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IMPLEMENTATION OF STATIC THRESHOLD SCHEMES IN A GPRS RADIO RESOURCE TEMPLATE

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ABSTRACT

This paper develops a template used for comparative analysis of five popular static buffer allocation schemes – Complete Statistical-Unpacked Buffer scheme (CSBS); Reassembly Buffer sharing Scheme (RBSS); Single Buffer Sharing Scheme (SBSS); Complete Sharing Scheme (CSS); and Sharing with Minimum Allocation Scheme (SMAS) applied to General Packet Radio Service (GPRS) system. GPRS system access point was analytically modeled and simulated. A delay expression used as a common platform for the fair comparison of the schemes was also developed. The system was analyzed using QoS parameters (blocking probability, delay, loss and loss rate) for varying buffer occupancy. The analysis presented RBSS and SBSS as the schemes with the best performance.

KEYWORDS: Buffer Allocation, GPRS, QoS, Resource, Template

INTRODUCTION

The first and second generation cellular mobile telephony systems such as Total Access Communication System (TACS) and Global system for mobile communication (GSM) focused on only voice services [1]. The systems used dedicated circuit switched links to carry voice services. Later generations provided support for multimedia services and could comfortably interface to the Internet using the GPRS system. The Internet, on the other hand, supports packet switched services in contrast with circuit switching networks [2, 3]. Resources are made available for the GPRS system to provide mobile subscribers with performance guaranteed packet data services over GSM radio channels [4].

Therefore, GPRS can be thought of as an overlay system on the existing second-generation GSM [1, 2, 3]. The GPRS system is classified into A, B and C. Class A GPRS supports both circuit and packet switching concurrently while class B provides for users the capability to switch from circuit to packet and back. Class C mobile connects to one system at a time and can be switched to either when the need arises [5].

GPRS systems employ resource sharing schemes to enhance network performance. Such schemes include complete resource partitioning (CRP), partial resource sharing (PRS) and complete resource sharing (CRS) schemes. PRS and CRS are most preferred for GPRS by researchers [6], [8], [9], [10]. In those cases, GPRS uses network resources only when user data are actually transmitted thereby providing more efficient use of the resources [11]. The aim of the above schemes is to allocate resources optimally to packet data traffic. It is quite obvious that the determination of optimum resource capacity is influenced by traffic type, traffic intensity, service rate and arrival rate. The most sensitive resource in the GPRS system could be considered as the buffer resource because voice and data traffic have contrasting QoS demand on it [12]. This paper initiates the first step into the development of a radio resource allocation template for the GPRS system. QoS of the template is presented for varying buffer occupancy- blocking probability, delay, loss and loss rate.

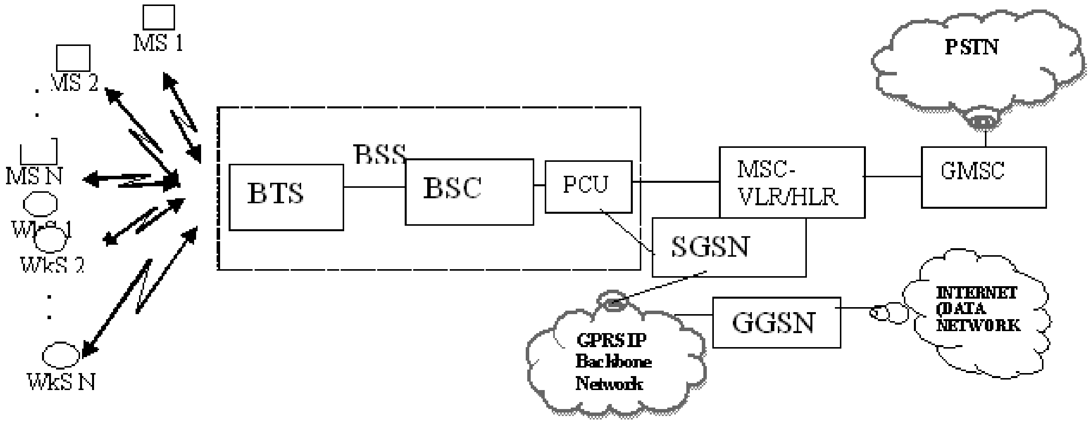
STATIC THRESHOLD SCHEMES

Storage facility (buffer) keeps arriving packets in a waiting queue when the service facility is busy processing and transmitting earlier packets [13]. Thus, the buffer capacity should be optimally allocated to avoid recurrent blocking of communication links as well as reducing the delay to a satisfactory significance. To achieve this goal, static threshold and dynamic threshold queueing schemes were introduced [13, 14]. The buffer capacity of a Static Threshold Scheme (STS) is continually constant as against the dynamic threshold scheme when the expected threshold capacity is exceeded. A good STS scheme compromises between efficiency and fairness of buffer sharing beyond the expected threshold. It therefore implies that usage parameter, control traffic and the expected behavior of the arriving traffic are tied to threshold values [15]. Five STS schemes which include CSBS, RSBS, SBSS, CSS and SMAS have been applied to management buffer resource over the years [16, 17, 18, 19, 20, 21 22,]. In CSBS scheme, random number of messages arrived at an average rate to a queue attached to identical severs. Servers in this case represent parallel transmission lines (channels) operating at the same service rate. Arriving message seizes available channels; if no channel is available, the arriving message is queued randomly in buffers with fixed sizes [20]. The RBSS buffer allocation strategy is used to study the behavior of the traffic pattern buffer storage space [21]. RBSS buffers form a linked between the originating and terminating switch. Each of these buffers is given fixed threshold [21]. Single Buffer sharing Scheme (SBSS) stores and forward packets in a storage facility linked with multiple service facilities. SBSS allocates buffer space equitably to users and thus eliminates wastage caused by idle resources. This implies that scalability and performs of a system are optimally improved if requests demanded is less than the system capacity [23, 24]. CSS scheme popularly used to model a store and forward (S/F) node, for instance, computer network access point. S/F node comprises a number of shared buffers and outgoing servers. In CSS Scheme an arriving customer is accepted into the buffers if any storage space is available independent of the server to which it is directed. The individual buffers are aggregated into a common pool of buffers. Empty buffers from the common pool are allocated to arriving requests on first come first serve basis. However the CSS scheme does not guarantee full utilization of the servers in saturated conditions. As in the case of CSS, SMAS also allocates empty buffer to request from a common pool of buffer. SMAS permanently reserves a minimum quantity of buffers to each of the servers in the S/F node. Any particular server that completes the processing and transmitting of traffic streams from the buffers allocated to it, demands for more request from the common pool of buffers. Thus SMAS can guarantee full utilization of traffic under heavy load contrary to CSS scheme [16]. This paper adopted the blocking probability of the five STS schemes and applied them to a common platform developed by this research paper based on Little's experiment on queueing system.

GPRS ARCHITECTURE

The GPRS architecture adopted in this paper is illustrated in Figure 1. The architecture comprises the mobile stations (MSs), workstations (WkSs), Base station subsystem (BSS), Serving GPRS support Node (SGSN), GPRS IP backbone network, and gateway GPRS support node (GGSN) connected to data networks [22, 25]. The MSs and WKSs send packets wirelessly to the Base station Transceiver (BTS) which provides radio access to the BSC. The packets are processed and routed appropriately by the packet control unit (PCU) at the BSS. SGSN performs the following main functions: user authentication, mobility management, link adaptation, data encryption, data compression, radio resource management, routing address translation, packet segmentation and tunneling [26, 27]. It then transmits the packets to the GPRS IP backbone for further routing. The GGSN provides supports to external packet data network [22]. Resources that support both packet voice and data traffic transmission are basically the radio channels (bandwidth) and the associated buffer occupancy. This work considered the management of radio resources at the SGSN in GPRS; specifically the allocation of the buffer occupancy at the node.

The analysis of the adopted STS schemes was based on the simulation of the analytical model developed on resource availability at the SGSN. Thus, CSBS, RBSS, SBSS CSS, and SMAS schemes are modeled and analyzed on a common platform in order to provide the basis for a fair comparison. The probability models of the STS schemes the adopted are given in [20, 21, 22, 23, 24]. The common platform is based on the Little's queueing buffer occupancy (L_k) and delay as stated in equations (1) and (2) [24, 28, 29]. Buffer occupancy is also known as the expected queue length in this paper.



Key

GMSC	- Gateway Mobile Switching Centre	BTS	- Base Station Transceiver
MSC	- Mobile Switching Centre	BSC	- Base Station Controller
MS	- Mobile Station	WkS	- Work Station
SGSN	- Serving GPRS support Node	GGSN	- Gateway GPRS Support Node
PSTN	- Public Switch Telephone Network	BSS	- Base Station Subsystem

Figure 1: GPRS and Architecture [22]

$$T = \sum_{K=1}^{M} \frac{\lambda_K}{\lambda} * T_K \qquad (1)$$

Where,

T= Total buffer delay,

λ= Total arrival rate,

T_K= k^{th} buffer delay,

λ_K= k^{th} arrival rate

and

$$L_K = \lambda_K * T_K \qquad (2)$$

Equation (2) can be further modified into the relationship between L_k and utilization factor for the buffer (ρ_k) after the application of geometric series principles and derivation as presented in equation (3) [24, 31, 32].

$$L_K = \frac{\rho_k}{1-\rho_k} \qquad (3)$$

Where,

$$\rho_k = \frac{\lambda_k}{\mu C_K}$$ = individual utilization factor

Substituting (3) into equation (2) produced the vital relationship between the individual buffer delay and utilization factor in equation (4)

$$T_K = \frac{\rho_k}{\lambda_k(1-\rho_k)} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad (4)$$

Additionally, substituting equations (3) and (4) into equation (1) resulted in the summation of individual buffer delays to produce the total system delay (T) as stated by equation (5)

$$T = \sum_{k=1}^{M} \frac{1}{\lambda} * \frac{\rho_k}{(1-\rho_k)} = \sum_{k=1}^{M} \frac{1}{\lambda} * \frac{\lambda_k}{\mu_k C_k \left(1 - \lambda_k / \mu_k C_k\right)}$$

$$= \sum_{k=1}^{M} \frac{1}{\lambda} * \frac{\lambda_K}{\mu_K C_K - \lambda_K} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad (5)$$

Recalling that $\lambda_k = \lambda(1-P_B)$ and then the substitution it into equation (5), produced equation (6) that relates the total delay of the buffer system to the total arrival rate, blocking probability, service rate and the total buffer queueing capacity.

$$T = \sum_{k=1}^{M} \frac{1}{\lambda} * \frac{\lambda(1-P_B)}{\mu_k C_k - \lambda(1-P_B)}$$

$$T = \sum_{k=1}^{M} \frac{1-P_B}{\mu_k C_k - \lambda(1-P_B)} \quad - \quad - \quad - \quad - \quad - \quad - \qquad (6)$$

Also, with the buffer capacities assumed the same and the buffer service rates also assumed equal, then output rate of the buffers are equal. $(\mu_1 C_1 = \mu_2 C_2 = \mu_3 C_3 = \ldots = \mu C)$

$$T = \frac{1-P_B}{\mu C - \lambda(1-P_B)} + \frac{1-P_B}{\mu C - \lambda(1-P_B)} + \ldots + \frac{1-P_B}{\mu C - \lambda(1-P_B)}$$

$$T = \frac{M(1-P_B)}{\mu C - \lambda(1-P_B)} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad (7)$$

Where,

μC= output rate of buffers

M = number of buffers

k = 1, 2, 3, …, M

P_B = blocking probability

μ= total service rate

C= total buffer capacity

METHODOLOGY

To determine the optimum buffer occupancy of a GPRS system that utilizes the STS schemes, two contrasting QoS parameters are considered in this work. These are the blocking probability (P_B) and the total buffer delay. The common platform used to determine the delay is the analytical expression shown in equation (7). The STS probability models adopted are substituted into (7)-the common platform use for fair comparison of delays in CSBS, RBSS, CSS, and SMAS schemes. Equations (7 & 8-12) are the tools employed to establish the optimum value. The values for the P_B and delays are thus determined for varying buffer occupancy in each individual analytical expression while keeping other traffic parameters constant. Loss and loss rate are also computed for varying buffer occupancy values. The analytical expressions are modeled and simulated with a template created using Microsoft Excel spread sheet. The model is run and statistics collected for each of the schemes at the end of the simulation and the results are plotted as shown in Figures 2, 3 and 4.

$$T_{(CSBS)} = \frac{M*\left(\sum_{j=0}^{R-1}\frac{\rho^j}{j!}+\frac{R}{R-\rho}*\frac{\rho^R}{R!}-e^{-\beta K}\sum_{j=1}^{K}\frac{R^R}{R!}\left(\frac{\rho}{R}\right)^J*\left(\frac{1-e^{-\beta}}{e^{-\beta}}\right)^J\binom{K-1}{j-1}\right)}{\left\{\begin{array}{l}\mu C\left(\sum_{j=0}^{R-1}\frac{\rho^j}{j!}+\frac{R}{R-\rho}*\frac{\rho^R}{R!}\right)- \\ \lambda\left(\sum_{j=0}^{R-1}\frac{\rho^j}{j!}+\frac{R}{R-\rho}*\frac{\rho^R}{R!}-e^{-\beta K}\sum_{j=1}^{K}\frac{R^R}{R!}\left(\frac{\rho}{R}\right)^J*\left(\frac{1-e^{-\beta}}{e^{-\beta}}\right)^J\binom{K-1}{j-1}\right)\end{array}\right\}} \tag{8}$$

$$T_{(RBSS)} = \frac{M\left(\frac{\rho^K}{K!}\left(\frac{K}{K-\rho}\right)+\sum_{i=0}^{K-1}\frac{\rho^i}{i!}-\frac{\rho^K}{K!}\left(\frac{K}{K-\rho}\right)\right)}{\mu C\left(\frac{\rho^K}{K!}\left(\frac{K}{K-\rho}\right)+\sum_{i=0}^{K-1}\frac{\rho^i}{i!}\right)-\lambda\left(\frac{\rho^K}{K!}\left(\frac{K}{K-\rho}\right)+\sum_{i=0}^{K-1}\frac{\rho^i}{i!}-\frac{\rho^K}{K!}\left(\frac{K}{K-\rho}\right)\right)} \tag{9}$$

$$T_{(SBSS)} = \frac{M\left(\sum_{n=0}^{C-1}\frac{\rho^n}{n!}\right)}{\mu C\left(\sum_{n=0}^{C-1}\frac{\rho^n}{n!}+\frac{\rho^C}{C!}\left(\frac{1-\left(\frac{\rho}{C}\right)^{(K-C+1)}}{1-\frac{\rho}{C}}\right)\right)-\lambda\left(\sum_{n=0}^{C-1}\frac{\rho^n}{n!}\right)} \tag{10}$$

$$T_{(CSS)} = \frac{M\left(\sum_{K=0}^{B}\binom{K+R-1}{R-1}\rho^K-\left(\frac{B+R-1}{R-1}\right)\rho^B\right)}{\mu C\left(\sum_{K=0}^{B}\binom{K+R-1}{R-1}\rho^K\right)-\lambda\left(\sum_{K=0}^{B}\binom{K+R-1}{R-1}\rho^K-\left(\frac{B+R-1}{R-1}\right)\rho^B\right)} \tag{11}$$

$$T_{(SMAS)} = \frac{M\left(\sum_{i=0}^{R}\binom{R}{i}\left(\frac{1-\rho^a}{1-\rho}\right)^{R-i}*\rho^{ia}\sum_{K=0}^{B}\binom{K+i-1}{i-1}\rho^K-\sum_{i=1}^{R}\binom{R-1}{i-1}\left(\frac{1-\rho^a}{1-\rho}\right)^{R-i}*\rho^{ia}\binom{B+i-1}{i-1}\rho^B\right)}{\left\{\begin{array}{l}\mu C\left(\sum_{i=0}^{R}\binom{R}{i}\left(\frac{1-\rho^a}{1-\rho}\right)^{R-i}*\rho^{ia}\sum_{K=0}^{B}\binom{K+i-1}{i-1}\rho^K\right)- \\ \lambda\left(\sum_{i=0}^{R}\binom{R}{i}\left(\frac{1-\rho^a}{1-\rho}\right)^{R-i}*\rho^{Pa}\sum_{K=0}^{B}\binom{K+i-1}{i-1}\rho^K-\sum_{i=1}^{R}\binom{R-1}{i-1}\left(\frac{1-\rho^a}{1-\rho}\right)^{R-i}*\rho^{ia}\binom{B+i-1}{i-1}\rho^B\right)\end{array}\right\}} \tag{12}$$

RESULTS AND DISCUSSIONS

Key performance indicator (KPI) parameters of GPRS requirements specified by Third Generation Partnership

Project (3GPP) standard for conservational, background, streaming and interactive traffic class include $P_B = 10^{-4}$-10^{-6}, delay <2s and theoretical throughput =171.2 kbits/s [32, 33]. The parameters are compared with data collected from the GPRS template developed; parameterized details of the template are; service facility R =3, ρ = 0.9, C = 1500 bit/s, μ= 2Mbps, λ = 10Mbps and variable buffer occupancy from 5-50 bits.

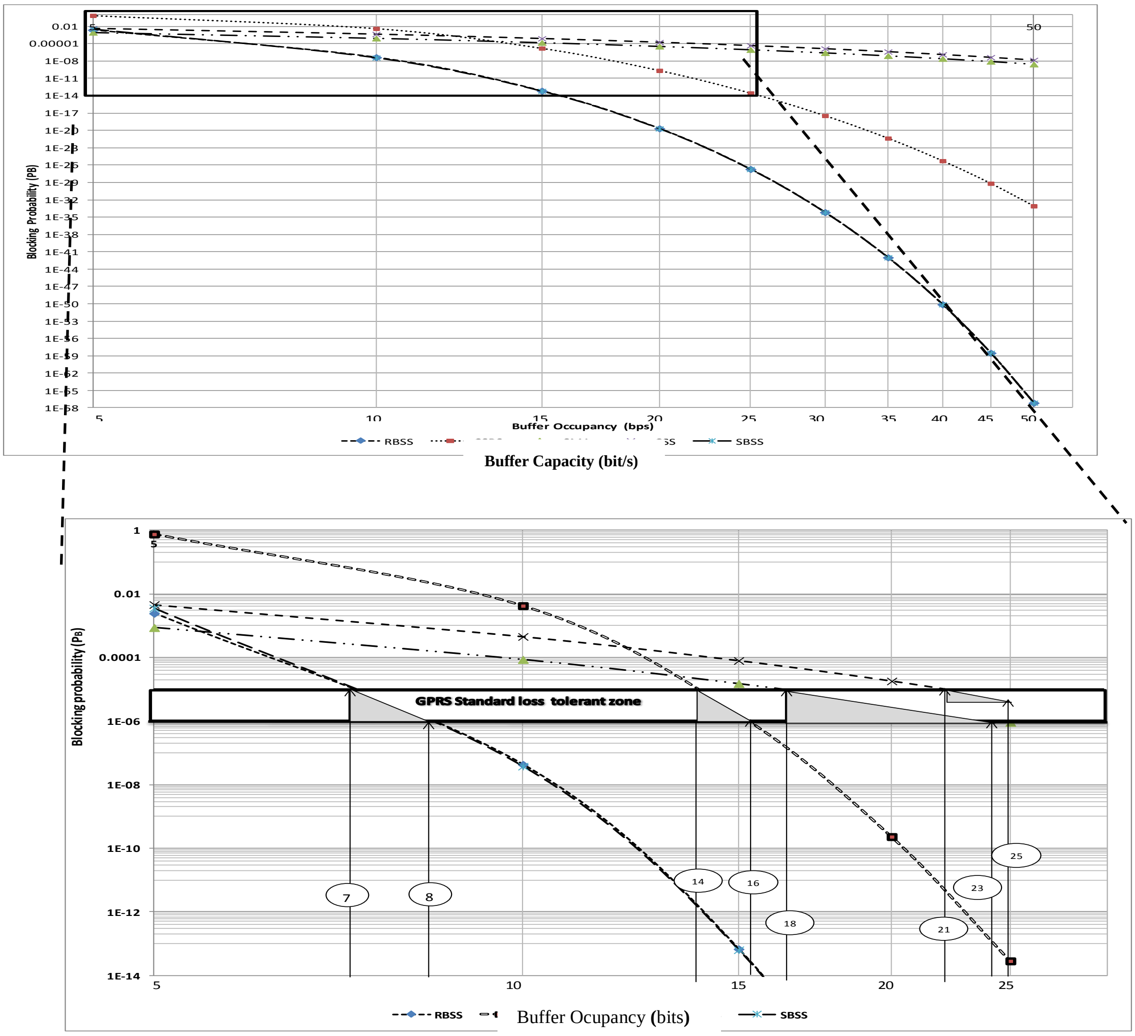


Figure 2: Blocking Probability (P_B) Against Buffer Occupancy

Figure 2 is used for the fair comparison of the different buffer sharing scheme in line with the GPRS specification; it is therefore regarded as a template for GPRS. P_B values of RBSS and CCSS decrease from 0.0024 and 0.00357 to 7-02E-68 and 7.22 E-68 respectively when buffer occupancy was in buffer occupancy was varied between 5 to 50 bits. P_B of CSBS7.56E-1 to 8.23E-34 for the same range of varied buffer occupancy. P_B of SMA and CSS reduces from 8.68E-4 and 4.58E-3 to2.77 E-9 and 1.46E-8 respectively when buffer occupancy was increase from 5 – 50 bits as illustrated in Figure 2. GPRS standard specifies a loss of 1 in 10000-1000000 ($P_B = 10^{-4}$-10^{-6}) for Class B GPRS [32, 33] for conversational, streaming interactive and background traffic class. This paper adopted 10^{-5}-10^{-6} specification and marked off the area by rectangular block and enlarged it as shown in Figure 2. Figure 2 shows the minimum and maximum number of buffer occupancy allocated by each of the schemes in that regard. The values of buffer occupancy are indicated in ovals with numbers written in them. The P_B rate (P_{BR}) with respect to change in buffer occupancy for each sharing scheme is computed from the slopes in the figure. The expression for P_{BR} is shown in equation (26). P_{BR} for SBSS and RBSS, CSBS, SMA, and CSS are -9.6E-6bps, -4.5E-6bps, -1.8E-6 bps, and -1.5E-6bps respectively. The negative sign implies a drop in P_{BR} as the buffer occupancy is increased. It important to mention that static buffer sharing schemes is influenced by both blocking probability and delay which have contrasting QoS. Thus Figure 3 shows the contrasting behavior of the static buffer sharing schemes.

$$P_{BR} = slope of curve = \frac{\Delta P_B}{\Delta BO} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad (26)$$

Where,

ΔP_B = change in P_B

ΔBO = buffer occupancy

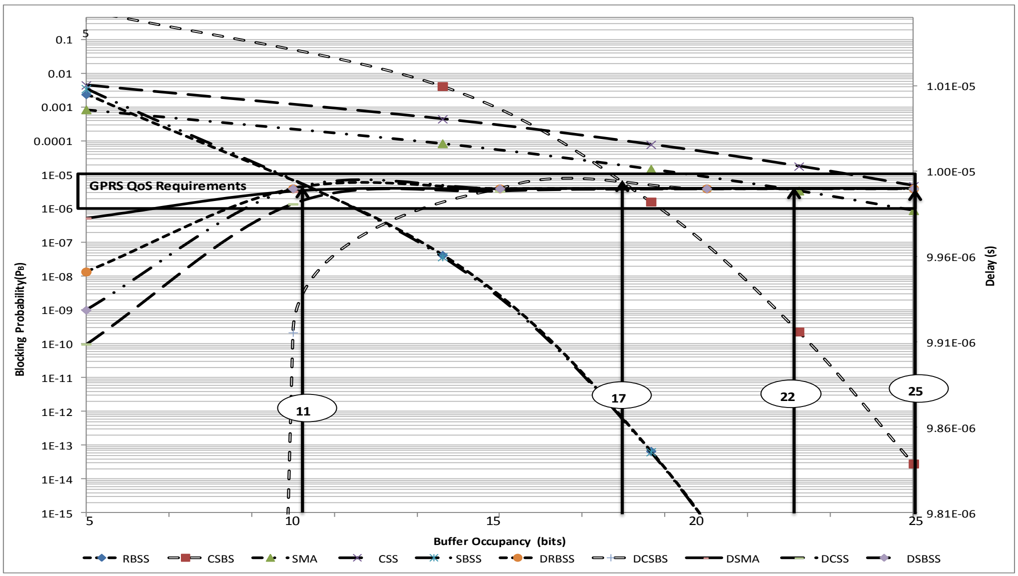


Figure 3: Graph of Blocking Probability and Delay Against Buffer Occupancy

Figure 3 is the graph of blocking probability and delay simultaneously plotted against buffer occupancy. It shows that P_B decreases with increase in buffer occupancy and delay increase with increase in buffer occupancy for the different buffer sharing schemes. It is revealed that SBSS and RBSS have the smallest P_B and SMA has highest P_B value when the buffer occupancy lies within the limit of 5 to approximately 16 bits. Above 16 bits CSS posses the highest P_B value. CSS has the smallest delay value and SBSS and RBSS has the highest delay value when buffer occupancy lies between 5-15bits. Above 15bits the delay values of all the sharing schemes converges to 0.1µs as shown in the marked off GPRS QoS requirements in Figure 3. Four unique points of intersection were noted between blocking probability and delays for the different statistic buffer sharing scheme in the marked off region that specifies the loss due to P_B. GPRS standard specifies a loss of 1 packet for 100000-1000000 packet transmitted ($P_B = 10^{-4}$-10^{-6}).

The intersections in Figure 3 define the point where optimum buffer resources are allocated for a given QoS in each of the STS schemes. The intersections occur at the approximate value of $P_B = 10^{-5}$-10^{-6} STS schemes and the corresponding delay is 9.999µs (0.00999ms); which is less than 5ms specified by GPRS [32]. Resources allocated by each of the schemes are depicted by an oval with numbers written inside as revealed in Figure 3. SBSS and RBSS, CSBS, SMA, and CSS allocated buffer occupancies of approximately 11, 17, 22, and 25 bits respectively. These values are extrapolated from the intersection points as indicated by the arrows and ovals emanating from the abscissa coordinate. Therefore it can be inferred that CCSS and RBSS have the best static buffer sharing techniques in this regard.

This work considers the loss of the schemes very paramount in the development of the template. Figure 4 depicts RBSS and SBSS as the best sharing schemes. Comparing the marked off rectangle in Figure 4 and the GPRS requirements, loss and delay values meets the recommendations of GPRS standard-within the loss region, delay parameters is < than 5s as specified by GPRS standard. RBSS and SBSS allocate buffer occupancy of 11 bits; CSBS allocates 20 bits; SMA allocates 25 bits; and CSS allocates 26 bits.

The behavior of delay of static buffer sharing schemes with respect to increase in blocking probability is extrapolated from the template; it is compared with the GPRS standard values. It was observed that the delays of the different STS schemes aligned with the delay specified by GPRS requirement.

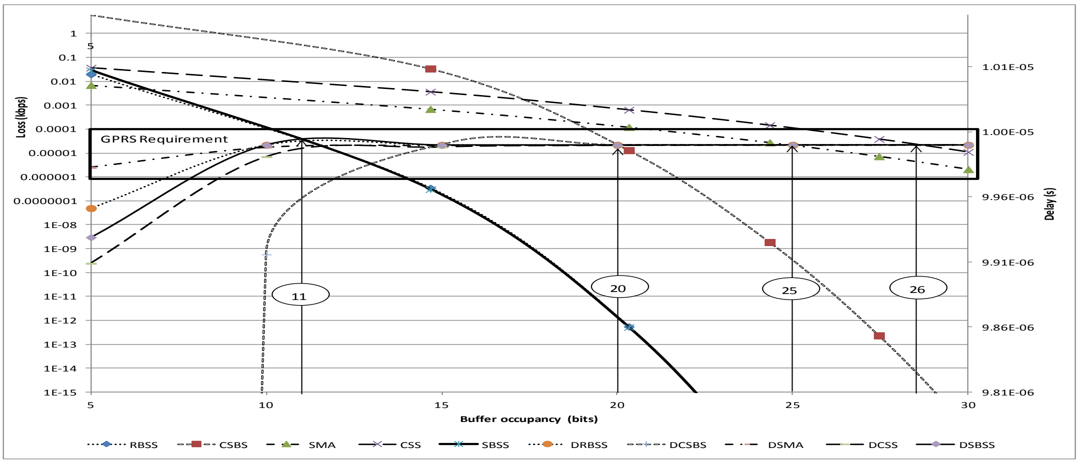


Figure 4: Graph of Loss against Buffer Occupancy

CONCLUSIONS

The results of the models show clearly that SBSS and RBSS are the best STS scheme and the least is CSS scheme. When the state vector parameter (a) in SMA buffer allocation strategy is equal to zero, SMA possesses the exact characteristics of CSS. Thus, the template developed for GPRS scheme is a fair comparisons for the static buffer schemes. It reveals the strength and weakness of each schemes and it very suitable for the GPRS system. Future works on GPRS will combine RBSS and SBSS scheme to develop a dynamic sharing scheme suitable to both GPRS and UMTS.

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