The Importance of Power-tail Distributions for Telecommunication Traffic Models

Abstract:

While the warnings given to designers of telecommunications networks are no doubt correct, the statistical analyses have not revealed how either simulation or analytic techniques can be applied to study the performance of such systems. On the other hand, it has been shown that `self-similar' data can be generated by a renewal process where the interarrival times come from a single power-tail distribution with a finite mean (but infinite variance). The simplest model for this would be a GI/M/1 queue. Alternatively, the results in [LIKH95] indicate that a Poisson process with a `disbursed' batch of packets whose number is distributed by a power-tail, can also generate self-similar data. In its simplest version, this can be transformed into an M/G/1 queue, where `G' is a power-tail distribution. We describe in detail the properties of power-tail distributions, and then present an analytic class of well-behaved distributions (a sub-class of which are Phase Distributions which can be used in Markov Chain models) that have truncated power-tails, and in the limit become power-tail distributions. This class was first used in [LIPS86] to explain the long-tail behavior of measured CPU times at Bellcore in 1986 [LELA86]. It was also used to show what might happen in data-retrieval systems which have power-tail file sizes [GARG92], and even to explain the distribution of medical insurance claims [LOWR93]. We then use these distributions to study the behavior of steady-state GI/M/1 queues as a model for telecommunications networks and...
present the results of a parametric study of the affects of different a's on the geometric parameter s [LIPS92] as a function of the utilization parameter r. The variance of a power-tail distribution is infinite if a <= 2, but our calculations show that the steady-state performance of these queues becomes worse only gradually as a drops below 2 with r fixed. The performance only becomes disastrous as a approaches 1 from above (i.e., the mean still exists). We also present calculations for distributions with truncated power-tails, and show that they too can yield extraordinarily large mean queue lengths. Of course, all this is done assuming steady-state behavior. But this may require inordinately many arrivals before such large queue lengths could be seen in reality. Discrete event simulation models must necessarily suffer from the same problem. We present an argument showing that the closer a is to 1, the more arrivals must occur before any system's steady state can be approached.

Stichworte:

Power-tail distributions; heavy/fat-tail distributions; stable distributions; regularly varying functions; asymptotically self-similar functions; truncated tails; G/M/1 queues; renewal processes; buffer overflow; utilization

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