Journal of Electrical Engineering
The Institution of Engineers, Bangladesh
Vol. EE 31, No. I & II, December 2004

Performance Parameters in GPRS Based Traffic with Data and Voice Integrated Transmission

Mohammad Rakibul Islam[1], Mohammad Ismat Kadir[1], Mohammed Nazrul Islam[2] and Shaikh Mostafa Al Masum[3]

[1]Department of Electrical and Electronic Engineering, IUT, Gazipur, Bangladesh
[2]Department of Electrical and Electronic Engineering, BUET, Dhaka, Bangladesh
[3]Department of Computer Science and Information Technology, IUT, Gazipur, Bangladesh
Email: rakibultowhid@yahoo.com

ABSTRACT

General Packet Radio Service (GPRS) is a new bearer service for Global System for Mobile (GSM) that greatly improves and simplifies wireless access to Packet Data Networks (PDN). We have presented an analytical model to analyze the performance of different sharing strategies in the circuit switched voice and packet switched data networks. We have compared the blocking probability, throughput and average delay time for these strategies. In the fixed sharing strategy, these traffic parameters show better performance for lower traffic. However, for higher traffic the partial sharing strategy turns out to be the best solution. The Partial sharing scheme also shows better performance than the complete sharing scheme in case of higher traffic.

1. INTRODUCTION

The growth of cellular mobile telephony and the number of Internet users are very much promising these days. Global subscribers of GSM have reached over 860 million and this figure is 78% of the total wireless subscribers by the beginning of the year 2002 [1]. Before the year 2001, most of the services provided by GSM carriers were circuit switched based on the data rates of 9.6 kbps. With the rapid deployment of IP and IP based services, introduction of new data service with high data rates became a dare necessity. That necessity brought packet switching based data service General Packet Radio Service (GPRS) with data rate up to 170 kbps.

GPRS is a standard from the European Telecommunication Standard Institute (ETSI) for the data service in GSM. The purpose of GPRS is to accommodate data services that are bursty in nature[2]. Several researches have been undertaken performance analysis of the GPRS. Some simulation studies were also done in [3,4]. Recently, Lindermann presented an analytical model for performance analysis of GPRS. He compared his analytical model with the detailed simulator [5]. Analysis was done in performance estimation for partial sharing strategies. Shaoji showed an analytical model for this particular strategy [6]. Some analysis is also done in finding Markov based model algorithm recently. Almudena showed the time varying error statistics in [7].

Despite these developments for such systems, GPRS is still facing problems. Theoretically GPRS terminals can provide up to 150-170 kbps data speeds downstream, but realistically they currently only have a maximum downstream speed of 50 kbps and upstream 10-28 kbps.Speeds will also depend on which GPRS version an operator uses, as well as how busy the network is at a particular time [1]. This encouraged us to work on this topic.

2. SYSTEM ANALYSIS

In our paper, we have considered three different sharing strategies between voice and data users. In the Fixed sharing strategy the channels are divided into two parts. One is for the voice channels and the other is for the data. Voice or data is not allowed to enter into the channel allocated for the other. In the partial sharing strategy some channels are dedicated for data channels and the rest are shared between voice and data with priority for voice call. In the complete sharing strategy the available channels are shared by voice and data channels. We are assuming these strategies as separate systems. After analyzing we will compare them with different traffic parameters.

2.1 Fixed Sharing Strategy

In fixed sharing strategy, the total number of channels m is statistically partitioned into two parts. One part is used by the voice calls and the other part by data traffic. The number of data channels is considered as m_d and the voice channels as m_v. In this type of sharing strategy there is, in effects no sharing at all.

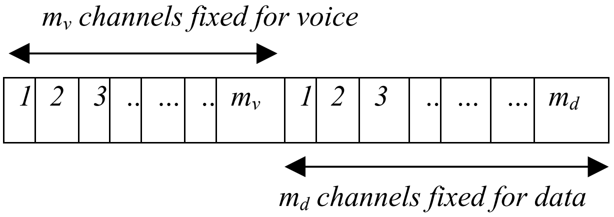

Fig. 1: Fixed sharing strategy.

2.2 Partial Sharing Strategy

In partial sharing strategy, m_d channels are remaining dedicated to data and the (m-m_d) channels are shared by both voice and data. Voice channels are given priority over the data packets. Thus if a voice call could not find a free channel in the sharing part then it will preemptively acquire a channel used by data traffic. If the number of channels used by data traffic is more than m_d, then it will acquire a free channel from the sharing portion on first come first served basis.

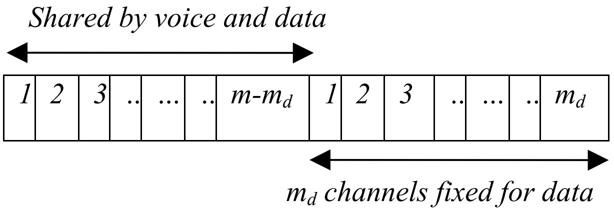

Fig. 2: Partial sharing strategy.

2.3 Complete Sharing Strategy

In complete sharing strategy, the total m channels are shared by voice and data. Voice channels are given priority over the data packets. Complete sharing strategy is a particular case of partial sharing strategy where $m_d = 0$.

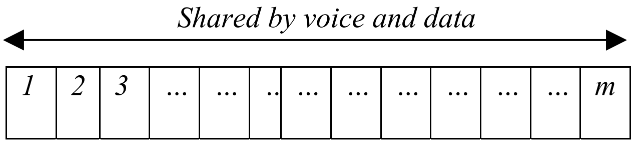

Fig. 3: Complete sharing strategy.

3. ANALYTICAL MODEL

In our paper, we have designed an analytical model for each of the three sharing strategies. We have considered a system with $m = 40$ channels. Then we have derived the equations for fixed and complete sharing strategies from the existing equations of partial sharing strategy [6].

3.1 Fixed Sharing Model

For the circuit switched voice services, the probability of n users in service is

$$P_c = P_{c0}\left(\frac{\lambda_v}{\mu_v}\right)^n \frac{1}{n!} \qquad n = 1,\, 2,\, 3 \cdots\cdots\cdots m_v \quad (1)$$

Where

$$P_{c0} = \left[\sum_{k=0}^{m_v}\left(\frac{\lambda_v}{\mu_v}\right)^k \frac{1}{k!}\right]^{-1}.$$

The probability of x channels available for the data services are obtained as

$$g(x) = g_0\left(\frac{\lambda_d}{\mu_d}\right)^{m_d - x} \frac{1}{(m_d - x)!} \qquad x = 1,\, 2,\, 3 \cdots\cdots\cdots m_d \quad (2)$$

Where

$$g_0 = \left[\sum_{k=0}^{m_d}\left(\frac{\lambda_d}{\mu_d}\right)^k \frac{1}{k!}\right]^{-1}.$$

For the transmission of single slot GPRS in a fixed number of C channels, the average queuing time can be obtained from the $M/M/C/N$ queuing system, where N is the maximum number of users in the system both in service and in queue. The steady state probability is

$$\begin{aligned} P_d &= P_{d0}\left(\frac{\lambda_d}{\mu_d}\right)^n \frac{1}{n!} & n < C \\ &= P_{d0}\left(\frac{\lambda_d}{\mu_d}\right)^n \frac{1}{C!C^{n-C}} & C \le n \le N \end{aligned} \quad (3)$$

Where

$$P_{d0} = \left[1 + \sum_{n=1}^{C-1} \left(\frac{\lambda_d}{\mu_d} \right)^n \frac{1}{n!} + \sum_{n=C}^{N} \left(\frac{\lambda_d}{\mu_d} \right)^n \frac{1}{C! C^{n-C}} \right]^{-1}$$

$$= \left[\sum_{n=0}^{C-1} (A_d)^n \frac{1}{n!} + \frac{A_d^C \left(1 - \left(\frac{A_d}{C} \right)^{N-C+1} \right)}{C! \left(1 - \frac{A_d}{C} \right)} \right]^{-1}$$

A new arrival is accepted into the system only if the number of users in the system is below the maximum accepted number *N*. Otherwise, it would be blocked. The blocking probability is given by Eq. 4.

$$P_N(C) = P_{d0} (A_d)^N \frac{1}{C! C^{N-C}} . \tag{4}$$

The average number of users in the system is

$$U_{avg}(C) = \sum_{n=1}^{N} n P_d$$

$$= P_{d_0} \left\{ \sum_{n=1}^{C} \frac{A_d{}^n}{(n-1)!} + \frac{C^c}{C!} \cdot \frac{\begin{array}{c} (C+1)\left(\frac{A_d}{C} \right)^{C+1} \\ -(N+1)\left(\frac{A_d}{C} \right)^{N+1} \\ -C\left(\frac{A_d}{C} \right)^{C+2} + N\left(\frac{A_d}{C} \right)^{N+2} \end{array}}{\left(1 - \frac{A_d}{C} \right)^2} \right\} \tag{5}$$

The average blocking probability, throughput and average delay can be computed by the following three equations

$$B_{avg} = \sum_{x=0}^{m_d} g(x) P_N(m_d), \tag{6}$$

$$S_{avg} = \lambda_d (1 - B_{avg}), \tag{7}$$

$$D_{avg} = \frac{1}{\lambda_d (1 - B_{avg})} \sum_{x=0}^{m_d} g(x) U_{avg}(m_d) - \frac{1}{\mu_d} . \tag{8}$$

3.2 Partial Sharing Model

In the case of partial sharing strategy, the equations for average blocking probability, throughput and average delay are given in (9) – (10) consecutively. These equations are independent from equations (6) – (8) of the fixed sharing model.

$$B_{avg} = \sum_{x=0}^{m_v} g(x) P_N(x + m_d), \tag{9}$$

$$S_{avg} = \lambda_d (1 - B_{avg}), \tag{10}$$

$$D_{avg} = \frac{1}{\lambda_d (1 - B_{avg})} \sum_{x=0}^{m_v} g(x) U_{avg}(x + m_d) - \frac{1}{\mu_d} . \tag{11}$$

3.3 Complete Sharing Model

In the complete sharing strategy, we have also derived the equations for average blocking probability, throughput and average delay. These equations are independent from equations (6) – (8) or (9) – (11).

$$B_{avg} = \sum_{x=0}^{m} g(x) P_N(x), \tag{12}$$

$$S_{avg} = \lambda_d (1 - B_{avg}), \tag{13}$$

$$D_{avg} = \frac{1}{\lambda_d (1 - B_{avg})} \sum_{x=0}^{m} g(x) U_{avg}(x) - \frac{1}{\mu_d} . \tag{14}$$

4. PERFORMANCE EVALUATION

In this paper we have compared the average blocking probability, throughput and average delay versus data traffic for the three types of sharing strategies. The following paragraphs describe the impact of traffic on the said parameters.

4.1 Impact of Traffic on Average Blocking

The average blocking probability for data traffic in the case of fixed sharing strategy remains zero up to m_d. But if the data user crosses m_d, the blocking probability will become very high. In the case of partial and complete sharing strategies, the blocking probability increases with the increase in data traffic. Compared to complete sharing strategy, the partial sharing strategy is less blocked, as there are some dedicated channels for the data traffic.

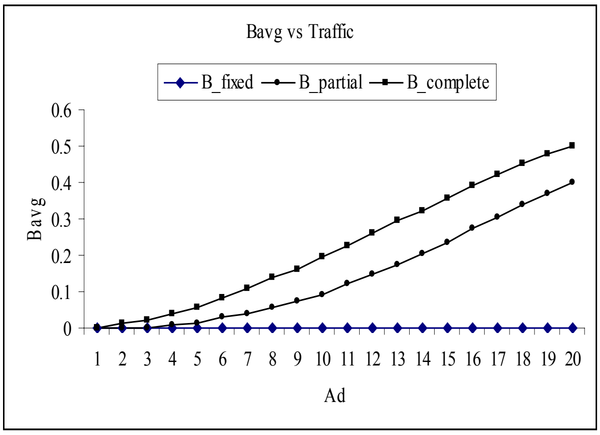

Fig. 4: Average blocking vs. traffic.

4.2 Impact of Traffic on Throughput

As the blocking probability in the case of fixed sharing strategy is zero up to m_d number of users, throughput is highest here for this range. Between the partial and complete sharing strategies, the partial sharing strategy gives better throughput, as its blocking probability is less. Allocating more number of dedicated data channels for partial sharing strategy will increase the difference in throughput between the partial and complete sharing strategies.

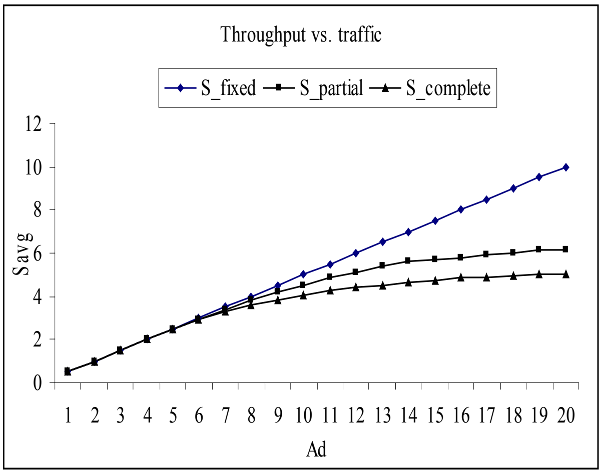

Fig. 5: Average throughput vs. traffic.

4.3 Impact of Traffic on Average Delay

In the fixed sharing strategy there is no delay up to m_d number of user. Then the delay starts increasing. In the case of partial sharing strategy, the delay becomes zero up to the number of users dedicated for the data channels. After that, the delay is introduced here. In the case of complete sharing strategy, the delay will be present from the very beginning and will increase almost linearly as the traffic increases. Up to a certain traffic size, the delay for the complete sharing strategy will be less than that of the partial sharing one; but after that the delay for the later would become less.

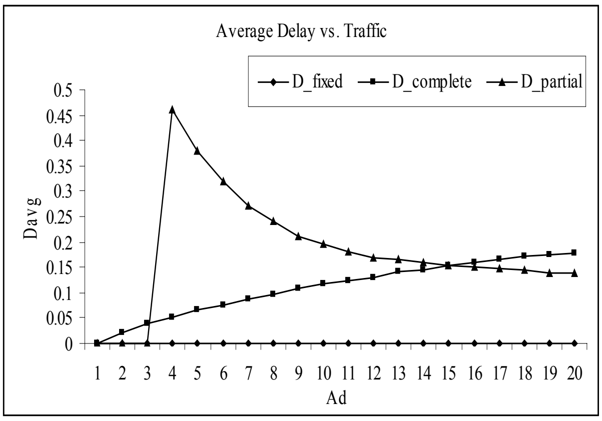

Fig. 6: Average delay vs. traffic.

5. CONCLUSION

The impact of traffic in a GPRS network is analyzed for different sharing strategies. Average blocking probability, throughput and average delay are calculated for the said strategies. A comparative study of the parameters is also performed among the various strategies and is shown graphically. For higher value of traffic, partial sharing strategy is found to be the best sharing strategy. On the other hand, the fixed sharing strategy gives less blocking, high throughput and less delay up to the point where the data channels are free. However, we cannot dedicate too many channels for the data users. In the complete sharing strategy with high voice traffic, data users face difficulties getting access to the free channels. As the voice has priority over data, the data users will be severely blocked in this case. Therefore, to improve the performance, it is proposed that the network should be designed to incorporate dynamic allocation of the sharing strategies from one to the other. The network will switch from one strategy to another based to the need at a particular time interval.

REFERENCES

[1] Cellular online, http://www.cellular.co.za/main.html

[2] ETSI, Digital cellular telecommunications system (Phase 2+), General Packet Radio Service (GPRS); Service description; Stage 2, GSM recommendation 03.60, 1999.

[3] C. Jain and D. J. Goodman, “General packet radio service in GSM,” *IEEE Communications Magazine,* vol. 35, pp. 122-131, 1997.
[4] G. Brasche, B. Walke, “Concepts, services and protocols of the new GSM phase 2+ general packet radio service,” *IEEE Communication Magazine,* vol. 35, pp. 94-104, 1997.
[5] C. Lindermann, A. Thummler, “Performance analysis of the general packet radio service,” *Computer Networks*, vol. 41, pp. 1-17, 2003.
[6] S. Ni and S. G. Haggman, “GPRS performance estimation in GSM circuit switched services and GPRS shared resource system,” *IEEE Wireless Communication and Networking Conference,* pp. 1417-1421, 1999.
[7] A. Konrad, B.Y. Zhao and A. D. Joseph, “A Markov-Based Channel Model Algorithm for Wireless Networks,” *Wireless Networks*, vol. 9, pp. 189-199, 2003.
[8] T. S. Rappaport*, Wireless communication, principles and practice*, 2nd edition, 2002.