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PERFORMANCE ANALYSIS OF DATA TRAFFIC IN A GPRS BASED WIRELESS NETWORK USING SHARING TECHNIQUES

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ABSTRACT

GPRS is a packet-based radio service that enables "always on" connections, eliminating repetitive and time consuming dial-up connections. It also provides real throughput in excess of 40 Kbps, about the same speed as an excellent landline analog modem connection. It greatly improves and simplifies wireless access to Packet Data Networks (PDN). An analytical model is presented in this paper to analyze the performance of different sharing techniques in the circuit switched voice and packet switched data networks. The blocking probability, throughput, average delay and utilization for these techniques are compared. Impact of data channels on these parameters is shown. In the partial sharing technique, these traffic parameters show better performance than the other sharing techniques. It is noted that in the lower traffic cases, fixed sharing is relatively better. We need to allocate dedicated data channel, which will not be shared with the voice channel. However, allocation of dedicated data channel is needed.

INTRODUCTION

There are several major second-generation (or 2G) digital cellular standards used throughout the world. The most widely used one Global System for Mobile (GSM), the Code Division Multiple Access (CDMA) standard called cdmaOne, Time Division Multiple Access (TDMA), and Personal Digital Communications (PDC) are used mainly in Japan. Over the next few years, there will be a transition to 2.5G and 3G technologies that, in addition to voice services, will add support for "always on" packet data access and, eventually, new multimedia type of wireless service. Out of three digital cellular subscribers worldwide more than two connect using GSM, making GSM the dominant worldwide standard. Additionally, a number of major North American TDMA service providers have decided to deploy GSM/GPRS (General Packet Radio Service) overlays, rather than continuing on a separate and unique evolution path towards 3G networks. Figure 1 shows the evolution paths of current technologies to 2.5G and 3G.

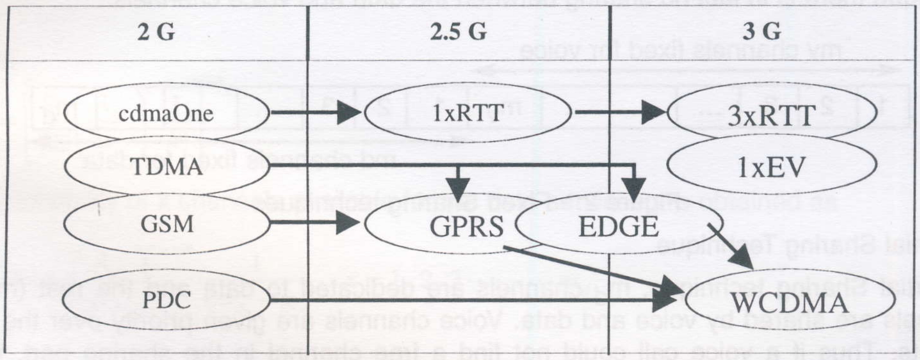

Figure 1: Evolution paths from 2G to 3G

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The European Telecommunications Standards Institute (ETSI) has chosen GPRS as the data transfer mechanism of choice for GSM Phase 2+ and as a migration path to the Universal Mobile Telecommunications System (UMTS) [1]. GPRS enhances the GSM system with the introduction of services based on a packet switching technique. These services provide a more efficient use of the

radio resources, by accommodating data sources that are bursty in nature, such as Internet applications. A number of studies directed to analyze the behavior of GPRS have been and are currently being performed to assess its Quality of Service (QoS, or related measures). Several works have been performed on simulation studies. [2,3,8,9]. Recently in the past, Lindermann presented an analytical model for performance analysis of GPRS. He compared his analytical model with detailed simulator [4]. The analysis has been done in performance estimation for partial sharing techniques. Shaoji also showed an analytical model for this particular technique [5]. Some analysis has also been done in finding the Markov based model algorithm recently. Almudena [6] showed the time varying error statistics. Our objective in this paper is to analyze the traffic in three different types of sharing techniques namely fixed sharing, partial sharing and complete sharing.

SYSTEM DEFINITIONS

In this paper three different sharing techniques have been considered between voice and data users. In the Fixed sharing technique 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 technique, some channels are dedicated for data channels and the rest are shared between voice and data with priority for the voice calls. In the complete sharing technique, all available channels are shared by the voice and data channels. These three techniques have been considered as separate systems. After the analysis, the findings have been compared with different available traffic parameters.

i) Fixed Sharing Technique

In Fixed Sharing technique, the total m channels are statistically partitioned into two parts. One part is used by the voice calls and the other part by the data traffic. The number of data channels is considered as m_d and the voice channels as m_v. In this type of sharing technique there is in fact no sharing between the data and voice channels.

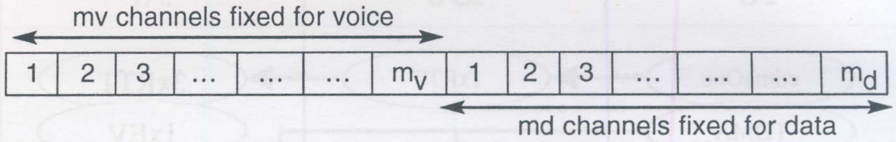


Figure 2: Fixed Sharing techniques

ii) Partial Sharing Technique

In Partial Sharing technique, m_d channels are dedicated to data and the rest (m-m_d) channels are shared by 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, it will preemptively acquire a channel used by the data traffic. If the number of channels used by the data traffic is more than m_d, it will acquire a free channel from the sharing portion on first come first served basis.

Shared by voice and data

1	2	3	...	...	...	m-m_d	1	2	3	...	...	...	m_d

md channels fixed for data

Figure 3: Partial Sharing techniques

iii) Complete Sharing Technique

In Complete Sharing technique, all the m channels are shared by voice and data. Voice channels are given priority over the data packets. Complete sharing technique is a particular form of partial sharing where $m_d = 0$.

Shared by voice and data

1	2	3	...	...	...	...	...	...	...	...	...	m

Figure 4: Complete Sharing techniques

ANALYTICAL MODEL

In this paper analytical models for each of the three sharing techniques have been developed. A system has been considered where total 40 channels are distributed among data and voice users according to the sharing techniques. In the fixed sharing 20 channels are allocated for data users and the rest 20 for the voice users. In the partial sharing technique, 3 channels are allocated for data users and the data and voice users share the rest. On the other hand, in the complete sharing technique, all the 40 channels are shared by both the data and voice users. The mathematical model is developed next for the three sharing techniques.

i) Fixed sharing technique

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

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

where

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

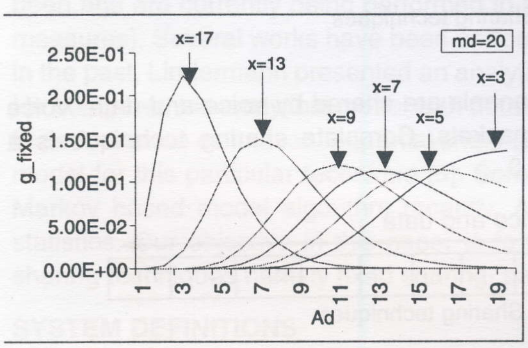
The probability of x channels available for the data services are obtained as

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

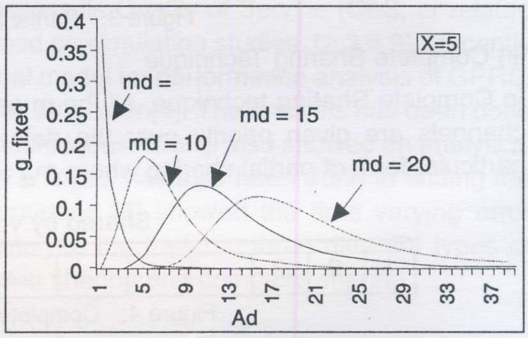
where

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

Figure 5 shows the g(x) vs data traffic which has a bell shaped curve. Part(a) shows that the peak value of g(x) decreases with the decrease in x for a fixed value of m_d. Again part(b) when the value of x is fixed, the peak value decreases with an increase in m_d.



(a)



(b)

Figure 5: g(x) vs Data Traffic (Ad) in Fixed sharing technique

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

$$P_d = P_{d0} \left(\frac{\lambda_d}{\mu_d} \right)^n \frac{1}{n!}, \qquad n < C$$

$$= P_{d0} \left(\frac{\lambda_d}{\mu_d} \right)^n \frac{1}{C! C^{n-C}}, \qquad C \leq n \leq N \tag{3}$$

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 will be blocked. The blocking probability is given by

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

The average number of users in the system is given by

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

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

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

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

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

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

ii) Partial sharing technique

In the case of partial sharing, the equation for average blocking probability, throughput and average delay is calculated. These equations are independent from the previous equations (6-8).

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

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

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

iii) Complete sharing technique

In the complete sharing technique, the equations for average blocking probability, throughput and average delay have also been derived. These equations are independent of the previous equations (6-11).

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

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

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

PERFORMANCE EVALUATION

In this paper a comparison of the average blocking probability, throughput, delay and utilization versus data traffic has been carried out for different techniques. Here, a different number of data channels are allocated for different sharing techniques. 20 channels are allocated for data users in the fixed sharing technique and 3 data channels in partial sharing technique. In the complete sharing technique, all the 40 channels are shared by the data and voice users.

Impact of data traffic on average blocking probability and throughput

It has been seen that the average blocking probability for data traffic remains zero up to the value of Ad=m_d for fixed and partial sharing technique. If the data traffic crosses m_d, the blocking probability increases linearly at the beginning and reaches its saturation afterwards. In the complete sharing technique the blocking probability is high compared to that of the other sharing techniques. In contrast, throughput in the later cases is reversed. The more the blocking the less is the throughput. The comparative analysis is shown in the Figure 6.

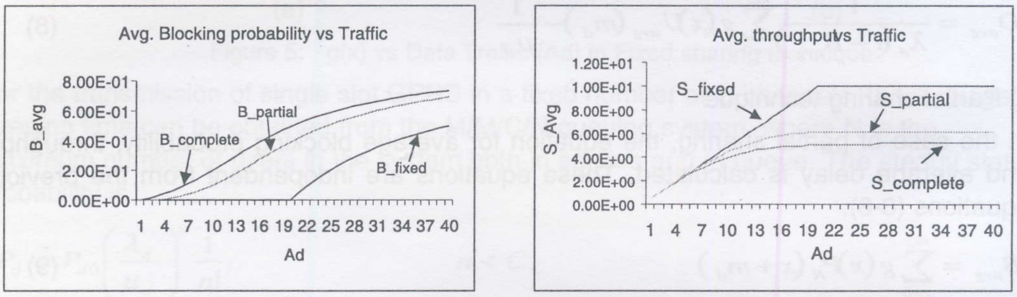


Figure 6: Average Blocking and Throughput against Traffic (Ad)

Among the three types of sharing techniques, partial sharing is the best if the same number of fixed channels allocated for data users is considered. A comparison of the performances between partial and fixed sharing technique for m_d=3 is shown in Figure 7.

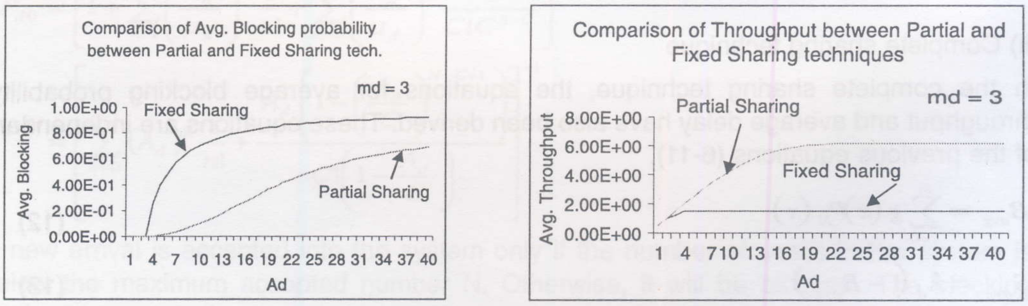


Figure 7: Comparison between fixed sharing and partial sharing techniques

IMPACT OF TRAFFIC ON AVERAGE DELAY

The comparison between partial and fixed sharing technique for a fixed dedicated data channel is shown in the Figure 8. In the fixed sharing technique there is no delay up to m_d number of users. After that, the delay starts increasing and reaches its saturation. In the case of partial sharing technique, the delay becomes zero up to the number of users dedicated for the data channels. In the case of complete sharing, delay will be there from the very beginning and increases almost linearly as the traffic increases to reach its saturation. Partial sharing technique turns out to be the best choice.

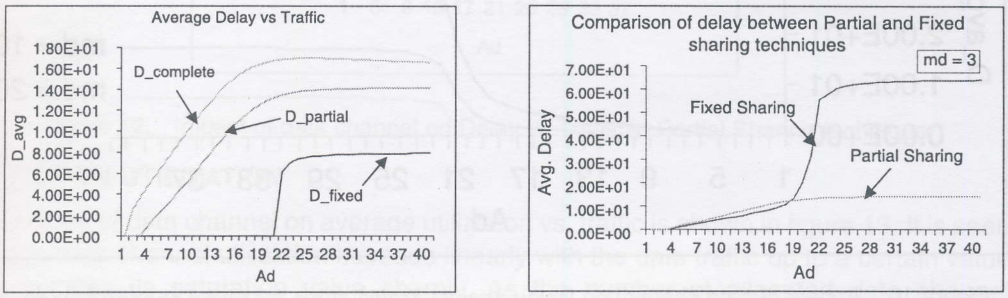


Figure 8: Average delay against Traffic

Impact of number of data channels in different sharing Techniques

Impact in fixed sharing technique

Figure 9 shows the impact of data channels on blocking probability and throughput for the fixed sharing technique. In case of fixed sharing, m_d channels are allocated as data channels and the rest m_v are as voice channels. The number of data channels can be varied depending on the data traffic demand. The more the number of data channels become available the less the average blocking probability would be. And the throughput will be more as well. The average blocking reaches its saturation quickly in the case of fewer numbers of allocated data channels than in a higher number of allocated data channels. Therefore, in the initial stages the slope $\frac{d(B\_avg)}{d(Ad)}$ is greater in case of a fewer number of data channel allocation.

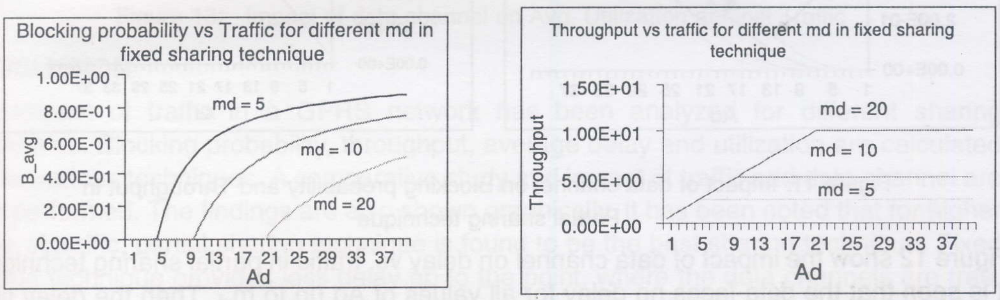


Figure 9: Impact of data channels on Blocking probability and Throughput for Fixed Sharing technique

In case of a fewer numbers of data channels, delay increases slowly up to a certain value of Ad which is equal to the value of C, but for higher number of data channels the delay is almost zero up to that particular value of Ad. After that value of Ad, average blocking becomes constant (Figure 10).

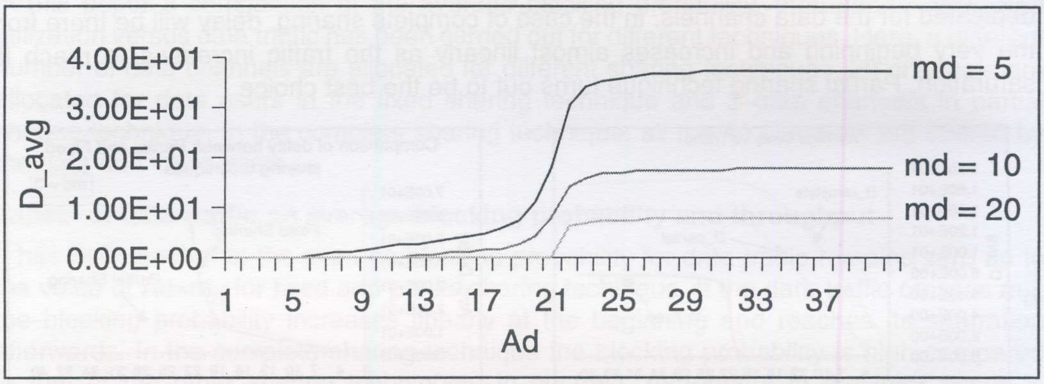
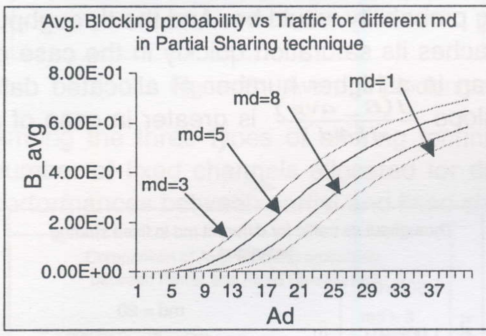


Figure 10: Impact of data channel on Delay against Traffic curve for Fixed sharing technique

IMPACT IN PARTIAL SHARING TECHNIQUE

In the case of partial sharing technique, m_d channels are allocated for data channels and the rest m_v channels for shared use by voice or data users. Increase in the number of dedicated channel for data traffic result in delayed blocking. Throughput will have no effect up to a certain value of Ad. The saturated throughput is higher in case of the allocated fixed data channels, where their number is higher.



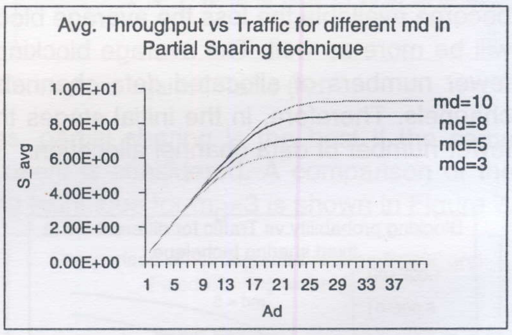


Figure 11: Impact of data channel on Blocking probability and Throughput in Partial sharing technique

Figure 12 show the impact of data channel on delay vs. traffic in partial sharing technique. It is seen that the data faces no delay for all values of Ad up to m_d. Then the delay time increases linearly up to some saturated value. The maximum average delay increases as the fixed data channel decreases.

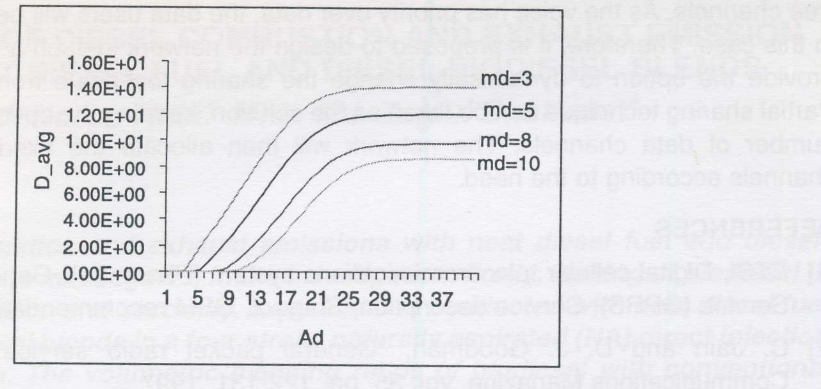


Figure 12: Impact of data channel on Delay vs Traffic in Partial Sharing technique

EFFECT ON UTILIZATION

The impact of data channel on average utilization vs. traffic is shown in figure 13. It is seen that the data channel utilization increase linearly with the data traffic up to a certain value and reaches its saturation value sharply. As the number of allocated data channel increases, the saturation comes later.

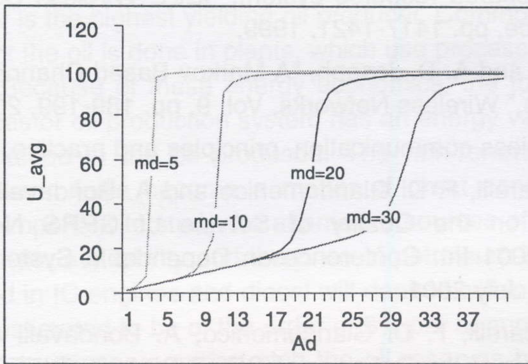


Figure 13: Impact of data channel on Avg. Utilization against Traffic

CONCLUSION

The impact of traffic in a GPRS network has been analyzed for different sharing techniques. Blocking probability, throughput, average delay and utilization are calculated for the various techniques. A comparative study and impact of traffic and data channel are then performed. The findings are also shown graphically. It has been noted that for higher value of traffic, partial sharing technique is found to be the best sharing technique. Fixed sharing technique provides less delay up to the point, where the data channels are free. However, too many channels could not be dedicated for data users. In the complete sharing technique 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, it is proposed to design the network in such a way so that it can provide the option to dynamically change the sharing technique from one to another. Partial sharing technique can be taken as the solution, keeping the option to vary the fixed number of data channels. The network will then allocate the fixed number of data channels according to the need.

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