant \ldots \geqslant F(t_{N-1})$ and $F(t_1)-F(t_2) \geqslant F(t_2)-F(t_3) \geqslant \ldots \geqslant F(t_{N-2})- F(t_{N-1})$

According to the characteristics of monotonic decreasing function, we can infer that the smallest value of $P_N(T)$ is existing when T is a fixed value and t1=t2=….=tN-1=T/N.

$$\mathrm{Min}(P_N(T)) = (1 - F(t))^{N-1}, \ when \quad t_i = t = T/(N-1), i = 1,...,N-1$$

From the proof result, the minimum of probability is (1-F(T/(N-1)))N-1 that the first N packet incoming time is smaller than T for all flows whose length bigger than N, and F(T/(N-1)) is the value of Weibull cumulate distribution curve in the point T/(N-1).

In measurement, the thresholds are set as following: $T_S$=16 seconds, N= 5. It can be inquired on the Weibull cumulate distribution curve that the value of $F(T_S/(N-1)) = F(4) = 0.028$, and then we can calculate $\mathrm{Min}(PN(T_S)) = (1-0.028)4 = 0.90$. The result of fast flows cumulate distribution curve in Fig. 4 expressed $F(T_S/(N-1)) = 0.012$. Minimal value is recalculated as following: $\mathrm{Min}(P_N(T_S)) = (1-0.012)^4 = 0.953$.

We use hypothesis estimation to test the estimated precision as timeout is set to 16 seconds, and calculate the ratio of sample errors via calculating the true error. This method is proposed by T.M.Mitchell [8] to calculate confidence interval of the true errors:

$$error_p(h) = \left[ error_S(h) \pm z_N \sqrt{\frac{error_S(h)(1 - error_S(h)}{n}} \right]$$

$error_S(h)$ is the sample error, which is ratio of wrong samples in the sampled individuals; $z_N$'s value is related with the confidence interval α; And $n$ is sample number from the examination. Let confidence equate 99%,(that means $z_N$ =2.58), n = 20000, $error_S(h)$ = 1-0.953 = 0.047. And then we calculate 99% confidence interval of the true errors $error_D(h)$.

$$error_p(h) = \left[ 0.047 \pm 2.58 \sqrt{\frac{0.047 \cdot (1 - 0.047)}{20000}} \right] = [0.047 \pm 0.00384]$$

The conclusion can be inferred that the ratio of flows shortening in the system using DToS timeout strategy is no more than 5% at worst. And the method used $T_D$ to prevent slow flows from shortening can also improve the precision of flow recognition. The experiments in § 5 show that the errors are much smaller than the worst cases estimated above.

## V. Experiment Results and Analysis

As flow definition described in Chapter1, The efficiency of flow recognition lies on the timeout strategy if using same flow specification. This paper analyzes one hour TRACE which gets from the CERNET on someday April, 2004. While using the same flow specification (5-tuple) and different timeout strategies, Fig. 5 describes the flows' cumulate distributions and the right of Fig. 6 describes the active flows' numbers in memory.

Fixed timeout algorithm used the timeout value is 64 seconds(FIX-64); Parameters used in MBET strategy are as following: $T_0$=4, S=5, P ={21,18,15,12,9}, then we can calculate $T_{MAX}=T_0*2^{5-1}=64$ that means the timeout threshold is set as 64 seconds(MBET); The thresholds used in DToS are N=5, $T_S$=16 (seconds), $T_D$=packetnum*$T_S$/N, $T_L$=64(seconds), ξ=1/16(The mean flow length in CERNET at normal is 20. When this value is changed to16, we define the network is under abnormal.).

The CDF curves in Fig. 5 describe that the number of flows is approximately equal using different timeout strategies. And this indicates these three timeout strategies will not reduce the efficiency of flow recognition if correct parameters are selected. But DToS strategy can improve the flow recognition's accuracy through protocol mechanisms to terminate TCP flows. Generally, the flows' number using DToS is bigger than that of using MBET, and the latter is bigger than Fix-64 strategy. The main difference of these three strategies is concentered in the number of short flows because burst flow that has one or more silence time in the head will be cut into two or more flows. Actually the flows that have been impacted are very few. We measure 10000 long flows random sampled from above dataset, and experiment result of the contrast between DToS and FIX-64 shows only 0.57% of long flows are affected. And so it can be concluded that the affection of DToS in efficiency of flow recognition is very little, and mostly this remoteness difference can be omitted.

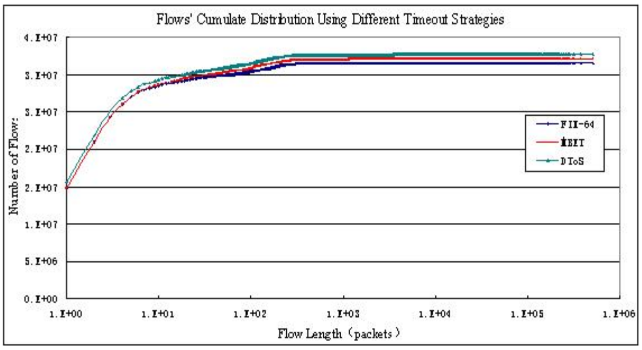


Figure 5. Flows' cumulate distribution using different timeout strategies

The upside of Fig. 6 illustrates the active flows number in the memory using different timeout strategies at normal. The active flows number reflects the memory usage of system because the memory that every flow takes is equal on the whole in flow recognition. The contrast among three strategies indicates, the memory of DToS takes is about 54% of that of FIX-64 and 64% of that of MBET. That is to say, DToS can save about 40% space contrasting to other algorithms at normal network situation.

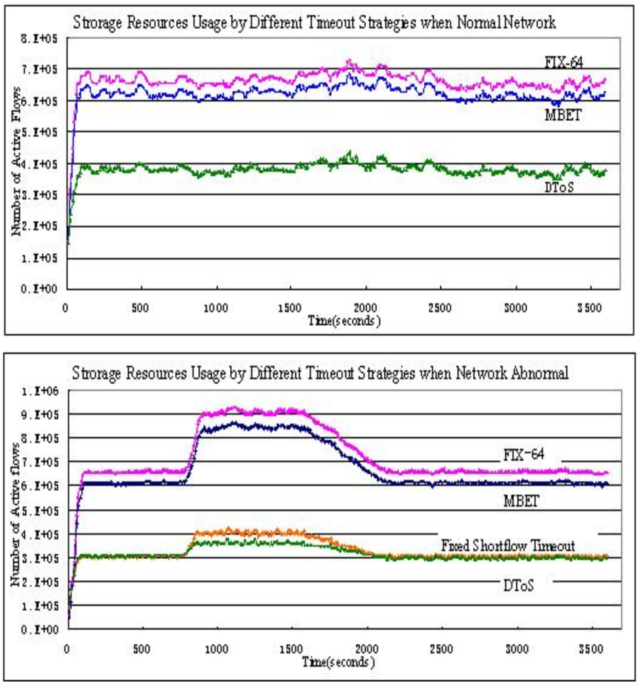


Figure 6. Resource usage of different timeout strategies at different situations.

The downside of Fig. 6 describes the active flows number kept in memory using different timeout strategies at abnormal. The dataset is simulated referent to the characteristics of CERNET flow rate metric and active flows. The parameters which are used in simulate: the mean value of new coming flows number in every second is 10700 at normal, the ratio of flows number and packets number is 1/20. At the point about 800 second, the flows number improved dramatically, and most new coming flows are short fast flows, and the range of flows increased is about 40%. This situation will kept 800 seconds, and then the flows number begins to decrease and come back to normal situation at the point about 2300 second. From the contrast of those curves, it can be seen that both of the active flows numbers of FIX-64 and MBET increase above 35%, but the increasing flows number using DToS without emergent measures is about 1/4 of the former two. And if using the threshold ξ to detect the changing of flow rate metric and use the dynamic timeout strategy, the increasing flows number is just a little bigger than 1/8 that of former two. It is proved that DToS has advantage than the other timeout strategies when the network traffic is abnormal.

## VI. Conclusion and Future Work

As aggrandizing of network bandwidth(i.e. OC48, OC192) and improving of network traffic, the efficiency of flow recognition is becoming one of most important and emergent problems in network flow measurements and applications. This paper points out the advantages and shortages in flow recognition based on detail analysis of existing flow timeout strategies. Through the flow rate metric observation of different time in CERNET backbone, this paper gets several characteristics about the flows rate metric in high-speed network. And then a new timeout strategy (DToS) is presented by taking advantage of former researches, which can use dynamic timeout to reducing the resource usage with little influence on flow recognition precision. The performance and error rate of this strategy is analyzed in detail at the following section, and experiments are also carried out to demonstrate the efficiency of this strategy.

The test result of using three different timeout strategies indicates that the resource usage of DToS is about half of the others. Especially, when the network is under abnormal where the number of short flows expands dramatically, DToS can identify this phenomenon by real-time flow rate metric monitoring, and use dynamic timeout to recognize and terminate abnormal flows as soon as possible, while the other timeout strategies can't response the abnormal efficiently which can cause the system resource exhausting. The experiment results show that the resource usage expanding rate of DToS is about 1/8 of the other two strategies when the measurement system facing abnormal traffic.

Though DToS algorithm improves the performance of measurement systems by optimizing the short flows timeout values, and enhances the precision of flow recognition through the observation result of flow rate metric, some burst long flows will be shortened to short flows because of the shortening timeout value for short flows which makes the precision of measurement decreased. But it is also proved in § 4.3 that decreasing of the precision can not be bigger than some fixed small value. This result of flow recognition can't be used to analysis the information of application layer for the flow specification of 5-tuple is based on the layer of TCP. The future work of this paper is finding out more flexible timeout strategy to satisfy the need of other widely used flow specifications.

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