A SURVEY OF NETWORK TRAFFIC GENERATION

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Abstract

Network traffic generation is very important for testing network equipment, network services, and security products. The paper firstly introduces the significance and the classification of network traffic generation. Then, the paper chronologically categorizes the research activities of network traffic generation into three different methods: 1) traffic generation based on network traffic model; 2) traffic generation based on traffic characteristics; 3) traffic generation based on application protocol. Thorough reviews of the major research achievements of each kinds are conducted. Finally, the paper identifies some open research issue and points out possible future research directions in traffic generation area.

Keywords: Network traffic generation, traffic model, traffic feature, application protocol.

1 Introduction

The actual network traffic is the extremely important resource for testing network equipment, network services, and security products. However, the actual traffic often does not have the repeatability and controllability because of instantaneous characteristics, Moreover, the actual traffic carries personal private information and behaviours, which greatly limits the use range and efficiency. How to extract the main characteristics of actual traffic, and generate similar traffic instead of using real traffic is the key issue. This paper attempts to systematically analyse the methods of traffic generation, in order to help people who is engaged in related research.

In early 1970's and 80's, people tried to use the Poisson model to generate traffic, because the network application was simple at the time, the result was satisfying. The last century 90's, the network traffic generated by the Poisson process was no longer consistent with the real network traffic [1]. In 1993, Leland and other scholars in Bell laboratory found that network traffic was self-similar [2]. So models which could generate self-similarity traffic appeared, such as ON/OFF model with heavy tailed distribution, FGN (Fractal Gaussian Noise) and multi fractal model. At the same time, people extracted the main characteristics of actual network traffic and generated traffic according to the analysis of characteristics. Yoonseon Han et al. extracted the main features (flow start time, flow duration, flow size) from the real traffic, and generated traffic according to the analysis of these characteristics. Dainotti, A. et al. extracted the packet interval time and packet size from HTTP flows, analyzed their PDF(Probability Distribution Function) and CDF(Cumulative Distribution Function), and used Lognormal distribution to describe the packet arrival interval and packet size. At present, the current traffic generation tool such as Iperf [3], puts packets together sequentially according to certain time intervals. It is used to test the TCP and UDP bandwidth and can report bandwidth and packet loss et al. Harpoon [4], is a kind of traffic generation tool based on flow-level. It can match the features of the byte, packet, and flow volumes in the original data over relatively coarse intervals (e.g., 300 seconds).

This paper firstly introduces the significance and classification of network traffic generation. Then, the research activities of network traffic generation are chronologically analyzed and categorized into three different methods: 1) traffic generation based on network traffic model; 2) traffic generation based on traffic characteristics; 3) traffic generation based on application protocol. Finally the prospect of future progress on traffic generation is presented.

2 Traffic generation based on network traffic model

Traffic generation technology based on network traffic model is based on the existing network traffic model, and configured with the parameters, thereby it generates traffic that conforms to the characteristics of traffic model. The typical network traffic models used to generate traffic are Poisson model, ON/OFF model with heavy tailed distribution, FBM/FGN model, the multi fractal model and so on.

2.1 Poisson model

The Poisson model was proposed by Erlang according to the characteristics of telephone service at the beginning of the twentieth Century [5]. The call arrival process can be regarded as a Poisson process. In the early stage of network traffic modeling, people began to use the Poisson model to research the network traffic.

The Poisson model refers that the number n(t) of the arrival packets follows Poisson distribution with parameter λt,

$$p_n(t)=\frac{e^{\lambda t}(\lambda t)^n}{n!}(n=0,1,2,...,N) \quad (1)$$

Poisson model was used to generate background traffic in paper [6], its packet arrival follows exponential distribution. Shawky et al [7] used Poisson process to describe packet number arrived, and configured transfer probability matrix to

transfer protocol and port. And packet size is determined by the extracted discrete probability density. The analysis [8, 9] shown that highly polymerized traffic tends to Poisson distribution. Thesis [10] described that new packet inter-arrival times were produced in a random manner by using negative exponential probability distribution with a known mean. New packet sizes were also produced in a random manner by using a truncated exponential probability distribution.

Generating traffic by Poisson model is relatively simple and practical, but with the complexity of network traffic becoming, the packet arrival process is no longer consistent with the Poisson distribution.

2.2 ON/OFF traffic model with Heavy tailed distribution

There are a mass of ON/OFF sources in ON/OFF model. Each source has two alternated ON and OFF cycle states. The source sends packets in a continuous rate only on the ON state. The ON or OFF state of each source follows the heavy tailed distribution (such as Pareto) independently.

The ON/OFF model with heavy tailed distribution can explain the self-similarity feature of traffic well [11]. DSGen (a Distributed Synthetic Network Traffic Generating System) was presented in [12]. The self-similar traffic was generated through aggregating multiple sub-streams that follow the ON/OFF model, and the ON and OFF cycles of each sub-stream obeyed the Pareto distribution. Fig.1 is the ON/OFF model that generates self-similar network traffic:

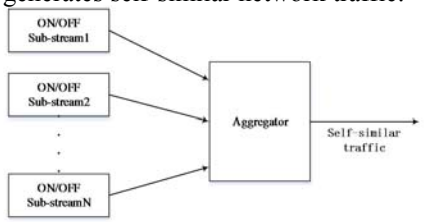

Fig.1: ON/OFF self-similar network traffic model

The experiment results shown that [13], when the number of superposed sources tended to infinite, the total traffic was asymptotically self-similar.

"SourcesOnOff" using the ON/OFF model was presented [14], it used different curves (Weibull, Pareto, Exponential, Gaussian etc.) to fit ON and OFF cycles. The BIC (Bayesian Information Criterion) was applied to calculate the distance between statistical distribution and the real data. This tool is currently unable to generate traffic other than TCP and UDP protocols. In [15], controller sent the task message to the agents. Then, the agents analyzed the message and called the corresponding plugins whose intervals of ON and OFF states follow Pareto distribution. Packets were send in fixed rate in ON state. With the help of third party software (such as Libnet), the types of network packets can be increased.

The self-similar traffic can be generate based on ON/OFF model, whose assumption is that all sources must be independent and identically distributed, and the output rate is constant.

2.3 Multi fractal traffic generation model

In fractal theory, the multi fractal is also called multi fractal measure. For many non-uniform fractal process, one dimension cannot describe all of its characteristics, so the continuous spectrum of the multi fractal measure is needed. In the self-similar model, the Hurst parameter shows only one fractal process in the long-term behavior. The multi fractal has been used to investigate the long-term as well as short-term traffic behavior. MWM (multi fractal wavelet model) was proposed in [16] which was based on WIG (independent Gauss wavelet domain) model. To ensure the non-negative scale coefficient, the factor $A_{j,k}$ was introduced and its value is in the range of [-1,1], and $W_{j,k} = A_{j,k} \times U_{j,k}$. So the following formula was gotten:

$$\begin{aligned} U_{j+1,2k} &= 2^{-1/2}(U_{j,k} + W_{j,k}) = 2^{-1/2}(1 + A_{j,k})U_{j,k} \\ U_{j+1,2k+1} &= 2^{-1/2}(U_{j,k} - W_{j,k}) = 2^{-1/2}(1 - A_{j,k})U_{j,k} \end{aligned} \quad (2)$$

The probability density function of the root scaling function $U_{0,0}$ can be specified, and its general distribution is the independent Gauss distribution, $A_{j,k}$ can be symmetric β distribution. Multi fractal model was used to generate traffic for MPEG-4 video [17], and Quartile-Quartile graph of generated traffic and the original MPEG-4 video traffic has good consistency.

2.4 FGN traffic generation model

The FBM (fractional Brownian motion) $X_H(k)$, is a continuous Gauss process whose mean is 0. Its stable incremental process $Z_H(k) = X_H(k) - X_H(k-1)$ is the fractional Gauss noise (FGN). Asymptotic self-similar series were produced by using the FFT method on the power spectrum of fractal Gauss noise [18], the generated series was self-similar.

The network traffic model contributes to comprehensively understand the inherent features of network traffic. It can describe the short range dependence, burstiness or long range dependence. The generated traffic based on network traffic model conforms to the intrinsic network features such as self-similarity. But this method lacks a reflection on statistical characteristics such as the packets and flows.

3 Network traffic generation based on traffic characteristics

Network traffic generation based on traffic characteristics can be categorized into two methods according to the hierarchy of characteristics: network traffic generation based on flow-level and traffic generation based on packet-level.

3.1 Network traffic generation based on flow-level

Flow is an important concept in the measurement, analysis, and simulation. A series of flows in the network constitute the network traffic. Flow characteristics from original network are used in network traffic generation.

The generated traffic based on flow level facilitates various performance tests. Harpoon is a new application-independent tool for generating representative packet traffic at the IP flow

level [19, 20]. It generated traffic according to the empirical distributions of file size, inter-connection times, and number of active sessions and so on in a given interval.

Harpoon can match the byte, packet, and flow volumes from the original data over relatively coarse intervals (e.g., 300 seconds), but may not match over shorter intervals and it may not match packet loss process, and flow durations.

Flow-level traffic matrix was proposed to generate network traffic [21]. The flow number was decided firstly by a random number generator of Poisson distribution, and then the five tuple were chosen. The distribution of flow duration fit well with Pareto distribution, and the flow size followed Weibull distribution. The method can reflect new flow occurrence rate, flow ratio, flow duration, and flow size, but lacks reflection on the packet level. C.Barakat et al. [22] hypothesized that as the traffic intensity increases, the shape parameter of Weibull used to describe flow arrival interval gets close to 1. Thus, the flow arrival process tends to be in good agreement with a Poisson process. The generated traffic was similar to original traffic in the distributions of flow arrival interval, flow duration and flow size.

Wang linfeng [23] used multi threads to send a series of flows to generate traffic. Each flow can be described with four parameters: inter-packet time, packet size, flow duration, flow interval. Users can configure different parameters distribution to generate the corresponding traffic accurately. A model for interdomain traffic simulation at the flow level was presented in [24]. The flow arrival process followed the heavy-tailed distribution, flow size followed exponential distribution, and flow rate followed the constant distribution. The traffic generated by the model was self-similar. Traffic generator was configured based on flow-level[25], including the flow duration, start time, generated packets and bytes, application types (DNS, Telnet etc.), packet size distribution(Constant, Exponential, Pareto etc.), inter-packet time distributions (Constant, Exponential, Pareto etc.). P. Siska et al. [26] used a graph-based approach to model the communication structure observed in real-world traces and to extract the flow characteristics. Normal distribution was used to describe the flow number in the interval of 300s, Values for duration, packets, and octets flow record fields were chosen by sampling from the lognormal distribution, and the end timestamps of flows were sampled from a uniform distribution. BreakingPoint generate mixed application traffic in the test according to the user profile. Smartbits can generate fixed flow rate according to configuration, they can be used in test and analysis for the switches, routers, network security equipment etc.

3.1 Network traffic generation based on flow-level

Packet characteristics such as the packet size and the packet arrival process from original network are used in network traffic generation.

An approach based on the packet-level characteristics of real network traffic is proposed in [27]. Plab was used to capture and analyze traffic. PDF and CDF statistics of inter-packet time (IPT) and packet size (PS) were gathered. IPT followed Weibull distribution, and the packet size followed lognormal distribution for the HTTP traffic. But it should enlarge the number and characteristics of the observed links, and extend the number of studied protocols. A packet-level traffic generator using the ON/OFF model was proposed in [28]. In the ON state, it generated the corresponding traffic according to the user's configuration with the IDT (Inter-departure time) and PS distribution (e.g. Exponential, Poisson,). The traffic generation tool Swing was introduced in [29]. It extracted the source IP and destination IP, packet size, packet arrival distributions, request size, response size in each HTTP session from the original flow. Each generator read a configuration file of characteristics. But it lost the spatial locality of the same host simultaneously engaging in, e.g., HTTP, P2P, and SMTP sessions, and only TCP protocol traffic was considered. D-ITG traffic generator was configured with parameters of packet size (PS) and inter-packet time (IPT) distribution [25]. These distributions can be Constant, Exponential, Pareto, Poisson, Weibull distribution etc. The special testing instruments, such as Ixia Company's Breakingpoint and Spirent Company's SmartBits, can also generate traffic based on packet-level, simulating traffic for testing equipment.

Network traffic characteristics such as packets and flow are used in generating network traffic. It can clearly understand the generating process of network traffic and generate self-similar traffic according to the suitable distribution. However, there is no coordinate thoughts on what distributions traffic characteristics follow and how many characteristics should be considered. Thus, the accuracy of generated traffic is different.

4 Network traffic generation based on application protocol

Many scholars developed different traffic generation tools for different application protocols traffic. The network traffic generation tool Iperf [3] for network performance test, is used to test the bandwidth of TCP and UDP. It has a variety of parameters and can report the bandwidth, delay jitter and packet loss. A tool named Tmix was proposed to generate TCP application workload in NS-2 simulator [30]. The tool first took a TCP packet header trace, and the trace was "reverse compiled" into a TCP connection vector, $C_i = <E_1, E_2, \cdots, E_k>$, $E_i = (a_i, b_i, t_i)$, where a_i is the size of the i_{th} ADU(application-data units) sent from connection initiator to connection acceptor, bi is the size of the i_{th} ADU sent from connection acceptor to connection initiator, and t_i is the think time between the receipt of the i_{th} "response" ADU and the transmission of the $(i+1)^{th}$ "request". The specific is shown in Fig.2.

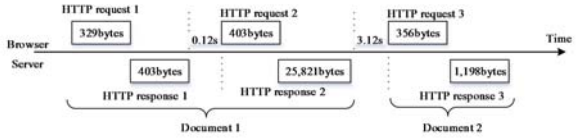

Fig.2: ADU exchanges in an HTTP 1.1 connection

Yu-Chung Cheng [31] et al. proposed a TCP trace replay tool. The tool captured packet traces using libpcap, extracted and analyzed link delays, packet losses, bottleneck bandwidth,

packet MTUs, and HTTP event timings, and used Dummynet [32] to recreate the network conditions and generated traffic whose response time, network delay are similar to original TCP trace. Geist[33] developed by Intel company's technology research laboratory and SURGE[34] developed by American Boston University are used to generate traffic for testing Web server pressure, the two tools generate self-similar network traffic using the ON/OFF model, and realize the aggregation of HTTP traffic. Paul Barford et al. [34] used NCSA Mosaic trace, extracted and analyzed the related characteristics and got their distributions (shown as Table 1), the SURGE tools generated self-similar traffic according to the related distributions.

Component	Model	Probability Density Function	parameters
File Size-Body	Log-normal	$p(x)=\frac{1}{x\sigma\sqrt{2\pi}}e^{-(\ln x-\mu)^2/2\sigma^2}$	μ=9.357; σ=1.318
File Size-Tail	Pareto	$p(x)=\alpha k^{\alpha}x^{-(\alpha+1)}$	k=133K; α=1.1
Popularity	Zipf		
Request Sizes	Pareto	$p(x)=\alpha k^{\alpha}x^{-(\alpha+1)}$	k=1000; α=1.0
Active OFF Times	Weibull	$p(x)=\frac{bx^{b-1}}{a^{b}}e^{-(x/a)^{b}}$	a=1.46; b=0.382
Inactive OFF Times	Pareto	$p(x)=\alpha k^{\alpha}x^{-(\alpha+1)}$	k=1; α=1.5
Embedded References	Pareto	$p(x)=\alpha k^{\alpha}x^{-(\alpha+1)}$	k=1; α=2.43

Table 1: Summary Statistics for Models used in SURGE

The streaming media traffic generation tool Gismo[35] developed by Boston University, uses the heavy tailed distribution model to generate self-similar traffic ,but it is only applied to the streaming media,. The special testing instrument Ixia BreakingPoint and Spirent company's SmartBits, can also configure specific application layer protocols, concurrent number, bandwidth, etc. but they cannot meet the variation of real Internet traffic.

Network traffic generation based on application protocol can generate traffic close to actual network traffic for a particular application protocol. It helps to study the specific application protocol. It can improve corresponding protocol network and service quality. The actual network traffic contains thousands of network applications, but there is no network traffic generation tool to simulate all network application protocols.

5 Prospect

At present the methods of traffic generation can be categorized into three kinds: traffic generation based on network traffic model, traffic generation based on traffic characteristics, traffic generation based on specific protocol.

The method based on network traffic model can characterize the traffic's short range dependence and self-similarity or burstiness, and it contributes to comprehensively understand the inherent law of network traffic. The method based on traffic characteristics uses the traffic and the distribution function of the packet or flow level. It can also clearly understand the generating process of network traffic, and generate self-similar traffic according to the suitable distribution. The method based on specific protocol can generate traffic close to actual network traffic for a particular application protocol. It helps to study the specific application protocol, and then improves corresponding protocol, network service quality.

Great achievements on the network traffic generation have been made so far, but there is a gap between the generated traffic and ideal requirements. We can get the following results through comprehensive analysis of the existing traffic generation methods: 1) the traffic generated by using traffic model can conform to traffic's inherent features, but it cannot reflect the characteristics of the packet and flow. 2) Most traffic generation tools focus on a specific network applications, there is no network traffic generation tool for all network application protocol. 3) Model of network traffic is not uniform. 4) Traffic generation method for backbone network is not evaluated, most tests of network traffic are for the campus network, the laboratory environment or open traffic set.

According to the above-mentioned questions, we look forward to the traffic generation development from the following several aspects:

(1) The discovery of new traffic characteristic and measured parameters

Most of the current self-similar models are characterized by a self-similarity parameter H. What characteristics are unknown in actual traffic remains to be explored. In 2008, Fonseca et al. [36] found long range dependence in traffic space with information entropy method. The new traffic generating method can conforms to the traffic features in the time series, and each packet has the same spatial information. The presented traffic characteristics almost follow Weibull, exponential, Poisson, Pareto and lognormal and so on. With the development for the research on the network traffic, people will find some new distributions that perhaps fit the traffic character better.

(2) The new physical development of traffic generation model

Since the physical model can explain the causes of network characteristics well, a better and more practical physical model that can explain the actual network behavior should be developed in the future. With the self-similarity found in the space structure of traffic, we can generate traffic that has self-similarity in time series and in space's information structure.

(3) The combination of a variety of network traffic generation method

The combined method of many traffic generation methods can make up the shortcoming each other. Network traffic generating method based on flow-level considers flow characteristics, and network traffic generating method based on packet-level considers packet characteristics, so we can combine the two methods. We first determine the basic characteristics distribution of flow, and then fill the packets interval and packets size in the flow duration, thus it can characterize traffic generation process more comprehensively, and generate traffic more close to actual network traffic. So the combination of many traffic generation method will also be need to be further investigated.

(4) The development of simple and accurate of generation method

The more parameters traffic generation method has, the more close to the actual traffic its generated traffic is. But it is more complex and difficult for the analysis and generation. However, the ideal traffic generation method is as simple as possible, its parameters are also less as far as possible and easy to calculate. Accuracy and complexity tend to be compromised in the network traffic generation.

Traffic generation methods provide an important technical support and guarantee for testing network equipment, network services, and security products. And the simulated network traffic provides reliable and rational analysis for network optimization, improving network protocol and network quality of service.

6 Conclusions

Network traffic generation is very important for testing network equipment, network services, and security products. The paper focuses on the research of the network traffic generation. We classify the existing methods for traffic generation into three categories and survey the network traffic generation method based on traffic model, traffic characteristics and application protocols. In addition, we sum up the drawbacks of the methods in generating similar network traffic. Finally, we outline several research directions. We hope this work can provide some help for the network traffic generation.

Acknowledgements

This work was supported in part by national science and technology major project of the ministry of science and technology of China No. 2012BAH45B01 and Fundamental Research Funds for the Central Universities No. 2014ZD03-03.

References

[1] Paxson V, Floyd S. Wide-Area traffic: The failure of Poisson modeling. IEEE/ACM Trans. on Networking, 1995, 1(3):226−244.

[2] Leland WE, Taqqu MS, Willinger W, Wilson DV. On the self-similar nature of Ethernet traffic. ACM SIGCOMM Computer Communication Review, 1993, 23(4):183−193. [Doi: 10.1145/167954.166255]

[3] The iperf TCP/UDP Bandwidth Measurement Tool [EB/OL]. : http://dast.nlanr.net/Projects/Iperf,2004.8

[4] Sommers, Joel; Kim, Hyungsuk; Barford, Paul. Harpoon: A Flow-Level Traffic Generator for Router and Network Tests, In Proceedings of ACM SIGMETRICS (poster), June, 2004.

[5] Bonald T. The Erlang model with non-poisson call arrivals. ACM SIGMETRICS Performance Evaluation Review, 2006, 34(1):276−286.

[6] Zhou Tianjin, Background traffic research in network simulation model. Harbin institute of technology, 2010

[7] Shawky, A.; Bergheim, H.; Ragnarsson,O.; Wratny,A. ;Pedersen,J. Characterization and Modeling of Network Traffic.Computer Engineering Conference (ICENCO), 2010 International

[8] N. McKeown and T. E. Anderson, ”A Quantitative Comparison of Scheduling Algorithms for InputQueued Switches”, Computer Networks, Vol. 30, No. 24, 1998, pp. 2309-2326.

[9] S. T. Chuang, A. Goel, N. McKeown and B. Prabhakar, ”Matching Output Queueing with a Combined Input/Output-Queued Switch”, IEEE Journal on Selected Areas in Communications, Vol. 17, No. 6, 1999, pp. 1030-1038

[10] Kos, A. and Bester, J. (2003) Poisson Packet Traffic Generation Based on Empirical Data. Systems, Cybernatics and Informatics, 1, 80-83.

[11] Willinger W, Taqqu MS, Sherman R, Wilson DV. Self-Similarity through high-variability: statistical analysis of Ethernet LAN traffic at the source level. ACM SIGCOMM Computer Communication Review, 1995, 25(4):100−113. [doi: 10.1145/217391.217418].

[12] Pan Yan-hui, Wang Tao, Zhao Jian-Peng. A Distributed Synthetic Network Traffic Generation System. Pervasive Computing Signal Processing and Applications (PCSPA), 2010 First International Conference

[13] LIKHANOV N, TSYBAKOV B, GEORGANAS N. Analysis of an ATM buffer with self-similar (“fractal”) input traffic[A].INFOCOM’95[C]. Boston, MA, USA, 1995. 985-992.

[14] Varet, A.; Larrieu, N. How to generate realistic network traffic. Computer Software and Applications Conference (COMPSAC), 2014 IEEE 38th Annual

[15] Pan Yanhui, Wang tao, Zhang Wei, Hao zhenhua.The network traffic generation based on ON/OFF model. Journal of Ordnance Engineering College, Apr.2007

[16] Riesi RH, Crouse MS, Rbeiro VJ. A multifractal wavelet model with application to network traffic. IEEE Trans. on Information Theory, 1999, 45(3):992−1018. [doi: 10.1109/18.761337]

[17] Wang shenghui, Qiu zhengding. Mpeg-4 video traffic multifractal modeling. Journal of communication, 2006, 27(10): 44-50

[18] Paxson V. Fast, approximate synthesis of fractional Gaussian noise for generating self-similar network traffic. ACM SIGCOMM Computer Communication Review, 1997, 27(5):5−18

[19] Joel Sommers, Paul Barford. Self-configuring network traffic generation. Proceedings of the 4th ACM SIGCOMM conference on Internet measurement. Oct. 2004

[20] Joel Sommers, Rhys Bowden, Brian Eriksson, Paul Barford, Matthew Roughan, and Nick Duffield. Efficient Network-wide Flow Record Generation. IEEE INFOCOM, April 2011

[21] Yoonseon Han, Sin-seok Seo, Chankyou Hwang, Jae-Hyoung Yoo, Hong, J.W.-K. Flow-Level Traffic Matrix Generation for Various Data Center Networks. Network

Operations and Management Symposium (NOMS), 2014 IEEE
[22] C. Barakat, P. Thiran, G. Iannaccone, C. Diot, and P. Owezarski. Modeling Internet backbone traffic at the flow level. IEEE Transactions on Signal Processing (Special Issue on Networking), August 2003
[23] Wang linfeng, Wang wenyong. Design and implementation of IPNM network traffic generation subsystem.2006
[24] Uhlig, S.: Simulating Interdomain Traffic at the Flow-Level. University of Namur, Belgium, TR-2001-11 (2001)
[25] A. Botta, A. Dainotti, and A. Pescap. A tool for the generation of realistic network workload for emerging networking scenarios. 2012.
[26] P. Siska, M. P. Stoecklin, A. Kind, and T. Braun, "A flow trace generator using graph-based traffic classification techniques," in Proc. IWCMC'10, Caen, France, June 2010, pp. 457–462.
[27] Dainotti, A.; Pescape, A.; Ventre, Giorgio. A Packet-level Characterization of Network Traffic.Computer-Aided Modeling, Analysis and Design of Communication Links and Networks, 2006 11th International Workshop.
[28] Hafsaoui, A.; Nikaein, N.; Lusheng Wang. OpenAirInterface Traffic Generator (OTG): A Realistic Traffic Generation Tool for Emerging Application Scenarios. Modeling, Analysis & Simulation of Computer and Telecommunication Systems (MASCOTS), 2012 IEEE 20th International Symposium.
[29] Vishwanath, K.V., Vahdat, A., 2009. Swing: realistic and responsive network traffic generation. IEEE/ACM Trans. Network., 17(3):712-725.
[30] M. C. Weigle, P. Adurthi, F. Hernandez-Campos, K. Jeffay, and F. D. Smith. Tmix: A tool for generating realistic TCP application workloads in ns-2. ACM SIGCOMM Computer Communication Review, 2006.
[31] CHENG, Y., HOLZLE, U., CARDWELL, N., SAVAGE, S., AND VOELKER, G. Monkey see, monkey do: A tool for TCP tracing and replaying. In Proc. of USENIX ATC (2004). [32] L. Rizzo. Dummynet. http://info.iet.unipi.it/~luigi/dummynet/
[33] K. Kant, V. Tewari, R. Iyer. Geist: A Generator for E-Commerce & Internet Server Traffic [A]. In: IEEE Interational Symposimn on Performance Analysis of Systems and Software[C]. Tucson, Arizona, 2001: 49-56.
[34] Paul Barford, Mark Crovella. Generating Representative Web Workloads for Network and Server Performance Evaluation [A]. In: Joint International Conference on Measurement and Modeling of Computer Systems[C]. Wisconsin, United States, 1998: 151-160.
[35] S. Jin, A. Bestavros. GISMO: Generator of Streaming Media Objects and Workloads [J]. Performance Evaluation Review, 2001, 29(3): 2-10.
[36] Fonseca N, Crovella M, Salamatian K. Long range mutual information. ACM SIGMETRICS Performance Evaluation Review, 2008, 36(2):32−37.