The Simulated Throughput of DS CDMA/Unslotted ALOHA Radio Network with Markov Modulated Poisson Process

Kuan-Fu Huang\textsuperscript{1}, Shu-Ming Tseng\textsuperscript{1}, Yung-Chung Wang\textsuperscript{2}
\textsuperscript{1}Department of Electronic Engineering, National Taipei University of Technology
\textsuperscript{2}Department of Electrical Engineering, National Taipei University of Technology
No.1, Sec. 3, Chunghsiao E. Rd., Taipei 106, Taiwan
E-mail: \textsuperscript{1}s2418005@ntut.edu.tw, \textsuperscript{1}shuming@en.ntut.edu.tw, \textsuperscript{2}ycwang@ee.ntut.edu.tw

Abstract
In this paper, the input traffic model of Direct Sequence-Code Division Multiple Access (DS CDMA)/Unslotted ALOHA network adopts the Markov Modulated Poisson Process (MMPP). MMPP model is capable of capturing and characterizing the multimedia traffic property. Furthermore, the throughput performance of DS CDMA/Unslotted ALOHA network is controlled by MMPP model. The simulation results show that the throughput performance of MMPP model is different from that of Poisson model.

1. Introduction
The Direct Sequence-Code Division Multiple Access (DS CDMA) technology has been adopted in related packet radio communication network. This is because DS CDMA can provide random access capability and high throughput performance. DS CDMA network combines with unslotted ALOHA protocol that can control a packet to transmit at any time, so it has asynchronous property. Although DS CDMA/unslotted ALOHA network has asynchronous property, it affects the throughput performance. The impact of asynchronous property on throughput performance of the DS CDMA/unslotted ALOHA network has been investigated in earlier studies [1][2][3].

However, earlier studies [1][2][3] for the DS CDMA/unslotted ALOHA network assume the input traffic model is a Poisson arrival process. Note that Poisson arrival process is one in which the inter-arrival times are an exponential distribution and has independent property. In practice, Poisson arrival process is not suited to multimedia traffic source model. The multimedia traffic has bursty features, and its time-varying arrival rates capture some of the important correlations between inter-arrival times.

In this paper, we study the throughput performance of the DS CDMA/unslotted ALOHA network, but the input traffic model is a Markov Modulated Poisson Process (MMPP) [4]. MMPP can model arrival process with certain bursty features and has been applied to ATM input traffic modeling [5][6][7][8]. Furthermore, we evaluate the throughput performance of the DS CDMA/unslotted ALOHA network when the input traffic model is a MMPP model to account for multimedia input traffic.

The rest of this paper is organized as follows: In Section II, the system model is presented. In Section III, the Markov Modulated Poisson Process (MMPP) as input traffic model is introduced. The simulation results are given in Section IV. Section V is the conclusion.

2. System Model
An unslotted ALOHA network with packet length L[bits] is considered in a single-carrier DS CDMA system with processing gain N. This network consists of a single hub station and finite number of the users.

When the transmitted packet is interfered with level k in an asynchronous DS CDMA network, the bit error probability \( P_b(k) \), \( k \geq 0 \), is given by simplified improved Gaussian approximation [9].

\[
P_b(k) = \frac{2}{3} \Phi \left( \frac{k}{3N} + \frac{N_0}{2E_b} \right) - \frac{1}{6} \Phi \left( \frac{k(N/3) + \sqrt{3}\sigma}{N^2/2E_b} + \frac{N_0}{2E_b} \right) - \frac{1}{6} \Phi \left( \frac{k(N/3) - \sqrt{3}\sigma}{N^2/2E_b} + \frac{N_0}{2E_b} \right)
\]

with

\[
\sigma^2 = k \left[ N^2 \frac{33}{360} + N \left( \frac{1}{20} + \frac{k-1}{36} \right) - \frac{1}{20} - \frac{k-1}{36} \right]
\]

\[
\phi(k) = \frac{2}{3} \Phi \left( \frac{k}{3N} + \frac{N_0}{2E_b} \right) - \frac{1}{6} \Phi \left( \frac{k(N/3) + \sqrt{3}\sigma}{N^2/2E_b} + \frac{N_0}{2E_b} \right) - \frac{1}{6} \Phi \left( \frac{k(N/3) - \sqrt{3}\sigma}{N^2/2E_b} + \frac{N_0}{2E_b} \right)
\]

\[
\phi(k) = \frac{2}{3} \Phi \left( \frac{k}{3N} + \frac{N_0}{2E_b} \right) - \frac{1}{6} \Phi \left( \frac{k(N/3) + \sqrt{3}\sigma}{N^2/2E_b} + \frac{N_0}{2E_b} \right) - \frac{1}{6} \Phi \left( \frac{k(N/3) - \sqrt{3}\sigma}{N^2/2E_b} + \frac{N_0}{2E_b} \right)
\]
where $N_0/2$ is the two-sided power spectral density of Gaussian noise, $E_b$ is the bit energy and $Q(x)$ is given by

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty \exp(-\frac{u^2}{2})du$$

(3)

In (1), bit errors in a packet are caused by the effect of the Multiple Access Interference (MAI) and/or Additive White Gaussian Noise (AWGN).

3. Markov Modulated Poisson Process (MMPP)

In this paper, the input traffic model of DS CDMA/unslotted ALOHA network is modulated by Markov Modulated Poisson Process (MMPP). MMPP is doubly stochastic process where the Poisson arrival rate is controlled by the state of Markov process, and the sojourn time in each state is exponentially distributed. In general, MMPP can be represented by a pair of matrices $(P, \Lambda)$, the first matrix being the infinitesimal generator of the Markov process and the second being a diagonal matrix specifying the arrival rate associated with each state of the Markov process.

$$P = \begin{bmatrix}
-\alpha_{00} & \alpha_{01} & \cdots & \alpha_{0m} \\
\alpha_{00} & -\alpha_{11} & \cdots & \alpha_{1m} \\
\vdots & \vdots & \ddots & \vdots \\
\alpha_{m0} & \alpha_{m1} & \cdots & -\alpha_{mm}
\end{bmatrix} \quad \text{and} \quad \Lambda = \text{Diag}[\lambda_0, \lambda_1, \cdots, \lambda_m]$$

(4)

For simplicity, two-state (only state 0 and state 1) MMPP model is considered and can be represented the matrices $(P, \Lambda)$ as follows:

$$P = \begin{bmatrix}
-\alpha & \alpha \\
\beta & -\beta
\end{bmatrix} \quad \text{and} \quad \Lambda = \text{Diag}[\lambda_0, \lambda_1]$$

(5)

According the parameter matrices of the two-state MMPP model, the steady-state probability $\pi_m$ for the state $m$ $(m=0,1)$ of the two-state MMPP model is defined as follows:

$$\pi_0 = \frac{\beta}{\alpha + \beta}, \quad \pi_1 = \frac{\alpha}{\alpha + \beta}$$

(6)

For the stationary of two-state MMPP model, the average arrival rate $E[\lambda]$, the average number of generated packet (packets/sec), can be obtained as follows:

$$E[\lambda] = \sum_{m=0}^{1} \lambda_m \cdot \pi_m = \frac{\lambda_0 \beta + \lambda_1 \alpha}{\alpha + \beta}$$

(7)

Then, the offered load $G$, defined as the average number of generated packets within a packet duration, (packets/packet duration) is easily found to be

$$G = E[\lambda] \cdot T_p$$

(8)

According to the (8) and (9), the average number of generated packet $E[\lambda]$ and offered load $G$ are controlled by the transient rates $\alpha$ and $\beta$ and effect the throughput performance.

4. Simulation Results

The simulation of DS CDMA/unslotted ALOHA network uses Binary Phase-Shift Keying (BPSK) modulation, the processing gain $N=30$, the fixed packet length $L=1000$ bits, and the data rate $R=9.6$ kbps. Every packet is received with equal power (i.e. perfect power control). We only consider the effect of the MAI and neglect AWGN.

The simulated throughput versus offered traffic for Poisson arrival process [1] and MMPP with variable transient rate and variable users is shown. These simulated results clearly shows that the bursty traffic affects the throughput performance and lead to different result....

Fig. 1 The state transition diagram for two-state MMPP sources.
between Poisson arrival process and MMPP, even if they have the same offered load and the same average arrival rate. In Fig.2, the MMPP with $\alpha = 0.001$, $\beta = 0.005$, $\lambda_1 = 100$ $\lambda_0$ and 50 users is considered. According to (7), the $\lambda_1$ gets large quantity in short sojourn time and causes large MAI. Consequently, the throughput performance of MMPP model is lower than that of Poisson process. On the other hand, the MMPP with $\alpha=0.5$, $\beta=0.01$, $\lambda_1=0$, and 50 users is shown in Fig. 3. Due to $\alpha>\beta$ and (6), the steady-state probability of state 1 of the two-state MMPP, which has no arrival rate and no MAI, is larger than that of state 0. The throughput performance of MMPP is higher than that of Poisson arrival process. Moreover, Fig.4 and Fig. 5 illustrate the effect of 500 users on the throughput performance. The throughput performance of MMPP is the same as Poisson arrival process. Therefore the assumption of Poisson arrival process may overestimate the throughput performance of the DS CDMA/unslotted ALOHA network.

5. Conclusion

The two-state Markov Modulated Poisson Process (MMPP) is applied to the input traffic model of DS CDMA/Unslotted ALOHA network and can capture the nature of multimedia traffic. The results show that its throughput performance depends on Poisson arrival rates and transient rates of the two-state,
and the number of users. Thus, our work is a generalization of the previous works based on the Poisson arrival process and evaluates the throughput performance of DS CDMA/unslotted ALOHA network with multimedia input traffic.

6. References


