Effects of ON-OFF Variability in Two-State Pareto Traffic Models on Multimedia Application Transmission Performance

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Abstract

Formulae of multimedia transmission buffer overflow probabilities are developed for an ON-OFF two-state Pareto multimedia source. Then, these are used to study the effect of ON-OFF variability on the multimedia application transmission impact. For the same utilization level, the variability of OFF periods tends to worsen the overflow performance, while that of ON periods tends to ease the buffer overflow. The variability of OFF period has the total different effects on the multimedia application transmission performance from that of ON period. This paper has developed an analytic approach to predict the buffer overflow probabilities for an ON-OFF Pareto multimedia source. Though the arrival process is far from Poisson, the proposed embedded Markov chain approach provides a very accurate prediction. Furthermore, the results of the approach are used to explore the effects of variability in ON-OFF periods on multimedia application transmission performance.

Index Terms – ON-OFF Pareto model, heavy tailed distribution, long-range dependence, multimedia application transmission performance

1. Introduction

Many researchers have proposed the ON-OFF two-state Pareto model [1][2] for long-range dependent multimedia traffic (LRD) [3][4][5][6][7]. Garroppo et al. [8] have studied a two-state LRD model, in which only the OFF period is Pareto distributed [9] and the ON period distribution is exponential. In this paper, formulae of buffer overflow probabilities are developed for an ON-OFF two-state Pareto source. Then, these are used to study the effect of ON-OFF variability on the multimedia application transmission impact. For the same utilization level, the variability of OFF periods tends to worsen the overflow performance, while that of ON periods tends to ease the buffer overflow. The variability of OFF period has the total different effects on the multimedia application transmission performance from that of ON period.

The remainder of this paper is organized as follows. Section 2 introduces the ON-OFF Pareto Model, while Section 3 describes the embedded Markov chain proposed in the current study. Section 4 performs a series of simulations and presents the numerical results. Finally, Section 5 summarizes the major contributions of the present study and provides some brief concluding remarks.

2. ON-OFF Pareto Model

We define the random variable X = the ON period, the random variable Y = the OFF period, r = rate at which data units are transmitted from the source to the buffer during the ON period, and c = rate at which data units are transmitted out of the buffer. The definitions are depicted in Figure 1.

The random variables X and Y are Pareto distributed. The probability density functions of X and Y are defined as

$$f_X(x) = a x^{-(a+1)}; \quad 1 < a < 2, 1 < x < \infty, \tag{1}$$

and

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$$f_Y(y) = by^{-(b+1)};\quad 1 < b < 2, 1 < y < \infty, \tag{2}$$

respectively. Pareto distribution with shape parameter (a in (1), b in (2)) between 1 and 2 has finite mean and infinite variance. If shape parameter is smaller than 1, Pareto distribution has even infinite mean. In [10], Neame et al. have shown that aggregation of a lot of Pareto distributions with shape parameter a exhibits LRD with Hurst parameter equal to (3-a) /2. So, shape parameter can represent the variability of the Pareto distribution. The closer to 1 the shape parameter is, the greater variability the distribution exhibits.

We define a random variable Z as the net increasing (or decreasing) data units after an ON-OFF cycle. Z can be expressed as

$$Z = (r - c)X - cY\ . \tag{3}$$

The probability density function of random variable Z can be a convolution form from those of the random variables X and Y:

$$f_Z(z) = \int f_X((r-c)y+z) f_Y(cy)/c(r-c)dy \tag{4}$$

The utilization ρ can be defined as

$$\rho = rE(X)/c(E(X)+E(Y)) \tag{5}$$

3. Embedded Markov Chain

Despite the arrival process being non-Poisson, we define an embedded Markov chain at instants related to the ends of ON periods. $P(n)$ is defined as the probability that the number of data units in buffer is an order of n ($10^{n-1} \sim 10^n$) at the end of an ON period. The transition from the state $n+1$ to the state n in an ON-OFF cycle needs that Z provides to drain 10^{n+1} from the buffer. Similarly, the transition from the state n to the state $n+1$ in an ON-OFF cycle needs that Z provides to fill 10^{n+1} from the buffer. Therefore, we have the following relationship

$$\frac{p(n+1)}{p(n)} \approx \frac{\int_{1}^{10^{n+1}} f_Z(z)dz}{\int_{-1}^{-10^{n+1}} f_Z(z)dz} \equiv g(10^{n+1}) \tag{6}$$

where $g(.)$ is used to simplify the notation for further discussion. We know that the summation of all $p(n)$'s equals 1. Consequently, we can get the following results:

$$p(n) = p(1)\prod_{i=1}^{n-1} g(10^{i+1}),\quad n = 2,3,4,... \tag{7}$$

where

$$p(1) = 1/[1+\prod_{i=1}^{\infty} g(10^{i+1})] \tag{8}$$

4. Numerical Results

The utilization is set as the same value 0.6 in all of the simulations. Figure 3 shows that the multimedia application transmission performance with greater OFF variability becomes worse when ON variability is fixed at 1.5. Figure 4 shows that the multimedia application transmission performance with greater ON variability becomes better when OFF variability is fixed at 1.5.

The function $g(10^{n+1})$ is an indication for multimedia application transmission queue-size growing. From Figure 5, the function $g(10^{n+1})$ becomes larger with greater OFF variability at a fixed ON variability. In the other hand, the function $g(10^{n+1})$ becomes smaller with greater ON variability at fixed OFF variability. The first simulation is to compare the results of analysis with the simulation. For Figure 2, the utilization ρ equals 0.6, shape parameters a and b are set as the same value 1.5. Despite the arrival process is non-Poisson, the numerical results show that the state probabilities predicted by analysis provide a very accurate prediction of those generated by simulation.

5. Conclusions

This paper has developed an analytic approach to predict the buffer overflow probabilities for an ON-OFF Pareto source. Though the arrival process is far from Poisson, the proposed embedded Markov chain approach provides a very accurate prediction. Furthermore, the results of the approach are used to explore the effects of variability in ON-OFF periods on Multimedia application transmission performance. With the same utilization, variability of OFF period worsens the multimedia application transmission performance at fixed ON variability; on the contrary, variability of ON period improves the Multimedia application transmission performance at fixed OFF variability. The results encourage to the further investigation of the relationship of ON and OFF distributions in a two-state model.

6. References

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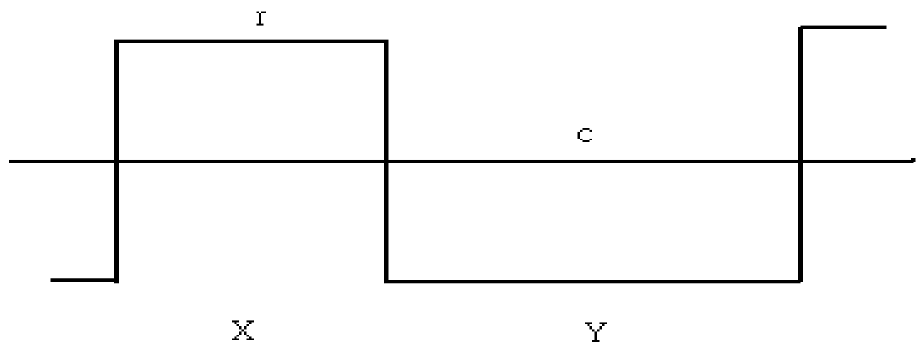

Figure 1. The definitions of ON period X, OFF periods Y, r and c.

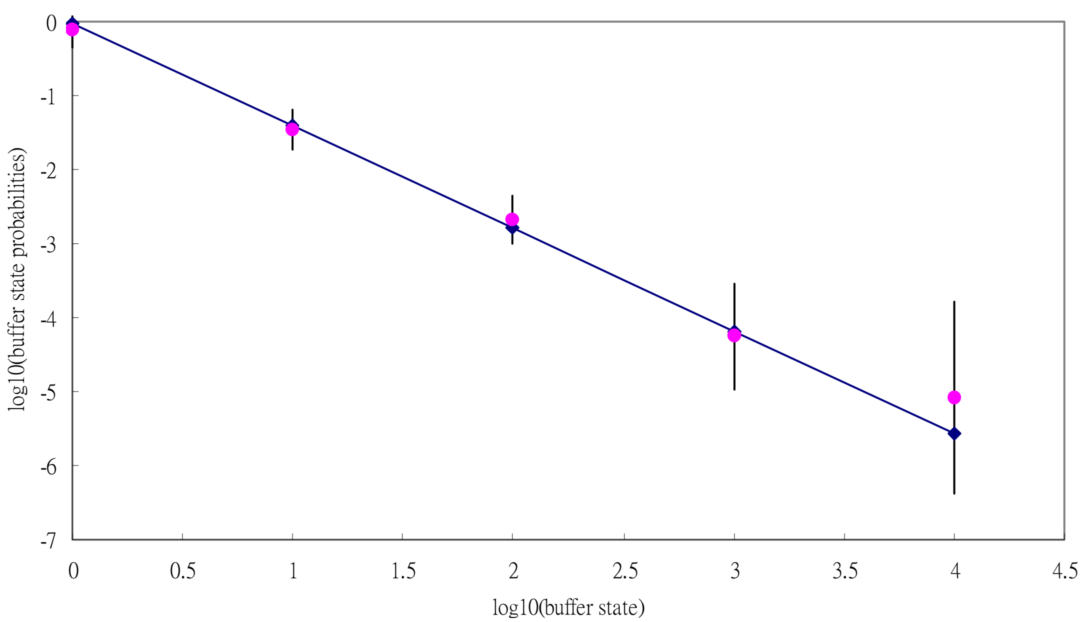

Figure.2. Comparison of 95% confidence interval of simulated state probabilities with analyzed state probabilities.

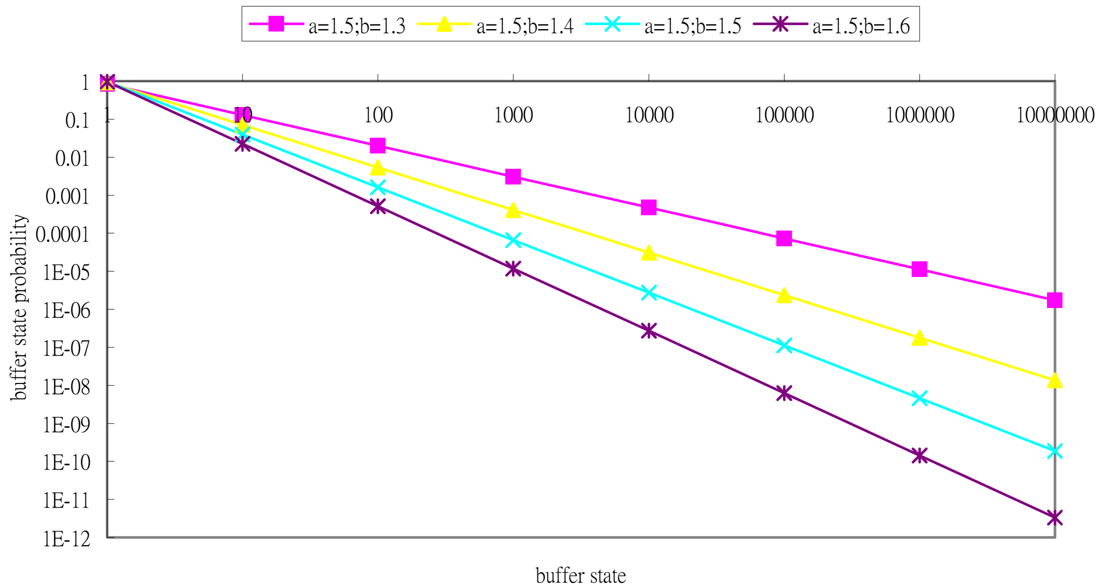

Figure 3. Multimedia application transmission performance comparison for the shape parameter a (ON) fixed at 1.5.

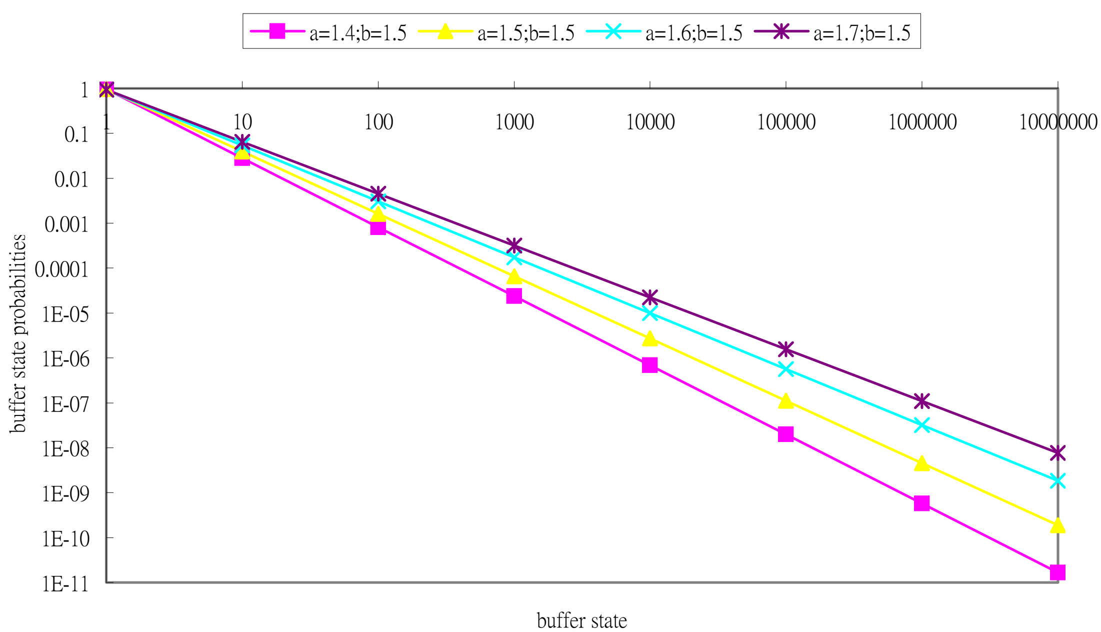

Figure 4. Multimedia application transmission performance comparison for the shape parameter b (OFF) fixed at 1.5.

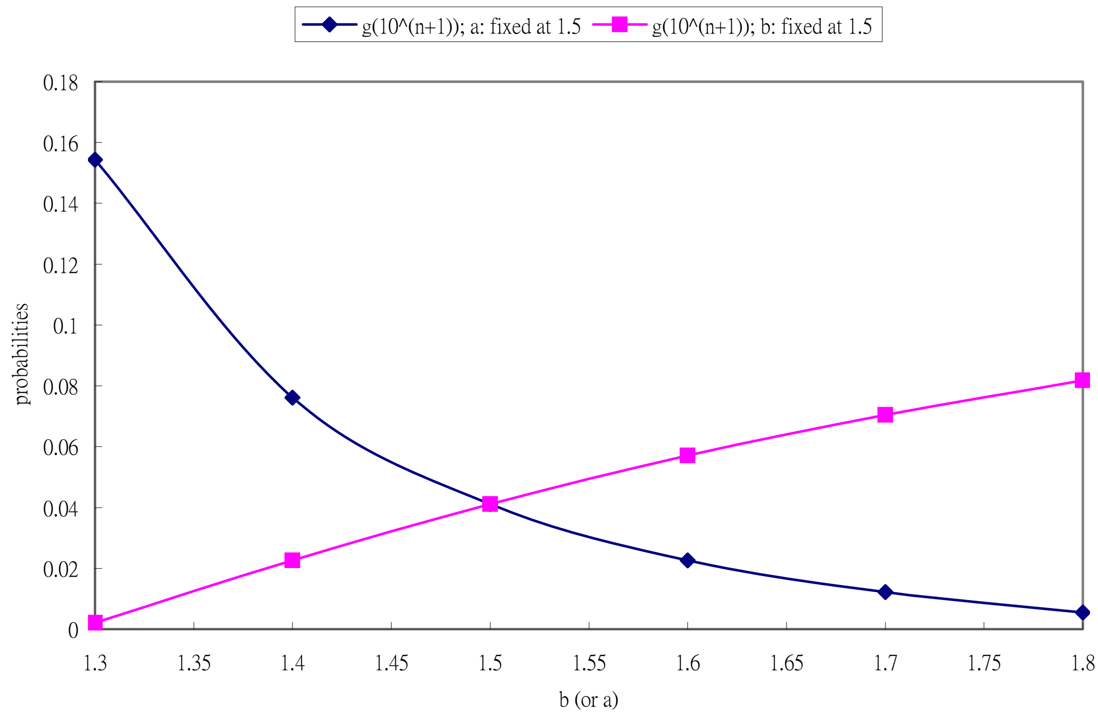

Figure 5. Multimedia application transmission queue-size growing function for fixed ON variability a=1.5 and OFF variability b=1.5.