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RESEARCH ARTICLE

TRAFFIC DIMENSIONING MODEL AND PERFORMANCE EVALUATION IN GSM/GPRS NETWORK.

Kolawole Samuel Farayola And Ibiwoye Mathew.
Department of Electrical/Electronic Engineering, Nigerian Defence Academy, Kaduna.

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Abstract

The way and manner limited resources (timeslots) of a GSM/GPRS network is shared between GSM services and GPRS services is key to maximization of revenue for the telecommunications companies as the revenue is directly proportional to how much users the system can attend to per time. Consequently, the aim of this work is to determine the best sharing scheme that will allow for the maximum utilization of the available timeslots by having more users of both traffic classes being served per time. The markov chain model was used to model the blocking probability of the circuit switched services while the markov modified engset model was used to model the probability of the packet switched services. These two models were now applied to three dimensioning (sharing) schemes that were considered in this work. These models were then implemented as M-codes on MATLAB and the plotted results were compared to arrive at the final conclusion of this work. The partial partitioning scheme were found to have lower data blocking probabilities and higher data throughput (of between 50% to 300% depending on the voice traffic load per time) for same number of users than its complete partitioning dimension scheme counterpart. The model was also validated with real network data and the result was consistent with the model. It was eventually concluded that of the complete sharing, complete partitioning and the partial partitioning schemes considered in this work, the partition partitioning scheme is the most efficient in timeslot allocation and usage and hence better revenue generation in the overall system as it can attend to more GSM and GPRS users simultaneously at a time.

Introduction:-

The Global System of Mobile communication (GSM) industry has continually experienced remarkable growth in all facets since its inception worldwide and even much more in Nigeria vis-à-vis the diversification of services provided, the technology employed and as well as even subscriber base on the network. Emergence of New internet (Packet) based services such as Multimedia Messaging, Internet surfing, video calls, Social Media Messaging all hinging on the subsisting GSM architecture has introduced some level of complications and peculiarities in the system. GSM resources which are afore reserved for majorly voice calls now has to serve voice and data services respectively and optimally. The growth in demand for GSM services has led to intense efforts in developing simulation tools for dimensioning of radio resources.(Fantacci, 2000; Hiew and Zuckerman, 2000)

Corresponding Author:- Kolawole Samuel Farayola.
Address:- Department of Electrical/Electronic Engineering, Nigerian Defence Academy, Kaduna.

The manner in which traffic resources are allocated or shared between voice (GSM) and Data General Packet Radio Service (GPRS) is a very key concept for optimization in cellular networks(Cornel, 2011). This is referred to as Radio Resource Dimensioning. Accurate dimensioning of traffic resources based on traffic evaluation and quality of service level for GSM/GPRS users is a decisive process in the efficient and well optimized operation of mobile telecommunication network (Cornel, 2011).

A GSM voice call needs the assignment of a single circuit, also called time-slot (TS), for its entire duration because it is a Time-Division Multiple Access (TDMA) scheme. On the other hand in GPRS (General Packet Radio Service) service each timeslot can be shared between several users by assigning different Temporary Flow-Identities (TFI) to the mobiles. Up to 32 TFI's can be allocated per TDMA. A mobile can identify it's its own blocks and decode them by monitoring the TFI of each radio block[2]. GSM services are circuit switched while GPRS services are packet switched as illustrated in the GSM/GPRS architecture in Fig 1

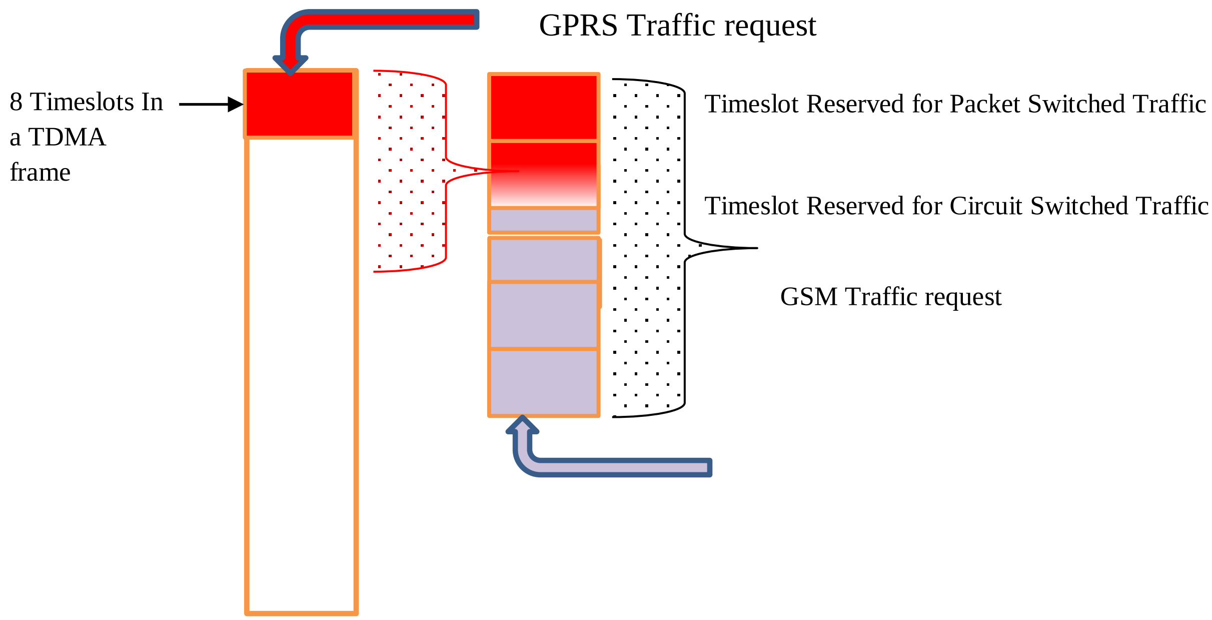

Fig 1:- Timeslots dimensioning for GSM/GPRS system

The way and manner GSM channel resources are dimensioned between voice and data traffic is of utmost importance for cellular operators when aiming to maximize call revenue. Thus, a lot of effort has traditionally been dedicated to dimensioning GSM traffic channels of all cells in the network, as on these channels the payload is carried. However, the emergence of new packet data services, which rely heavily on signaling procedures, poses new challenges to the maximum call and data revenue simultaneous for network operators. Hence a model to optimally share these channel resources between voice and data traffic for maximum call revenue has to be developed. A range of channel allocation schemes have been proposed to increase cellular systems efficiency in radio resource management.(Dahmouni, Mori and Vanton, 2005; Dobrescu, Hossu and Mocanu, 2008) The aim of this work is to quantitatively determine how to optimize allocation of traffic resources between circuit and packet switched traffic in a GSM/GPRS network

Methodology:-

In traditional circuit-switched GSM networks, on each frequency carrier a 200 kHz bandwidth is shared between 8 voice calls. Each voice call is given a circuit, also called time-slot (TS) because it is a Time-Division multiplexing scheme (TDMA) lasting a duration of 0.577ms carrying 114 bits of information. Each voice call needs the assignment of a single time-slot for its entire duration (Cornell, 2011). On the other hand in GPRS service each timeslot can be shared between several users by assigning different Temporary Flow-Identities (TFI) to the mobiles. Up to 32 TFI's can be allocated per TDMA. A mobile can identify its own blocks and decode them by monitoring the TFI of each radio block. Data flows are multiplexed by a scheduling algorithm.

The channel allocation in GPRS is different from the original allocation scheme of GSM. GPRS allows a single mobile station to transmit on multiple time slots of the same TDMA frame. This results in a very flexible channel allocation: one to eight time slots per TDMA frame can be allocated to one mobile station. On the other hand, a time slot can be assigned temporarily to a mobile station, so that one to eight MS can use one time slot. Moreover, uplink and downlink channels are allocated separately, which efficiently supports asymmetric data flow. Unlike in conventional GSM, a channel is permanently allocated for a particular user during the entire duration of call whether silent or not. In contrast to this, in GPRS the channels are only allocated when data packets are sent or received, and they are released after the transmission.

Three main radio resources sharing schemes will be considered in this study. They are Complete Sharing (CS), Complete Partitioning (CP) and Partial Partitioning (PP). In CS all radio channels are shared between voice and data, there is no dedication of resources to either voice or data. The time slots are used on the first come first serve basis. In CP, time-slots are divided into two sets, one for data and the other for voice. Partitions dedicated to voice will not be used for data even if data needs more resources than provisioned at that particular point in time, while in PP, a channel is divided into three partitions; one set shared between voice and data traffic and the two sets, each one being reserved for strict usage of its dedicated traffic, voice or data.

These three schemes will be modelled using appropriate standard model for voice and data traffic; the classical markov chain model and the markov modified engset model to see the advantages and disadvantages of one scheme over the other vis-à-vis the throughout and the blocking probability.

Review Of Related Work:-

Dimensioning configuration of traffic resources is crucial to enhance the performance of complex mobile networks (Salvador et al, 2006) in their paper presented an automatic optimization algorithm for adaptation of permanent signaling resources in GSM/GPRS, which is based on statistical measurements of signaling and call traffic in order to greatly minimize the overall revenue losses caused by blocking effects in a real network. The ability to detect if traffic resources reserved for a certain traffic class are under- or over-dimensioned is crucial for a proper performance of the algorithm. In particular, blocking rate was selected to model the congestion effects derived from the reassignment of Time Slots (TSLs).

Balint et al. (2011) focused on the problem of performance evaluation in GSM/GPRS networks. They considered different resources allocation strategies such as: Complete Partitioning (CP) where time-slots (TS) are divided into two sets and each type of traffic is allowed to use only its dedicated set, Partial Partitioning (PP) where one set is shared between voice and data traffic and two sets each one being reserved for strict usage of its dedicated traffic: voice or data They also studied the influence of different operational details concerning TS (time-slots) assignment: FR (full rate), HR (half rate) and packing. They finally established dimensioning rules based on traffic evaluation and quality of service level for GSM/GPRS users. The major works in this field are based on analytical models using queuing theory and continuous-time Markov chains, and assuming an infinite number of users in the cell.

Christoph and Axel (2002) investigated how many packet data channels should be allocated for GPRS under a given amount of traffic in order to guarantee appropriate quality of service. They presented a model that constitutes a continuous-time Markov chain. Markov model explicitly represents the mobility of users by taking into account arrivals of new GSM and GPRS users as well as handovers from neighboring cells. Markov model represents just one cell and employs the procedure for balancing incoming and outgoing handover rates. In applying markov model, it is assumed that GSM calls and GPRS calls arrive according to two mutually independent Poisson processes, with arrival rates λ_{GSM} and λ_{GPRS}, respectively. GSM calls are handled circuit switched, so that one physical channel is exclusively dedicated to the corresponding mobile station. After the arrival of a GPRS call, a GPRS session begins. During this time, the BSC schedules the radio interface (i.e., the physical channels) among different GPRS users. GPRS users receive packets according to a specified traffic model. The amount of time that a mobile station with an ongoing call remains within the cell is called dwell time. If the call is still active after the dwell time, a handover toward an adjacent cell takes place. The call duration is defined as the amount of time that the call will be active, assuming it completes without being forced to terminate due to handover failure.

The principles for channel allocation for effective radio resource management in a GSM and GPRS cellular network were investigated using different methods by some authors(Georgeta, Cornel and Adrian ,2011); Manson, 2008; Vannucci and Chitmmu, 2004)). Jean-Lien, Wei-Yeh and Hung (2004) in their work proposed a scheme that employs channel allocation and admission control mechanism to guarantee the Quality of service (QoS) and improve the channel utilization. Each GPRS connection request was associated with two bandwidth parameters: the requested bandwidth (b_{req} Kbps) and the minimum required bandwidth (b_{min} Kbps). Each GPRS connection request demands for a bandwidth of b_{req} Kbps, and the minimum bandwidth to be guaranteed is b_{min} Kbps once this connection request is admitted. The bandwidth allocated to each GPRS connection was varied between b_{req} and b_{min} Kbps. Upon the arrival of a GPRS connection request, the call admission controller has to figure out the number of channels required. They let C_{req} denote the number of channels allocated for GPRS to offer a bandwidth of b_{req} Kbps if it is admitted, and C_{min} denote the minimum number of channels required to offer a bandwidth of b_{min} Kbps for an admitted GPRS connection. The work assumed that each Packet Data Channel

Model Design:-

In this work, the methodology employed to determine which is best of the proposed resource sharing scheme is that of comparison of the final blocking probabilities for circuit switched service and the throughput for the packet switched services for the three schemes.

Model for Circuit switched traffic blocking probability:-

For voice call, the maximum number of active user at full rate on the GSM system is equal to the maximum number of traffic channel (timeslots) available for voice call. The number of active timeslots at any time t is regarded as the state of the system. E.g. when there are 2 active calls, the system is said to be in state 2, when there are 20 active calls, the system is said to be in state 20 and so on. So generally, the system is said to be in state k at any time t and can transition to state k-1 (when $k \neq 0$) when a call departs (μ) to state k+1 ($k \neq N$) when a call arrives (λ). N is used to denote the maximum number of voice channel available for call on the system. Possible states ranges from 0 to N such that $0 \leq k \leq N$ as illustrated in a state transition diagram in Fig 2

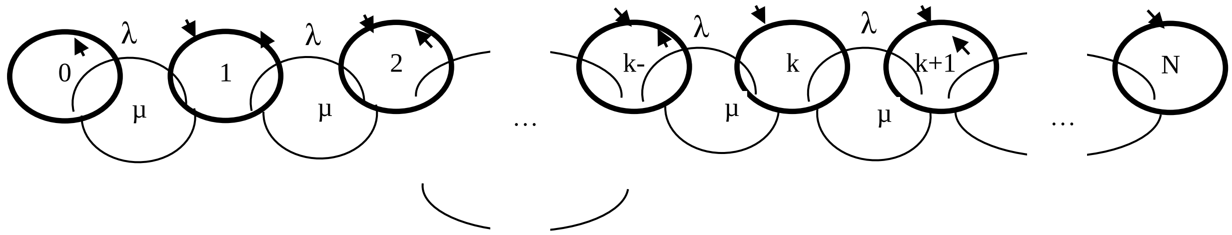

Fig 2:- State Space Call Arrival (λ) / Departure (μ) Transition Diagram

The chances that the system will be at a particular state is associated to a certain probability. Most importantly for the purpose of this work, the probability that the system that will be in state N (maximum capacity) will be evaluated for the three schemes. This probability is known as the blocking probability P_N of the GSM system.

Fig 2 resulted into a markov chain. The call arrival times are independent and memoryless and can be described by a Poisson process of mean λ, which is known as the call arrival rate; also that the call holding time (call duration) is random process and can be described by an exponential distribution with mean 1/μwhere μ is the call departure rate.

Traffic per user denoted as A_o

= User call rate x Average call duration

$$= \lambda \times \frac{1}{\mu} = \lambda/\mu \text{ erlang} \quad (1)$$

Total Traffic for N users in the system denoted as A

$$= \text{Number of user x Traffic per user} = NA_o \text{ erlang} \quad (2)$$

According Poisson distribution, the probability that k calls will arrive in a time duration t is given as

$$P(k) = \frac{(\lambda t)^k e^{-\lambda t}}{k!} \qquad \text{For } k=0, 1, 2, 3, 4, \ldots \quad (3)$$

Now considering the probability that a call arrives within an infinitesimally small time duration Δt.

Probability that one call arrives in Δt (poisson probability) assuming the system transitions from state 0 to 1. So k = 1

$$P(One\ call\ arrives) = (\lambda \Delta t)\, e^{\lambda \Delta t}$$

Since $\Delta t \simeq 0$, then $e^{\lambda\Delta t} \simeq 1$

$$P(One\ call\ arrives) \simeq \lambda\Delta t \qquad (4)$$

Also considering the probability that a call departs from the system.
Call departure behavior conforms to the Poisson process with departure rate μ given by

$$\mu = {}^{1}/_{T}$$

where T is the average call time
Probability that 1 call departs in an infinitesimal time interval Δt

$$P(k=1) \simeq \mu\Delta t \qquad \text{in state 1}$$

However in state k, k channels are occupied. hence, the probability of call departure in state k

$$P_k\ (one\ call\ departs) = k\mu\Delta t \qquad (5)$$

Looking at Fig 2 again, it is obvious that call arrives and departs for every state except for state 0 and N
Considering any state k, three possible different scenarios could result into the system being in that state k; as follows

1. The system transitions from state (k-1) to (k) if one call arrives
2. The system transitions from state (k+1) to (k) if one call departs
3. The system remains in state (k) if no call neither arrives nor depart

Now relative to time, the system is in state k at time (t+Δt) if one of the following occurs

a. The system is in state (k-1) at time t and one call arrives in Δt

$$P_a = prob\ (sys\ is\ in\ state\ k-1) \times prob\ (one\ call\ arrives)$$
$$P_a = (P_{k-1})(\lambda\Delta t)$$

b. The system is in state (k+1) at time t and one call departs in Δt

$$P_b = prob\ (sys\ is\ in\ state\ k+1) \times prob\ (one\ call\ departs)$$
$$P_b = P_{(k+1)} \times (k+1)\mu\Delta t \qquad = P_{(k+1)}(k+1)\mu\Delta t$$

c. The system is in state k and call neither arrives or departs in time interval Δt

$$P_c = prob(sys\ is\ in\ state\ k) \times prob(call\ neither\ arrive\ nor\ depart)$$
$$P_c = P_k \times (1 - \lambda\Delta t - k\mu\Delta t)$$

Generally, the probability that the system is in state k at time t+Δt is expressed as

$$P_k = P_a + P_b + P_c$$
$$P_k = (P_{k-1})(\lambda\Delta t) + P_{(k+1)}(k+1)\mu\Delta t + P_k(1 - \lambda\Delta t - k\mu\Delta t)$$
$$(\lambda + k\mu)P_k = \lambda P_{(k-1)} + (k+1)\mu P_{k+1} \qquad (6)$$

Eqn 6 is known as the steady state probability for markov chain
It is important to know that state 0 and state N are special cases because no call can depart in state 0 and no call can arrive in state N.
Now considering special case state 0 as shown in Fig 3

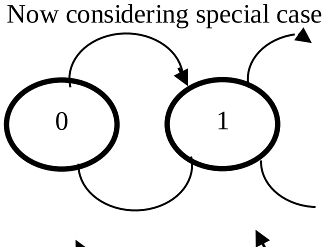

Fig 3:- Special case state 0

The probability that the system will be in state 0 is computed as
Prob (*state 0*) = prob (*state 0 and no call arrives*) + prob (*state 1 and 1 call depart*)

$$P_0 = P_0(1 - \lambda\Delta t) + P_1\mu\Delta t$$
$$P_1 = \left(\frac{\lambda}{\mu}\right)P_0 \qquad (7)$$

So now substituting eqn 7 into eqn 6

$k = 1$ $\qquad (\lambda + \mu)P_1 = \lambda P_0 + 2\mu P_2$

$$P_2 = \frac{1}{2}\left(\frac{\lambda}{\mu}\right)^2 P_0 \qquad (8)$$

Also substituting eqn 8 into eqn 6, we will arrive at eqn 9

$$P_3 = \frac{1}{6}\left(\frac{\lambda}{\mu}\right)^6 P_0 \qquad (9)$$

Generalizing, eqns 7, 8, 9 ,we have eqn 10

$$P_k = \frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^k P_0 \quad (10)$$

Equation 10 is the steady state probability of state any state k

As fundamental rule in probability theory, the sum of all probability has to be 1

$$\sum_{k=0}^{N} P_k = 1$$

$$\sum_{k=1}^{N} \frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^k P_0 = 1$$

$$P_0 = \frac{1}{\sum_{k=1}^{N} \frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^k} \quad (1)1$$

For another special case of state N, where the blocking probability is computed

From eqn 10

$$for\ k = N \qquad P_N = \frac{1}{N!}\left(\frac{\lambda}{\mu}\right)^N P_0$$

Substituting for P_0 in P_N

$$P_N = \frac{\frac{1}{N!}\left(\frac{\lambda}{\mu}\right)^N}{\sum_{k=1}^{N} \frac{1}{k!}\left(\frac{\lambda}{\mu}\right)^k} \quad (12)$$

Eqn 12 is the blocking probability as function of call Arrival and departure rate

Where $\lambda = Call\ arrival\ rate$

$\mu = {}^{1}/_{T} = Call\ departure\ rate$

$T = Average\ duration\ of\ the\ call$

$$Total\ Traffic(A) = \lambda \times T = \lambda \times {}^{1}/_{\mu}$$

$$A = {}^{\lambda}/_{\mu} \quad (13)$$

Now expressing the blocking probability in terms of average call duration. We substitute eqn 13 into eqn 12

$$P_N = \frac{\frac{1}{N!}(A)^N}{\sum_{k=1}^{N} \frac{1}{k!}(A)^k} \qquad Blocking\ probability$$

(14)

Model for Packet data traffic blocking probability:-

Assuming there is a fixed number N of data mobile in the cell. Each connected mobile is doing an ON/OFF/ON/OFF….. traffic cycle with an infinite number of pages. The data traffic is thus modeled assuming the following parameters.

1. The ON periods refers to the download time which is characterized by a discrete random variable X_m with an average value E(σ).
2. The OFF period which refers to the reading time (the time it takes to read the data downloaded) is modelled as a random variable T_{off} with and average value of E(τ).
3. The Maximum number of GPRS users in active transfer (On and Off)

$$n_{max}(TS_D) = \min(N, 32, mTS_D) \quad (15)$$

Where m – is the maximum number of users that can use a single timeslot.

Some data traffic parameters useful for this modeling are as defined below

The average data arrival rate λ_D

$$\lambda_D = \frac{1}{E[\tau]} \quad (16)$$

Average data rate per time-slot μ_D:

$$\mu_D = \frac{x_B}{E[\sigma]t_B} = \frac{\mu_{GPRS}}{E[\sigma]} \quad (17)$$

Where t_B : the radio block duration

x_B : the number of data bytes that are transferred over one time-slot.

And the GPRS throughput is given as $\mu_{GPRS} = \frac{x_B}{t_B}$

Now based on these two parameters λ_D and μ_D, the data blocking probability ρ_D which characterizes data traffic, similar to that of Voice is derived as

$$\rho_D = \frac{\lambda_D}{\mu_D} = \frac{t_B E[\sigma]}{x_B E[\tau]} = \frac{E[\sigma]}{E[\tau]\mu_{GPRS}} \quad (18)$$

Considering the markov chain engset model as shown in Fig 4

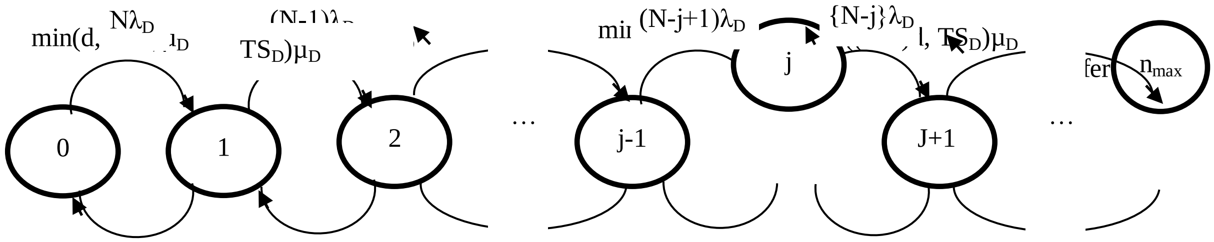

fig 5, transition from state j to state j+1, λ_j can be given as

$$\lambda_j = (N-J)\lambda_D = (N-j)\frac{1}{E[\tau]} \tag{19}$$

For j = 0, 1,……..n_{max}-1

The transition rate μ_D of the death process from state j to j-1 is given as

$$\mu_j = \min(jd,\ TS_D)\,\mu_D = \min(jd,\ TS_D)\,\frac{\mu_{GPRS}}{E[\sigma]} \tag{20}$$

For j = 1, 2, ….. , n_{max}

The state j of the markov chain corresponds to the number of the data mobile that are simultaneously in active transfer (in ON state). The maximum bandwidth capacity usable at any point in time is TS_D. As a result of the maximum download capacity d of each GPRS mobile, two scenarios are possible as follows

1. If $jd < TS_D$, the available bandwidth is not fully utilized by data mobile, then the transaction rate from state j to state j-1, as given by a complete transfer of one mobile, is expressed as

$$\mu_j = \frac{jd\mu_{GPRS}}{E[\sigma]} \tag{20}$$

2. If $jd < TS_D$ the radio resource allocator will have to share the TS_D timeslots among the j data mobiles & the transition rate from state j to state j-1 is given as

$$\mu_j = \frac{\mu_{GPRS}}{E[\sigma]} * TS_D = TS_D\ \frac{\mu_{GPRS}}{E[\sigma]} \tag{21}$$

Now letting $P_D(j)$ be the steady state probability that j users are in active transfer according to the engset model, it is expressed as in below [1]

$$P_D(j) = P_D(0)\ \frac{C_N^j}{\prod_{i=1}^{j}\min(d,\frac{TS_D}{i})\ \frac{i\mu_{GPRS}}{E[\sigma]}}\ \frac{1}{E[\tau]^J} \tag{22}$$

The steady state probability in terms of data traffic P_D is defined as

$$P_D = \frac{E[\sigma]}{E[\tau]}\ \frac{1}{\mu_{GPRS}}$$

$$P_D(j) = P_D(0)\ \frac{C_N^j}{\prod_{i=1}^{j}\min(d,\frac{TS_D}{i})}\ P_D^j \tag{23}$$

As it is seen, the steady state probability distribution depends on the ratio $\frac{E[\sigma]}{E[\tau]}$.

The average total data throughput is then determined using the expression

$$X_{cp} = \sum_{j=1}^{n_{max}} P_D(j)\ j\ r(j) \quad .(24)$$

Where r(j) is the effective bandwidth received by each user.

$$\text{r(j)} = \min\left(d,\frac{TS_D}{i}\right)\mu_{GPRS} \qquad for\ j = 1, \dots\dots n_{max}$$

Therefore, the blocking probability can thus be expressed based on engset model as expressed in eqn .25]

$$B_{cp} = P(0)\ \frac{C_{N-1}^{n_{max}}}{\prod_{i=1}^{n_{max}}\min(d,\frac{TS_D}{i})}\ P_D^{n_{max}} \tag{25}$$

B_{cp} Represents the probability that TS_D timeslots are being used by n_{max} users among (N-1) users.

The average total throughput X_{PP} [1] for partial partitioning scheme is also as shown in eqn 26

$$Xpp = \sum_{s=0}^{ts-tsd} bvcp(s) * Xcp * \min(ts - tsv, ts - s) \quad .(26)$$

Where s = the part of tsvd that is eventually used for data traffic

Implementation:-

The fundamental model for Circuit switched and packet switched traffic, i.e. based on the markov chain model and engset model have been established earlier. These models are now applied to GSM/GPRS network TDMA frame (consisting of 8 timeslots), where these timeslots has been shared to either or both of the traffic class based on a particular resource dimensioning schemes and the results of the models on this schemes are compared to verify the comparative advantage of one over the other. These dimensioning scheme are as illustrated in Fig 5

Complete Sharing (a)

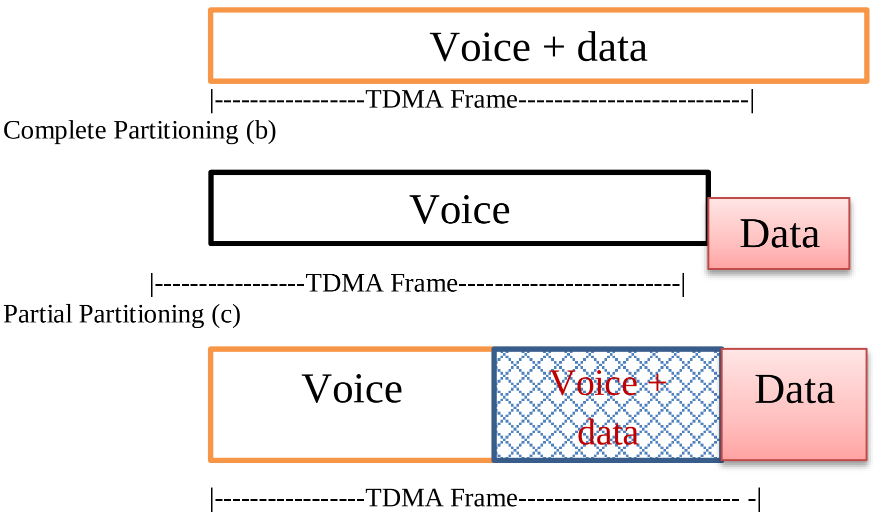

Fig 5:- TDMA dimensioning scheme Illustration

For data traffic modelling, The following parameters were adopted; $E[\tau] = 12s$, $E[\sigma] = 5KB$, GPRS mobile class (d+u) ; 4+1, and a CS2 coding scheme with $\mu_{GPRS} = 13.4kbits/s$. in modeling the complete partitioning scenario with TRX containing TDMA frame dimensioned as follows; TS=8, $TS_V = 7$, and $TS_D = 1$. Furthermore, considering a cell with the partial partitioning strategy equipped with a single TRX dimensioned to provide TS=8, $TS_V = 3$, and $TS_D = 1$.

Voice Model:-

Circuit switched traffic model:-

The probability that a GSM network service network can still take more traffic request onto itself considering its resources and also the number of users already on the network is given in equation .27.

$$P_N = \frac{\frac{1}{N!}(A)^N}{\sum_{k=1}^{N}\frac{1}{k!}(A)^k} \qquad (27)$$

ALGORITHM

1. Define the total traffic erlang as A
2. Define the total number of user capable of latching on to a cell.
3. Initialize a summative accumulator Acc as Zero
4. Initialize a counter k from 1 to N
5. For every value of k as it increments from 1 up to N;
6. Accumulate into Acc the outcome of ((A^k) / factorial (k)) for every value of k
7. Compute the probability P(k) = ((A^k)/factorial (k)) / Acc
8. Increment k and repeat 6 and 7 until k equals N
9. Plot k against P(k)

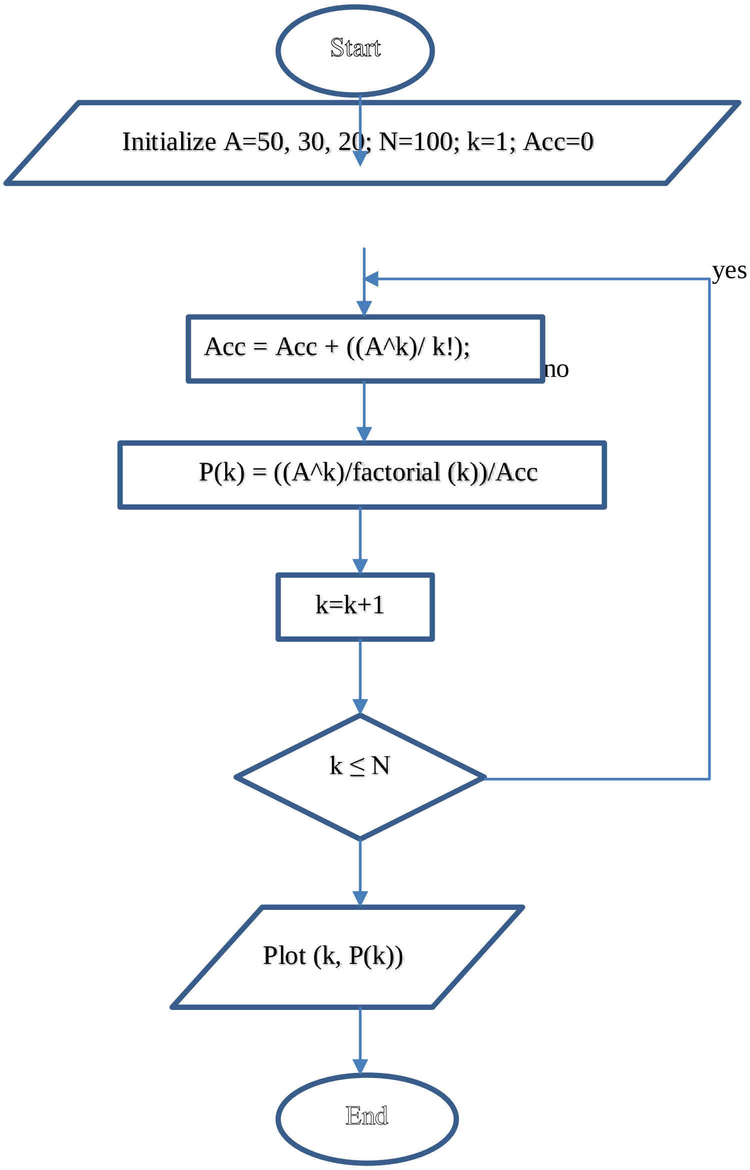

Fig 6:- Flowchart to evaluate the voice blocking probability

Complete Partitioning for Voice:-

In complete partitioning, as shown in Fig 5b, the TDMA is segmented into 2 distinct partitions. The peculiarity of this method of partitioning is that it is not smart i.e. if one segment has more traffic request than it can handle, it cannot borrow unused timeslot from other segment. As a derivative of equation 27, equation 28 is adapted for the voice blocking probability (bvcp) of the complete partitioning scheme.

$$bvcp = \frac{\frac{\rho_v^{(TS_V)}}{TS_V!}}{\sum_{i=0}^{TS_V} \frac{\rho_v^{i}}{i!}} \quad (28)$$

The algorithm in Fig 7 models the circuit switched aspect of this scheme.

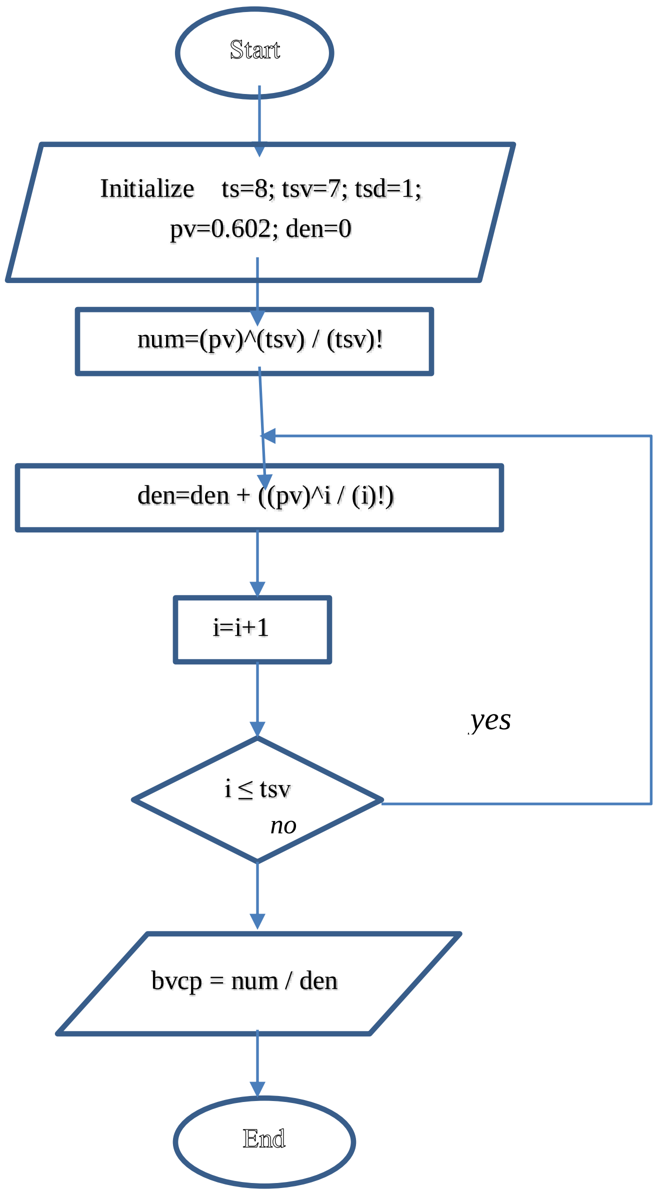

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Fig 7:- Flowchart to evaluate the voice blocking probability for complete partitioning

Data Model:-

Complete partitioning scheme Packet blocking probability:-

According to the markov modified engset model as shown in equation 23, the probability that the GPRS system will reject incoming request relative to the number of users on the network at any point in time is as implemented below for the complete partitioning scheme.

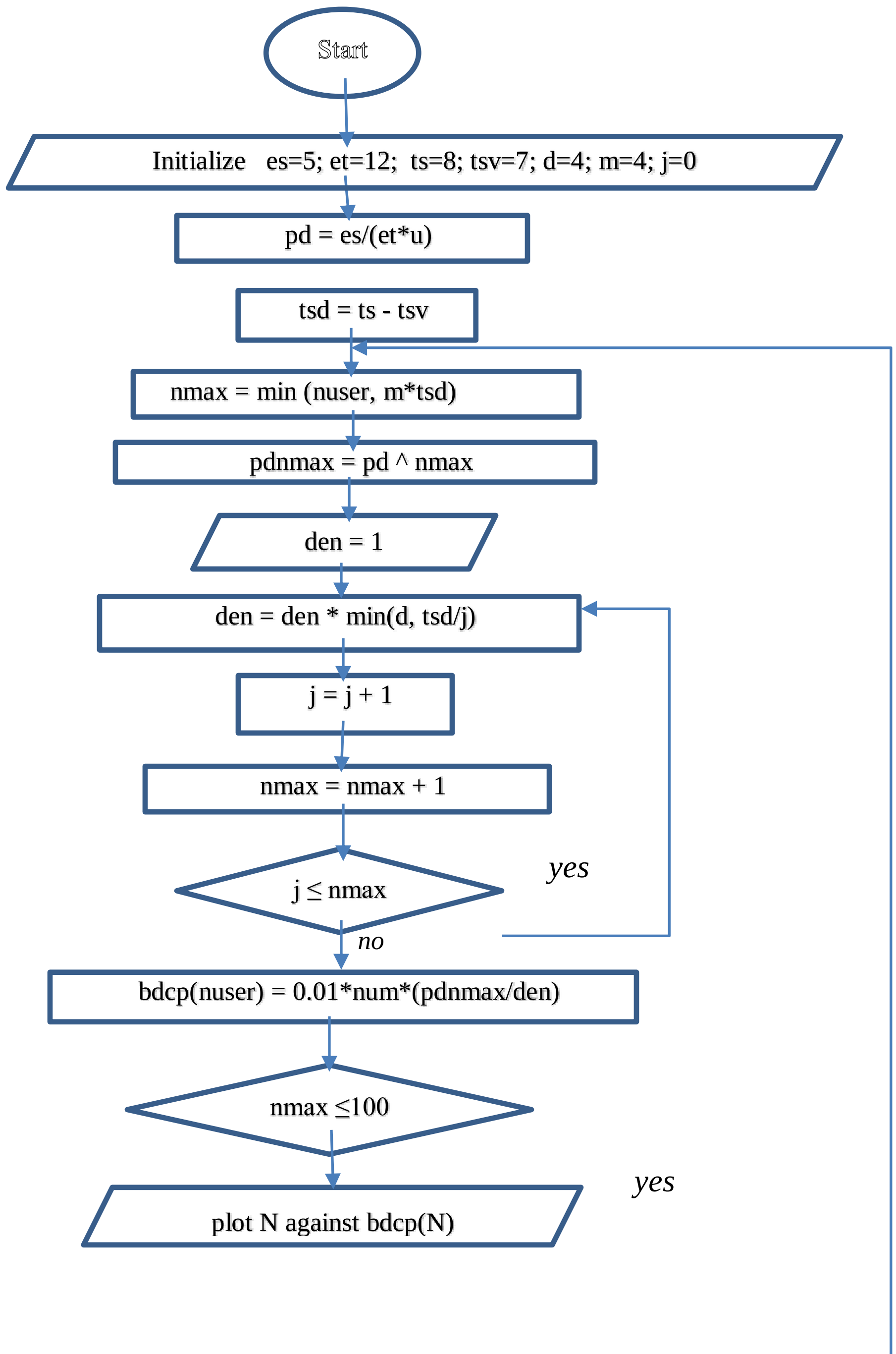
The scenario under consideration is within the scope of 1 TDMA frame consisting of 8 timeslots that is to be statically shared between voice and packet data by the flowing algorithm. Due to the overall priority given to circuit switched service over packet switched traffic, and also the unique allocation of 1 timeslot to 1 voice call whereas, multiple GPRS users can simultaneously use a single timeslot. So, 7 timeslots are statically reserved for voice traffic and I timeslot reserved for packet data traffic.

$$B_{cp} = P(0)\,\frac{C_{n_{max}}^{N}}{\prod_{i=1}^{n_{max}} \min(d, \frac{TS_D}{i})}\, P_D^{n_{max}} \qquad (29)$$

1. Initialize constants
   Average of ON period Discrete random variable, es = 5;
   Average of OFF period Discrete random variable et = 12;

Average data rate per time slot (according to CS2 coding scheme, u=13.4;
Total timeslot ts=8;
Voice time slot tsv=7;
Timeslots simultaneously for downlink d=4;
Maximum number of users on a timeslot m=4;

2. Initialize the number of user for a loop from 1 to nuser.
3. Get maximum number of active user; nmax=minimum of nuser, m or tsd
4. Evaluate $P_D^{n_{max}}$
5. Evaluate $C_{n_{max}}^N$, that is N combination n_{max}
6. Initialize a multiplicative accumulator as 1
7. For j = 1 to nmax, evaluate $\prod_{i=1}^{n_{max}} \min(d, \frac{TS_D}{i})$
8. Evaluate the overall blocking probability for that particular number of GPRS user on the network by bdcp(nuser) = k*num*pdnmax/den; where k is a normalizing constant
9. Plot the blocking probability against the number of GPRS users



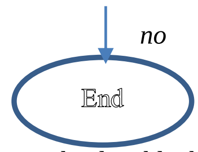


Fig 8:- Flowchart to evaluate the data blocking probability for complete partitioning

Partial Partitioning for Circuit switched service:-

In partial partitioning, the TDMA frame is divided into 3 segments. One reserved solely for circuit switched service, another reserved solely for packet switched service and the last segment is dynamically allocated to either circuit and/or data switched services on demand although priority is still given to circuit switched traffic. This is expected to increase the total traffic capacity of the GSM/GPRS system.

$$bvpp = \frac{\frac{\rho_v^{(TS_V+TS_{VD})}}{(TS_V+TS_{VD})!}}{\sum_{i=0}^{TS_V+TS_{VD}} \frac{\rho_v^{\,i}}{i!}} \qquad 30$$

1. Initialize total timeslot (ts), static voice ts, and static dynamic ts.
2. Evaluate the dynamic timeslot portion for voice/data/both.
3. Initialize a test voice traffic value pv=ρ_v.
4. Initialize an additive accumulator d = 0.
5. Evaluate the numerator of bvpp equation as num
6. For i =1 to (tsv+tsvd), evaluate the denominator of bvpp
7. Evaluate $bvpp = \frac{num}{den}$

Partial partitioning scheme Packet data blocking probability.

As earlier stated earlier for partial partitioning scheme, the 8 Timeslots TDMA is partitioned into 3 segments reserved for Voice, Data, and Voice + Data respectively. Here is an algorithm that shows the effect of this partitioning scheme over the complete partitioning scheme. The equation below is used to dimension this scheme.

$$bdpp = \sum_{s=0}^{ts-tsd} bvcp(s) * bdcp * \min(ts - tsv, ts - s) \qquad 31$$

Where s = the part of tsvd that is eventually used for data traffic

Among the tsvd timeslots, those not used by time slots may be used for data traffic with a probability that is equal to the probability that (ts-tsd-s) are used by GSM users; bvpp (ts-tsd-s).

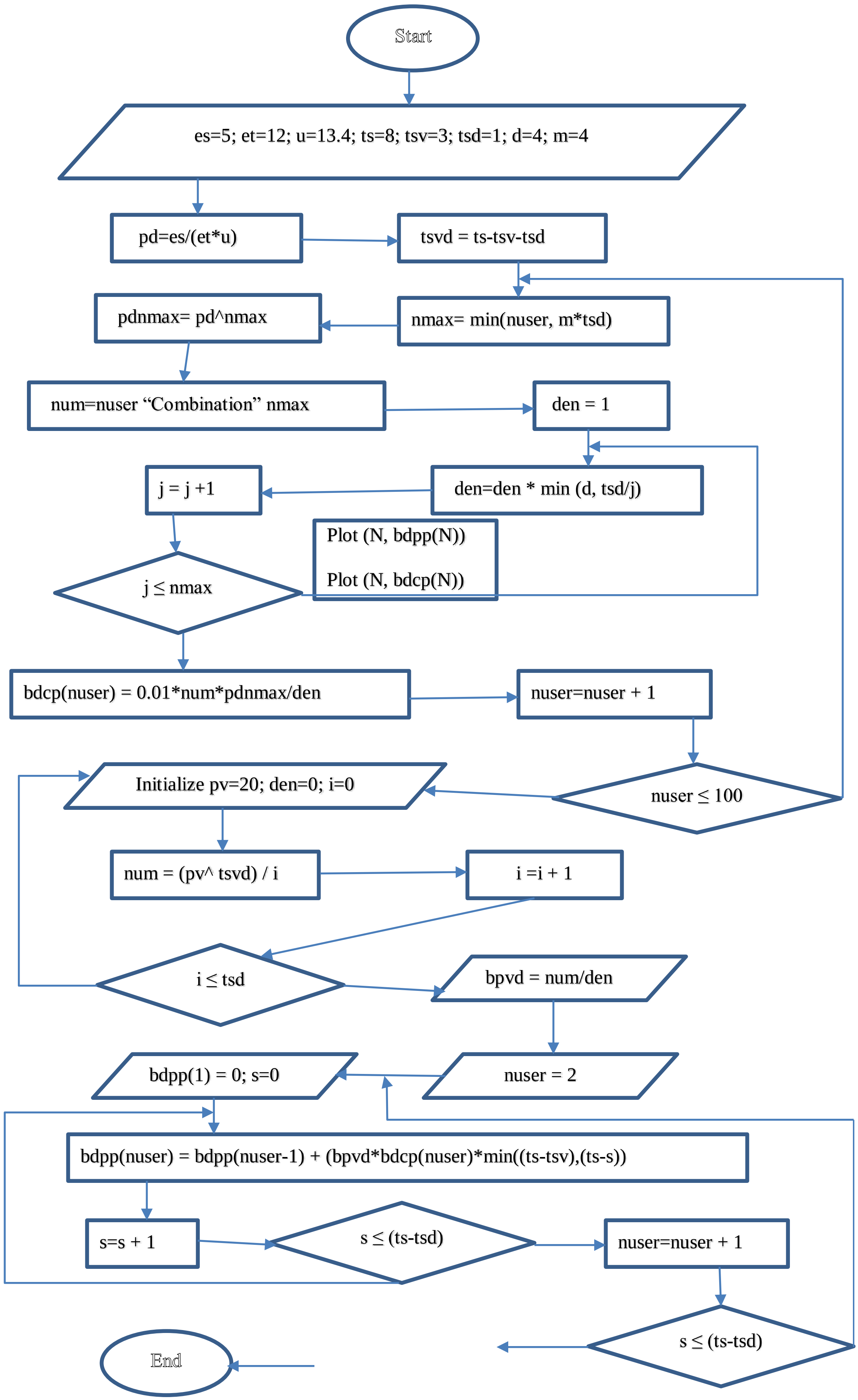

Start
es=5; et=12; u=13.4; ts=8; tsv=3; tsd=1; d=4; m=4
pd=es/(et*u)
tsvd = ts-tsv-tsd
pdnmax= pd^nmax
nmax= min(nuser, m*tsd)
num=nuser "Combination" nmax
den = 1
j = j +1
den=den * min (d, tsd/j)
Plot (N, bdpp(N))
Plot (N, bdcp(N))
j ≤ nmax
bdcp(nuser) = 0.01*num*pdnmax/den
nuser=nuser + 1
Initialize pv=20; den=0; i=0
nuser ≤ 100
num = (pv^ tsvd) / i
i =i + 1
i ≤ tsd
bpvd = num/den
bdpp(1) = 0; s=0
nuser = 2
bdpp(nuser) = bdpp(nuser-1) + (bpvd*bdcp(nuser)*min((ts-tsv),(ts-s))
s=s + 1
s ≤ (ts-tsd)
nuser=nuser + 1
s ≤ (ts-tsd)
End

Fig 9:- Flowchart to evaluate the data blocking probability for partial partitioning

Data throughput comparison between CP and PP dimensioning scheme:-
Another major performance indicator for the determination of the more efficient dimensioning scheme is the GPRS system average throughput. The average throughput will be evaluated for complete partitioning scheme as expressed in eqn 24 and for the partial partitioning scheme in equation 26. The m-codes below evaluates the throughputs, Xcp and Xpp against the number of GPRS users on the network.

Results And Discussions:-

Circuit switched traffic model:-

The algorithm and code were implemented for three different system erlang capacities, A=50, 30 and 20. The progressive blocking probabilities were generated in accordance to eqn .27 and plotted on the same axes.

According to the result, the probability that an incoming call will be blocked when the system is in state 1 is 0 for all the system erlang capacity for GSM. The blocking probabilities continues to grow tending to Unity as more GSM users become active on the system. It is important to also note that the lower the blocking probability, the more can additional users latch onto to the system for GSM service.

Table 1 shows the results of the M-codes and is coplotted on a cartesian plane in Fig 10 showing the blocking probabilities for each system capacities against active GSM users on the system. The three capacities under consideration are ploted all on the same axes for glaring comparison.

Table 1:- Probability that calls will be blocked by the GSM system with increasing User

Number of active GSM users	A=50	A=30	A=20
1	0	0	0
2	0.038461538	0.0625	0.090909091
6	0.117402972	0.192409849	0.281854252
11	0.214693528	0.349871891	0.505531772
16	0.311296981	0.502870677	0.707966524
21	0.406939421	0.648097212	0.868563968
26	0.501197078	0.779382114	0.962804793
31	0.593395179	0.886377962	0.994573161
36	0.682433694	0.957112703	0.999619076
41	0.766503862	0.989566819	0.999986451
46	0.842707122	0.998489088	0.999999736
51	0.906837994	0.99987005	0.999999997
56	0.954207568	0.999993112	1
61	0.982548906	0.999999766	1
66	0.995137401	0.999999995	1
71	0.999037597	1	1
76	0.999864583	1	1
77	0.999912075	1	1
78	0.999943641	1	1
79	0.999964331	1	1
80	0.999977707	1	1
81	0.999986239	1	1
91	0.999999942	1	1
92	0.999999969	1	1
93	0.999999983	1	1
94	0.999999991	1	1
95	0.999999995	1	1
96	0.999999998	1	1

97	0.999999999	1	1
98	0.999999999	1	1
99	1	1	1
100	1	1	1

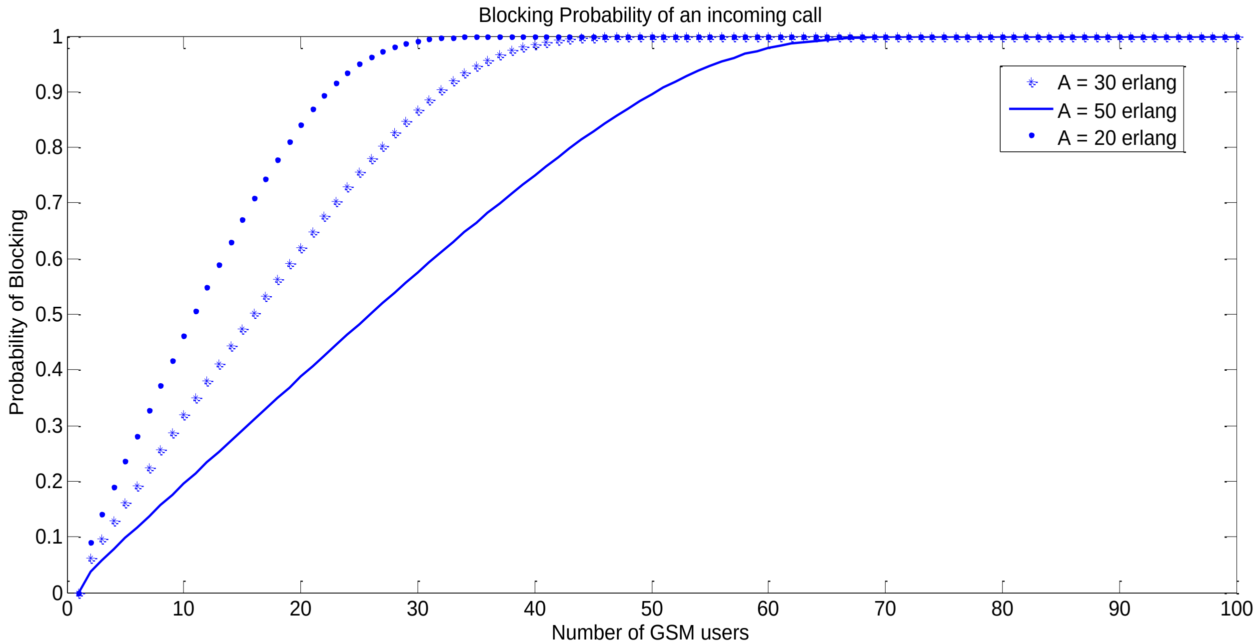


Fig 10:- Probability that calls will be blocked by the GSM system

With reference to the plot in fig 10 of the probability of blocking a new user on the network in a situation where all available TDMA frame timeslot can be allocated to voice (Complete sharing) against an incremental number of GSM users based on the markov chain model. The probability that a 50 erlang system currently hosting 40 GSM users will reject the 41^{st} caller is 0.75 while it is approximately 1 for a 30 erlang GSM system. This means that for a 50 erlang system on state 40, there is a 75 out of 100 chance that it won't allow the next incoming call while it is sure that a 30 erlang system in same state will definitely reject any additional incoming call. It is quite obvious from the plot that the probability that a GSM system will reject when in a particular state is inversely proportional to the erlang capacity of the system.

This relationship in Fig 10 is largely dependent on the traffic load capability of the system expressed in erlang. The probability that a 50 erlang GSM system will allow more call simultaneously is higher than that of a 20 erlang system in the same state.

The voice blocking probability of complete versus partial partitioning scheme:-

The voice blocking probability for a complete partition dimensioning scheme (bvcp) has been evaluated using the M-code 7 timeslots out of 8 was expressly dimensioned for the complete partitioning scheme while 1 timeslots is allocated to packet switched services because of the higher priority given to voice over data. For the partial partitioning timeslots out of 8 is statically allocated to voice service with 4 time slots dynamically provisioned for voice traffic making a total of not more than 7 out of 8 timeslots are eventually allocated to handle voice traffic if the need arises for partial partitioning scheme, which is eventually same for the complete partitioning scheme. Now applying the markov chain model to these 2 dimensioning scheme for voice, the blocking probability for same voice traffic load is the same for both scenarios as shown in Table 2.

From Table 2, it was clear that the voice blocking probabilities of the complete partitioning and partial partitioning scheme is exactly the same. The reason is that, partial partitioning scheme as far as voice is concerned will behave exactly like the complete partitioning scheme when the circuit switched traffic request is at maximum because of the priority given to voice call on a GSM/GPRS system. The difference only comes in when there are fewer active users, then the free timeslots (that would have readily served GSM users if there is the need), would be available to the GPRS users

Table 2:- Voice traffic blocking probability for CP and PP scheme

Traffic Load (ρv)	CP voice (bvcp)	PP Voice (bvpp)
0.5	0	9.40E-07
1	7.30E-05	7.30E-05
1.5	0.000756554	0.000756554
2	0.00344086	0.00344086
2.5	0.009983011	0.009983011
3	0.021864315	0.021864315
3.5	0.039608257	0.039608257
4	0.062748943	0.062748943
4.5	0.090170495	0.090170495
5	0.120518635	0.120518635
5.5	0.152503455	0.152503455
6	0.185054736	0.185054736
6.5	0.217365242	0.217365242
7	0.248871449	0.248871449
7.5	0.279209064	0.279209064
8	0.3081647	0.3081647
8.5	0.335633333	0.335633333
9	0.361584508	0.361584508
9.5	0.386037033	0.386037033
10	0.409040783	0.409040783

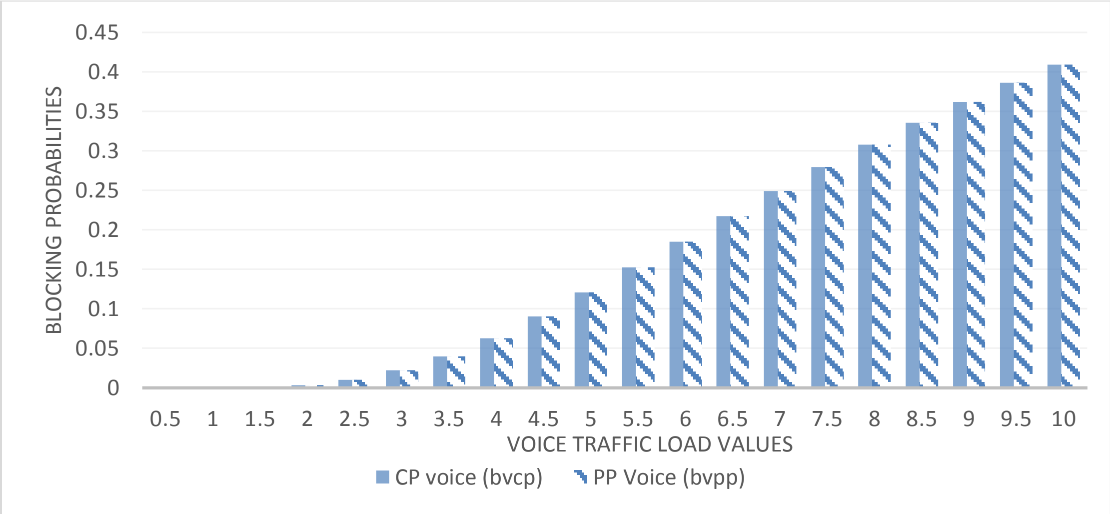


Fig 11:- Voice traffic blocking probability for CP and PP scheme

So it can be safely concluded that circuit switched services doesn't really care whether or not the complete or partial partitioning scheme is used. The advantage of one over the other will be obvious for packet switched services.

Packet Switched traffic Model:-

With reference to the packet switched models as implemented on both the complete partitioning scheme and the partial partitioning scheme, the outputs of the models as implemented on Matlab in terms of its blocking probability as performance index will be shown and discussed here. The advantage of one partitioning scheme will also be established here based on the results. It is worthy of note that of circuit and packet switched service, packet switched services are given lower priority in timeslot allocation.

Firstly, we are going to see the result of the complete partitioning scheme and thereafter the partial partitioning scheme in contrast.

Complete partitioning scheme Packet blocking probability:-

In reference to the implementatiton with a static 1 out of 8 timeslot allocated to serve packet switched service, the algorithm, flowchart and the m-codes were written to output the blocking probabailies as the system changes state i.e. at different quantity of active GPRS users on the network. Table 3 shows an excerpt of the blocking probabilities at different states figure 12 shows a cartesian representation of the table

Table 3:- Packet blocking probabilities for complete partitioning scheme

Number of GPRS user	Blocking Probability
1	0.000310945
2	1.93E-05
6	3.37E-06
11	7.40E-05
16	0.000408337
21	0.0013428
26	0.003354195
31	0.007059514
36	0.013215976
41	0.022721024
46	0.036612326
51	0.056067777
56	0.082405497
61	0.117083833
66	0.161701354
71	0.217996857
76	0.287849365
81	0.373278125
86	0.47644261
91	0.599642519
96	0.745317777
100	0.879769384

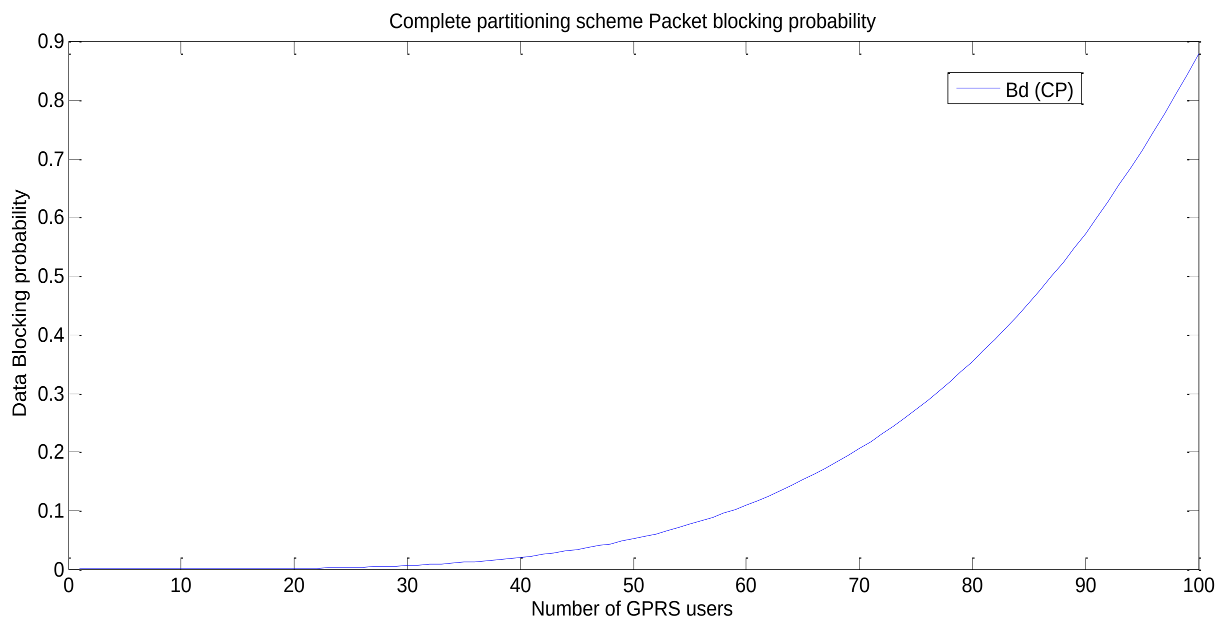


Fig 12:- Data blocking probability for CP versus System State

Referring to fig 12, the system state changes through the horizontal axis from state 0 to state 100 and a corresponding change in the probability that the system will prevent the next user from access its resources as it becomes congested. According to the plot, the 85th user has a 50% chance of been allowed to access GPRS service and a 50% chance of being blocked or queued. It is also noticed that the probability that more packet request to the system will be blocked is increasing with the number of active users on the system. With 90 active users, the system will likely reject 7 out 10 request for packets. The probability of data blocking is much lower with lesser number of active GPRS user on the system. Figure 12 shows how used up the timeslot resources allocated to service packet switched request are; especially now (in the case of complete partitioning scheme), that the system cannot borrow free time slots to use and service its overwhelming packet data service requests at the moment. This economically means less actual income for the commercial telecom operator.

As will be seen in the contrast later in this work, systems dimensioned using the complete partitioning scheme will get congested earlier than it counterpart

Partial partitioning scheme Packet data blocking probability:-

Referring the algorithm, flowchart and m-code generated modelling the blocking probability of active GPRS users for a system dimensioned in accordance to the partial partitioning scheme. The code is implemented on four different voice traffic load ρv = 2, 5, 10, 20 erlang, (which indicates how available the dynamic partition is, for GPRS requests). As it will be seen, the blocking probabilities tends towards that of the complete partitioning scheme as the voice traffic load increases. The dynamic partition tends to be more used by voice as the voice traffic load increases. The result of the implementation is as shown in table 4

Table 4:- Data blocking probability for partial partition scheme vs complete partitioning

Number of GPRS user	**ρv = 20**	**ρv = 10**	**ρv = 5**	**ρv = 2**	**CP**
1	0	0	0	0	0.000310945
2	7.84065E-07	6.25239E-07	3.85146E-07	9.20828E-08	1.93E-05
6	1.04824E-06	8.35904E-07	5.14915E-07	1.23109E-07	3.37E-06
11	8.06208E-06	6.42897E-06	3.96023E-06	9.46834E-07	7.40E-05
16	5.71498E-05	4.55731E-05	2.80729E-05	6.71184E-06	0.000408337
21	0.000240419	0.000191718	0.000118098	2.82355E-05	0.0013428
26	0.000735263	0.000586323	0.000361173	8.63514E-05	0.003354195
31	0.001832787	0.001461525	0.000900295	0.000215248	0.007059514
36	0.003966239	0.003162809	0.001948282	0.000465806	0.013215976
41	0.007739437	0.006171681	0.00380174	0.000908942	0.022721024
46	0.013955196	0.01112833	0.006855023	0.001638938	0.036612326
51	0.023643759	0.018854307	0.011614205	0.002776791	0.056067777
56	0.038091222	0.030375188	0.018711038	0.004473542	0.082405497
61	0.058867967	0.046943245	0.028916919	0.006913622	0.117083833
66	0.087857085	0.070060116	0.043156853	0.010318187	0.161701354
71	0.127282807	0.101499479	0.06252342	0.014948457	0.217996857
76	0.179738935	0.143329713	0.088290738	0.021109054	0.287849365
81	0.248217264	0.197936575	0.121928425	0.029151345	0.373278125
86	0.336136016	0.268045866	0.16511557	0.039476774	0.47644261
91	0.447368264	0.356746104	0.21975469	0.052540207	0.599642519
96	0.586270365	0.467511188	0.2879857	0.068853267	0.745317777
100	0.720567761	0.574604329	0.353954802	0.084625537	0.879769384

The data in table 4.are plotted in fig 13. It shows glaring comparison of the between the dimentioning schemes (CP and PP) for various voice traffic load conditions

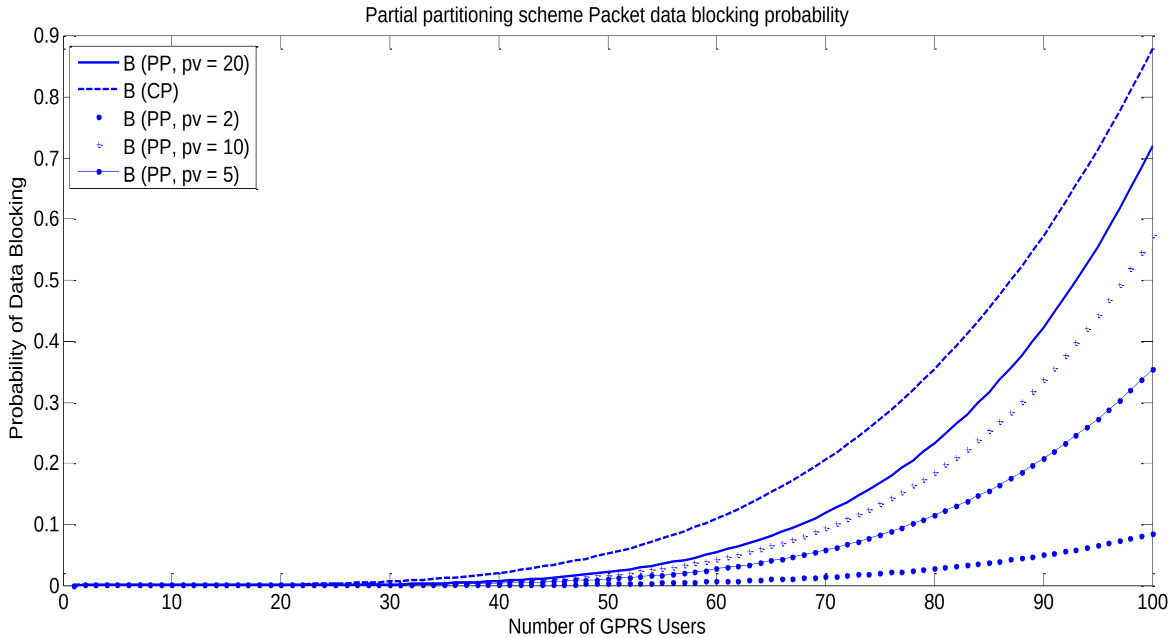


Fig 13:- Data blocking probability for partial partition scheme vs complete partitioning

The major aim of comparison to determine which of the partitioning scheme is most efficient is much more evident in this section. In figure 13, the data blocking probabilities for the complete partitioning scheme in contrast to partial partitioning scheme for different voice traffic load values. Four scenarios of the partial partitioning scheme is considered depending on the amount of the dynamic timeslot partition is being used by voice traffic which has a preferential treatment over data packet request. The higher the voice load traffic value, the more of the dynamic timeslot partition is being used for voice.

At the state of 90 active users on the system, the probability of data blocking for the complete partitioning scheme is highest with a likelihood of 7 out of 10 packet request being blocked relative to the partial partitioning scheme with the lowest voice traffic load value of 2 (being considered for the sake of comparison) where only a probability of about 1 of 10 packet request will likely be blocked as more of the dynamic timeslot partition is available for packet data request to use. For the highest voice traffic load value of 20 being considered, the data blocking probability is much higher than that of 2 as more of the dynamic timeslot allocation is being used by the voice traffic. At the state where there 90 active user, the probability of data blocking for voice traffic load value of 20 is 5 out of 10 request which is still even much more effective than the complete partitioning scheme.

So from the comparison, it is quite obvious that the partial partitioning scheme is much more efficient in handling more packet switched traffic request in a GSM/GPRS system than its complete partitioning scheme counterpart. This position is going to be verified by determining the data throughputs for the complete and partial partition dimensioning scheme.

Data throughput comparison:-

The m-code was written to evaluate the average data throughputs for a GPRS system whose TDMA frame is partitioned partially and one whose TDMA frame is partitioned completely. In execution of the code, the partial partitioning scheme takes into consideration the voice traffic load in the evaluation of the system throughputs. Voice traffic load ρv = 2, 5, 10, 20 erlang were considered to reflect various degree of usage of the dynamic partition by circuit switched traffic requests. Table 5 shows the an excerpt from result of the m-code in a tabular form showing the various throughputs values in kbps for each state of the GPRS system

Table 5:- Data Throughput comparison between CP and PP schemes

Number of GPRS users	Xcp	Xpp (pv=20)	Xpp (pv=10)	Xpp (pv=5)	Xpp (pv=2)
1	3.129609669	3.142160083	3.089279063	3.288622	3.3444
2	5.213979131	6.002641177	5.624504006	6.290635538	6.10472
3	7.323138537	8.50504715	8.297457039	8.8988335	9.25582
4	8.851492551	10.29254492	10.68246175	11.79439389	12.38142
5	10.10831464	11.96696489	13.07576407	14.27844051	15.57435
6	11.66293973	13.46976739	15.57693074	16.58782557	18.704
7	12.73297877	14.80064036	17.86093087	18.89721064	21.61966
8	13.16827289	15.98421142	19.81800803	21.62480831	24.4286
9	13.25456743	16.63882962	21.77508518	23.93960254	26.99008
10	13.31115597	17.33728188	23.9299805	26.15674434	30.92456
11	13.33673	18.03573414	26.05538576	28.38434619	33.89919
12	13.34112	18.47279467	28.20178308	30.61194803	35.26228
16	13.34124	19.08826354	36.22048776	39.62232607	44.0554
17	13.34124	19.1254883	37.42480194	41.78263513	46.1587
18	13.34124	19.30780879	37.93911979	43.18622905	48.3035
19	13.34124	19.49012927	38.03676144	44.58982296	50.2768
22	13.34124	20.12434676	37.98409984	47.52118936	54.244
23	13.34124	20.15931487	38.04746778	47.94511134	55.2382
24	13.34124	20.15931487	38.11083572	48.20107912	56.23391
25	13.34124	20.15931487	38.26280254	48.29161043	56.6412
26	13.34124	20.15931487	38.3588467	48.38214173	57.2341
27	13.34124	20.15931487	38.45718224	48.58597217	58.2103
28	13.34124	20.15931487	38.55551777	48.60067284	58.1869
29	13.34124	20.15931487	38.55551777	48.61537908	58.95374
30	13.34124	20.15931487	38.55551777	48.63008532	59.1648
31	13.34124	20.15931487	38.55551777	48.76988269	59.2865
32	13.34124	20.15931487	38.55551777	48.92725836	59.4688
33	13.34124	20.15931487	38.55551777	48.95885282	59.5054
34	13.34124	20.15931487	38.55551777	48.99044728	59.5192
35	13.34124	20.15931487	38.55551777	48.9872915	59.5192
36	13.34124	20.15931487	38.55551777	49.07091655	59.5192
98	13.34124	20.15931487	38.55551777	49.15454159	59.5192
99	13.34124	20.15931487	38.55551777	49.15454159	59.5192
100	13.34124	20.15931487	38.55551777	49.15454159	59.5192

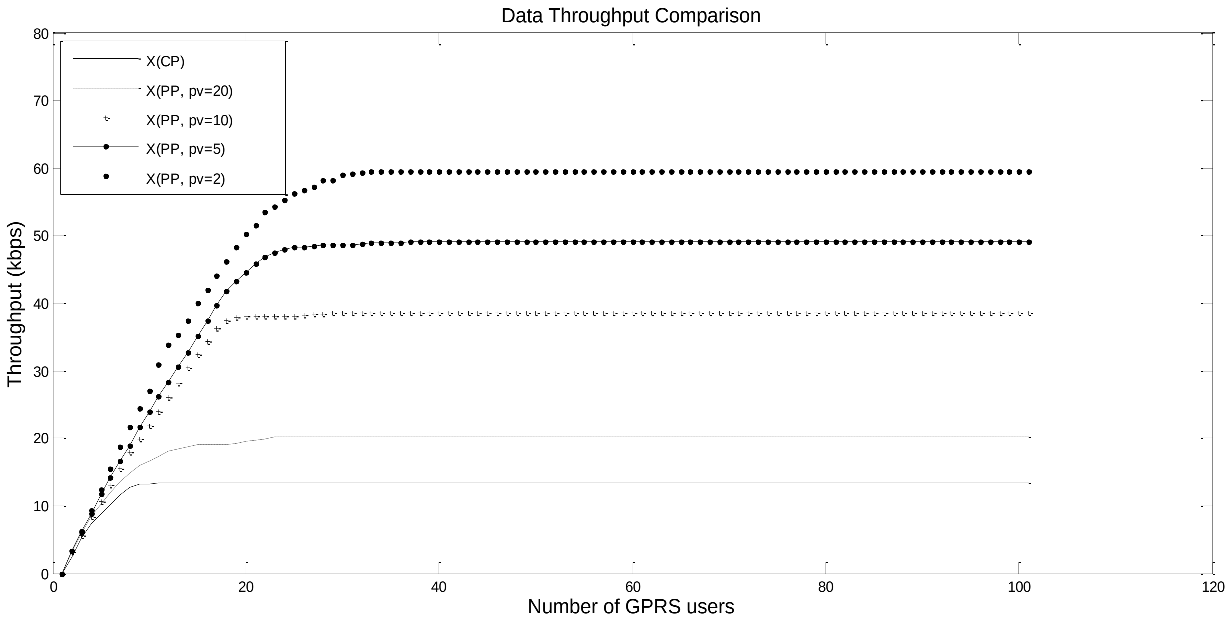


Fig 14:-Data Throughput comparison between CP and PP schemes

The complete partitioning scheme is obviously the one with the lowest average throughput in fig 14. This is because of its rigidity and the fact that there is no chance at all for the GPRS traffic request to borrow some free time slots when idle. Four different scenarios of the partial partitioning (PP) scheme were also painted with different voice traffic loads; 20, 10, 5, 2 erlang.

The PP scheme with voice traffic load of 20 erlang uses more of the dynamic timeslot reservation and leaves very less for GPRS traffic request to use. In this scenario, voice has used its priority over data and the data throughput value is near that of the complete partitioning scheme.

Furthermore, the PP scheme with voice traffic load of 2 erlang has the highest average throughout in fig 12 is the highest. This is because, the circuit switched traffic request for timeslot resources is relatively low and as such the dynamic parturition is unused by voice thereby being very available for use by data traffic resulting in relatively very high throughput value.

It is then safe to say that in partial partitioning, as voice traffic load increases, the average throughput decreases and vice versa. Also, for any voice traffic load, partial partitioning dimensioning scheme has better data throughput than its complete partitioning counterpart. In the case of maximum possible traffic load in PP scheme, it assumes same efficiency as CP scheme.

Conclusively, going by the blocking probability performance indicator and that of the average data throughputs, GSM/GPRS systems that adopts the partial partitioning scheme performs in serving more users better than those dimensioned by the complete partitioning scheme.

Conclusion And Recommendation:-

The main purpose of this work is to relatively determine the BEST method of allocating timeslot resources on GSM/GPRS system between circuit switched traffic (GSM/Voice) and packet switched traffic (GPRS/Packet Data) to achieve the best possible concurrent performance of the system in serving both voice traffic requests and packet traffic requests. The main comparison was done between the complete partitioning scheme and the partial partitioning scheme; emphasis being on the dynamicity of the number of timeslots that can serve packet data users when those timeslots are not being used by voice traffic request which has higher priority.

Models were developed for circuit switched traffic and packet switched traffic to simulate the behavior of both traffic classes with respect to the number of active users on the system and how these time slots are being used. These models were then applied to the dimensioning schemes in review and it relative behaviors were shown as implemented with MATLAB.

At end of the implementation, it became clear; the performance difference between the complete partitioning scheme and partial partitioning scheme more significantly in handling packet switched traffic service. It was seen that even though both scheme handles voice traffic in a similar way as it eventually has same number of maximum timeslots allocable to voice traffic. Notwithstanding, in cases when the maximum timeslots allocable to voice is not all being used up, the partial partitioning scheme can always find a use for those unused timeslot in service of packet data traffic request as against the complete partitioning scheme that will rather leave those unused timeslot idle even if the GPRS system is congested. This is shown clearly in fig 4.4 of chapter 4 of this work. In conclusion, for maximal overall performance of the GSM/GPRS network, the partial partitioning scheme is highly recommended over any other dimensioning scheme

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