

RESOURCE SHARING FOR SATELLITE COMMUNICATION AND MOBILE COMMUNICATION NETWORKS

by

SUNIR KOCHHAR
B.S. Birla Institute of Technology, India

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APPROVED BY

A handwritten signature in black ink, reading "Ronald R. Hummel". The signature is written in a cursive style with a large initial 'R'.

Major Professor

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SECTION I

1.1 INTRODUCTION

There has been considerable growth in the application of spread spectrum techniques to communication networks involving several transmitters and receivers. A spread spectrum communication system can transmit more than one signal at the same frequency at the same time by selective addressing and code-division multiplexing techniques. Acquisition of the spread system code and synchronization are essential tasks for the terminals in these systems. Initial acquisition will introduce a delay for a user who wants to be a part of the spread spectrum system, reacquisition would introduce a delay in polling by the central control terminal. These initial and subsequent delays are important for both the users and system stability.

It is possible, however expensive, that each network terminal be capable of acquisition and synchronization without any aid from the network control terminals. In this situation each network terminal should be capable of carrying out all network control functions and must have a very precise timing source. As there is usually a large number of network terminals, the system would become very expensive. Another approach is to make the network terminals as simple as possible and let the network control terminals carry out most functions relating acquisition and

synchronization. These systems would be far less expensive as compared to the first alternative, however, they would be inferior in terms of network response times. An illustration which describes the issues addressed in this chapter is discussed next.

A network with N network terminals (NT) and M network control terminals (NCT) is considered. It is assumed that a network control terminal is capable of deriving frequency and range information of the NTs. The NCTs are responsible for maintaining alignment of their broadcasts with the satellite beacon to the NTs all the time. For simplicity only one NCT is considered in the discussion. The NTs align their pollbacks to the received control link parameters from the NCT, the NTs do not have any additional range or frequency information of other NTs. A NT wanting to communicate with another NT would send this information to the NCT. The NCT will provide all the essential information concerning frequency, range and code of the other terminal. If a NT is not reacquired by the NCT during pollback then it is considered for a fresh acquisition (like initial acquisition which takes considerably longer than reacquisition). It may also drop out from the system and decide to join the system at a later time. From the NTs point-of-view the following issues are of utmost concern:

- a) How long will it take before the NT is initially acquired and is a part of the polling cycle? This will be termed as initial waiting time.

- b) How long will it take for an NT to establish a link with another NT with the help of the NCT? Which will be termed as service waiting time?
- c) If a NT drops out of the polling cycle, how long will it take before it joins the polling cycle again?

From the NCTs point of view the following issues are of most concern.:

- d) How long its been since a NT is polled last in the polling cycle? This will be termed as polling cycle time. Since the reacquisition time for polling of NT's depends on how long it was last polled the polling cycle time is of importance for stable operation of the network. In a situation in which a few NTs take longer time for reacquisition(reacquisition time being a random number), would cause the reacquisition times of the rest of the NTs in the polling cycle to increase. If this process continues, many NTs may not be reacquired within some prespecified time and will thus drop out of the polling cycle.
- e) How to optimize on the number of acquisition servers

(A) and obtain a stable network operation and also provide a given grade of service specified in

terms of initial waiting time and service waiting times.

The above discussed factors would depend on the number of NTs (N), number of control terminals (M), number of acquisition servers (A), number of polling servers (P), acquisition schemes, polling schemes, acquisition and reacquisition time distributions. Acquisition and reacquisition times in turn depend upon the time source, the satellite type, frequency of operation, apriori information available to the NCT about the NTs and the acquisition and synchronization schemes used for a single pair of the transmitter and receiver.

The acquisition and synchronization process itself is not addressed in this chapter and has been approximated by a set of distributions based on operational considerations for a system.

The basic system considered is described in Figure 1.1. Analysis are carried out for the case when the polling queue and acquisition queue can be considered as independent queues. This assumption greatly simplifies the analysis. From the operational point-of-view this is a reasonable assumption in steady state. This assumption, however, is not valid when NTs drop out of polling cycle due to a limit on their reacquisition time and join the acquisition queue. This case of coupled queues is studied by simulations.

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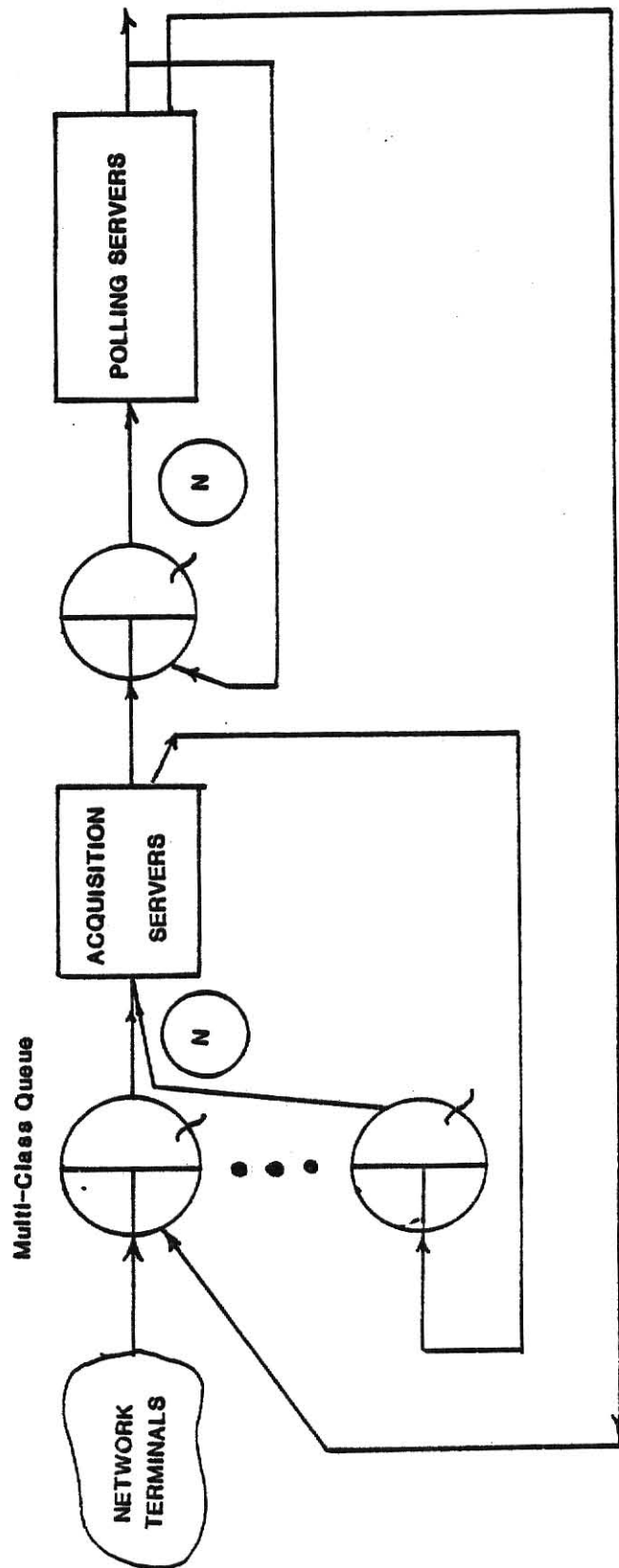


FIG 1.1 Simulation Model For Critical Control Circuits Response Times

1.2. ANALYSIS OF ACQUISITION AND POLLING CYCLE TIMES

The network can be considered in two states. Initially all the NTs are in the acquisition queue and no NTs are in the polling queue. In the steady-state most NTs are in the polling cycle and those dropped out during the reacquisition and have not yet been acquired are in the acquisition queue. The acquisition queue may also have NTs which joined the system later and have not yet been acquired. Transient case when all NTs are in the acquisition queue is not necessarily during start up of the system, but can occur any time when most NTs drop out of the polling cycle in a short period of time.

1.2.1 TRANSIENT CASE

In the transient case the initial waiting time depends on the search strategy. One case is when every NT is searched for a maximum duration of time T_m and if not acquired, it is considered lost. This is known as single class search. By the shortest processing time rule, that if we acquire the NTs which take the least time first, then on an average every NTs waiting time is minimized [Ref. 15]. But as the NT's acquisition time is not known apriori to the acquisition a multiclass search is introduced. If a NT is not acquired in less than time T_i then the acquisition process is stopped and the NT is dropped to the $(i+1)$ th class and acquisition of next NT in the i th class is started. When all the NT of the i th class are acquired then

the acquisition of the $(i+1)$ th class is started. A new arrival always joins the highest priority class. The NTs in the $(i+1)$ th class can be considered as fresh acquisition (earlier service lost) or, if possible start the search from where it was left in the i th class (no loss in service). Both cases are possible in a real life situation. In the analysis a two class search is considered and can be generalized to a k class ($k > 2$) search. The average initial waiting time of NT's with one acquisition server would be

$$W = W_1 + W_2 \quad (1)$$

Where $\bar{W}_1$ is the average waiting time of NTs in the first class and W_2 the average waiting time of NTs in the second class.

$$W_1 = 1/2 \sum_{i=0}^{N-1} i \bar{t}_1 \quad (2)$$

$$\bar{W}_2 = \frac{N - N_1}{2N} \sum_{j=0}^{N-N_1-1} j \bar{t}_2$$

(3)

Where N_i is the number of terminals acquired in the Class I search, and $\bar{t}_i$ the average search time for NTs in the i th class search. Approximating the initial acquisition by an exponential distribution with mean $1/\mu$ the expression for N_1 would be

$$N_1 = N (1 - e^{-\mu \bar{t}_1}) \quad (4)$$

$$\bar{t}_1 = \frac{\int_0^{\bar{T}_1} t \mu e^{-\mu t} dt}{\int_0^{\bar{T}_1} \mu e^{-\mu t} dt} \quad (5)$$

$$\bar{t}_1 = \frac{1 - e^{-\mu \bar{T}_1} (1 + \mu \bar{T}_1)}{\mu (1 - e^{-\mu \bar{T}_1})} \quad (6)$$

1.2.2 STEADY STATE CASE

In the steady state case all the NTs are assumed to be in the polling cycle. A NT dropping out of the polling cycle may exit from the system or may become an arrival for the acquisition server as shown in Figure 1.1 The polling cycle time for a NT would be

$$t_c = \sum_{i=1}^{N_p} t_i$$

Where t_i is the polling time for i th NT and N_p the number of NTs in the polling cycle. So the polling times of NTs vary in a random order, hence t_i would be a random variable with some mean and variance. Due to the fact that NTs drop out of the polling cycle and then may drop out of the system or may again join the acquisition queue, the number of NTs in the polling cycle N_p would also be a random variable. However, in the steady state it will be assumed that N_p is a fixed number less than N . Using the central limit theorem which states that if a relatively large number of independent random sources, are added, then the resultant probability density function approaches the gaussian density function, the distribution of t_c can be approximated by a gaussian distribution (N_p being very large). The mean and standard duration of the distribution would be

$$t_c = N_p \bar{t}_i$$

$$\sigma_{t_c} = N_p \sigma_{t_i}$$

However, as mentioned earlier, the polling time for a NT depends upon the last time it was polled. Let t_j be the duration of j^{th} polling cycle and t_{ij} would be the duration of the i th poll in the j^{th} polling cycle. Thus we now have

$$t_{ij} = t + k [t_{\text{NOW}} - t_{\text{LAST}}]$$

Where t now is the current time, t last the last time the NT was polled, k is a constant and t a random variable independent of t last. Hence, the mean and variance would be

$$\bar{T}_j = N_p \bar{t} + N_p k T_{j-1}$$

$$\sigma_{T_j} = N_p \sigma_t + N_p k \sigma_{T_{j-1}}$$

For the steady state case as j

$$\bar{T} = \frac{N_p \bar{t}}{1 - N_p k}$$

$$\sigma_T = \frac{N_p \sigma_t}{1 - N_p k}$$

Thus for a stable operation $N_p k < 1$.

1.3.0 SIMULATION RESULTS

The purpose of simulation is to verify the analysis whenever possible and obtain the behavior pattern when analysis becomes interactable. The model shown in Figure 1.1 was simulated using simulation language SLAM (Simulation Language for Alternative Modeling). The flow chart describing the simulation is shown in Figure 1.2, the SLAM simulation model is shown in Figure 1.3.

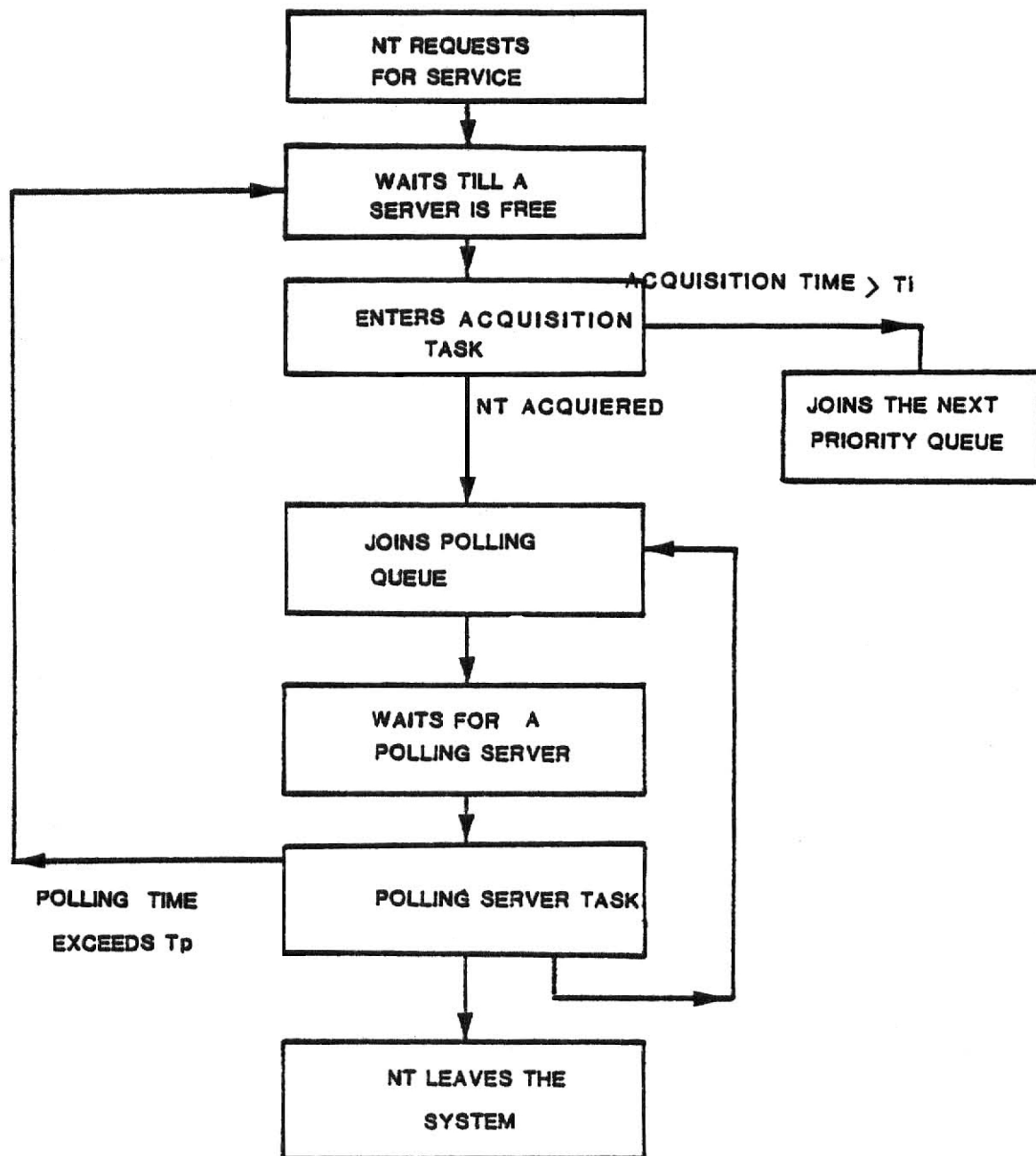


FIG1.2 Simulation Flow Chart For Critical Control Circuits Response Times

The acquisition servers have a multiclass queuing scheme with a limit on the service (acquisition) time T_{ak} for each class k . Initially all the arrivals (NTs) would join the first queue which has a limit on its service time T_{a1} . If the NT does not complete service by T_{a1} , service to it is stopped and it joins the queue for the next class. Once all the waiting arrivals in the K th queue are served then only the arrivals in the $(k + 1)^{th}$ queue have access to the server. Arrivals which complete service within the limit T_{ak} imposed on its service time join the polling queue. The polling search times are limited to time T_i . If the service time of an arrival exceed T_i , service to it is immediately stopped and it either drops out from the system, or joins the acquisition queue. Simulation results were obtained for various values of T_i with and without multiclass acquisition queues and are shown in Table 1.1. Simulation results were also obtained for different schemes of acquisition which are discussed later in this section and the results shown in Table 1.2.

First the effect of limiting the reacquisition (polling service) times. The polling service times T_i was limited to 0.5, 1.0, 2.0 and 20 for a mean service time of 0.5. It is observed as T_i increases the average waiting time in the acquisition queue decreases. This is because the rate of fallbacks from the polling queue decreases, which results in a smaller acquisition queue and hence lower waiting times.

At the same time for an extreme case when there are no fallbacks from the polling cycle, there is an increase in the waiting times for acquisition servers. This is because the statistics only represent a transient condition, hence the longer waiting times.

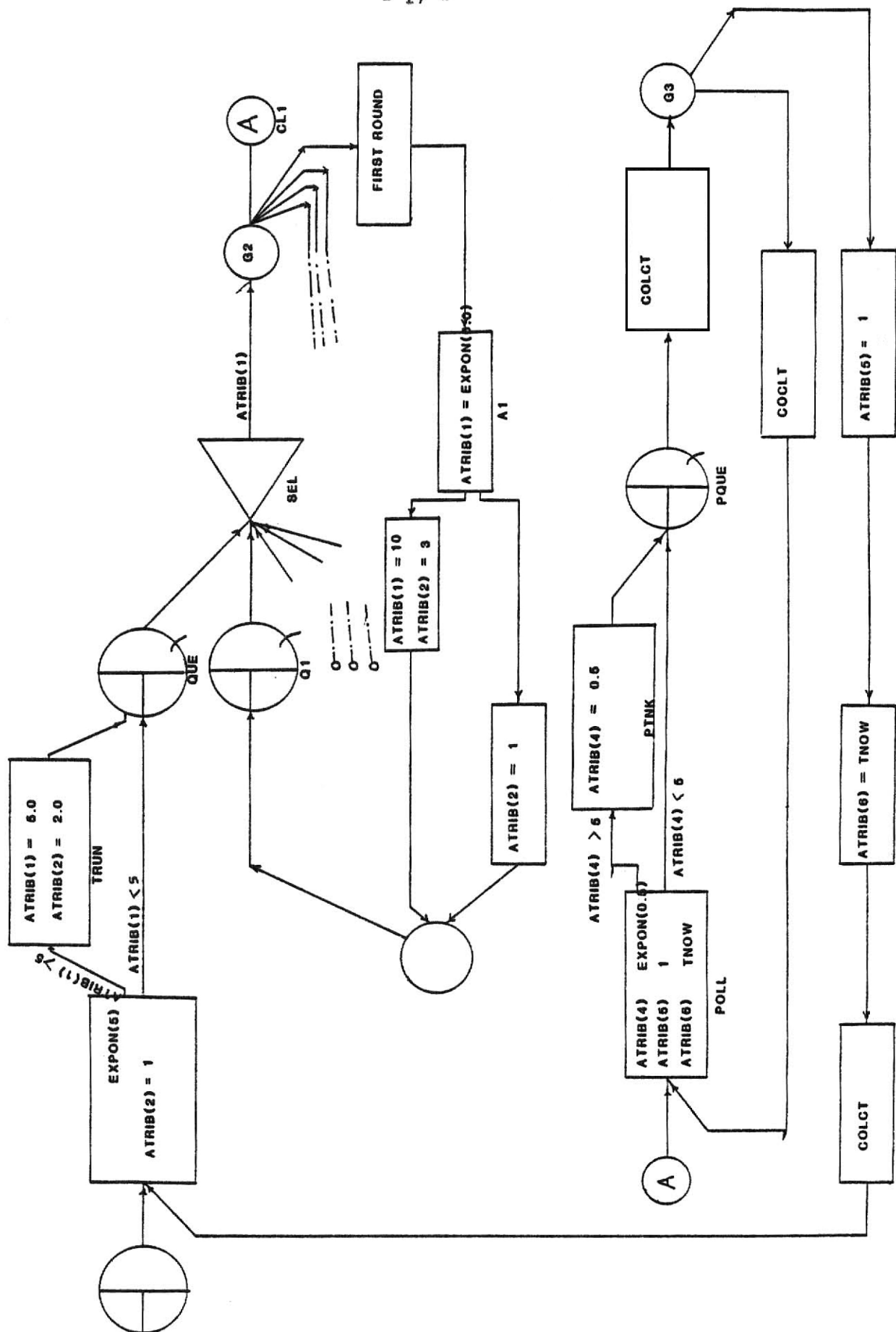
The average polling time increases as the limit on the polling service time T_i is increased. This increase is due to the following reasons. Firstly, as the limits on the polling times T_i is increased the percentage dropouts for the polling cycle decreases. This increases the average number of NT's in the polling cycle, thus causes a longer polling queue length which is reflected by an increase in the average waiting times. Secondly, as the value of T_i is increased it effectively increases the average service time. This in turn would increase the waiting times of the NTs in the polling queue. Limiting the polling time is one way to obtain a stable operation for the polling cycle. However, limiting the polling time would cause the NTs to drop out from the polling service and join the acquisition queue. An optimal situation would minimize the number of NTs dropping out of the polling cycle and at the same time obtain its stable operation. Average lengths of the polling queues indicate that the limit t_i should not be very high, as otherwise the polling queue length becomes very large. As seen from the graph in Figure 1.4 the optimum value of t_i would be less than $1/\mu$ where μ is the mean of the polling

service time. Simulations were also performed for a case with no multiclass search for the acquisition servers. The results are also tabulated in Table 1.1. It is observed that multiclass search provides far less average waiting times for the NTs in the acquisition queue.

The system was also simulated for two acquisition servers and one polling server. The acquisition servers were modeled in two ways which are discussed next.

In the first model both the acquisition servers work in parallel on two NTs simultaneously (Type A). The second model has the two acquisition servers working on the same NT. As soon as one of the acquisition servers completes service to the NT, the other server stops service to the NT, and both of them simultaneously start service on a new NT (Type B). For the Type A model the waiting times of the NTs in acquisition queues is observed to be approximately half as compared to the single server case. As the NTs are now acquired at a faster rate the arrival rate at the polling server is higher. This results in an increase in the average waiting time of the NTs in the polling queue. In the Type B model as both the acquisition servers work on the same NT the probability of a NT to fall from the j^{th} queue to $(j+1)^{\text{th}}$ queue is decreased. This is also reflected by the simulation results in Table II. This decreases the average acquisition times for the NTs. As now the arrival rate at the polling queue would be higher than for Type A

the average waiting time of the polling queue shows an increase.



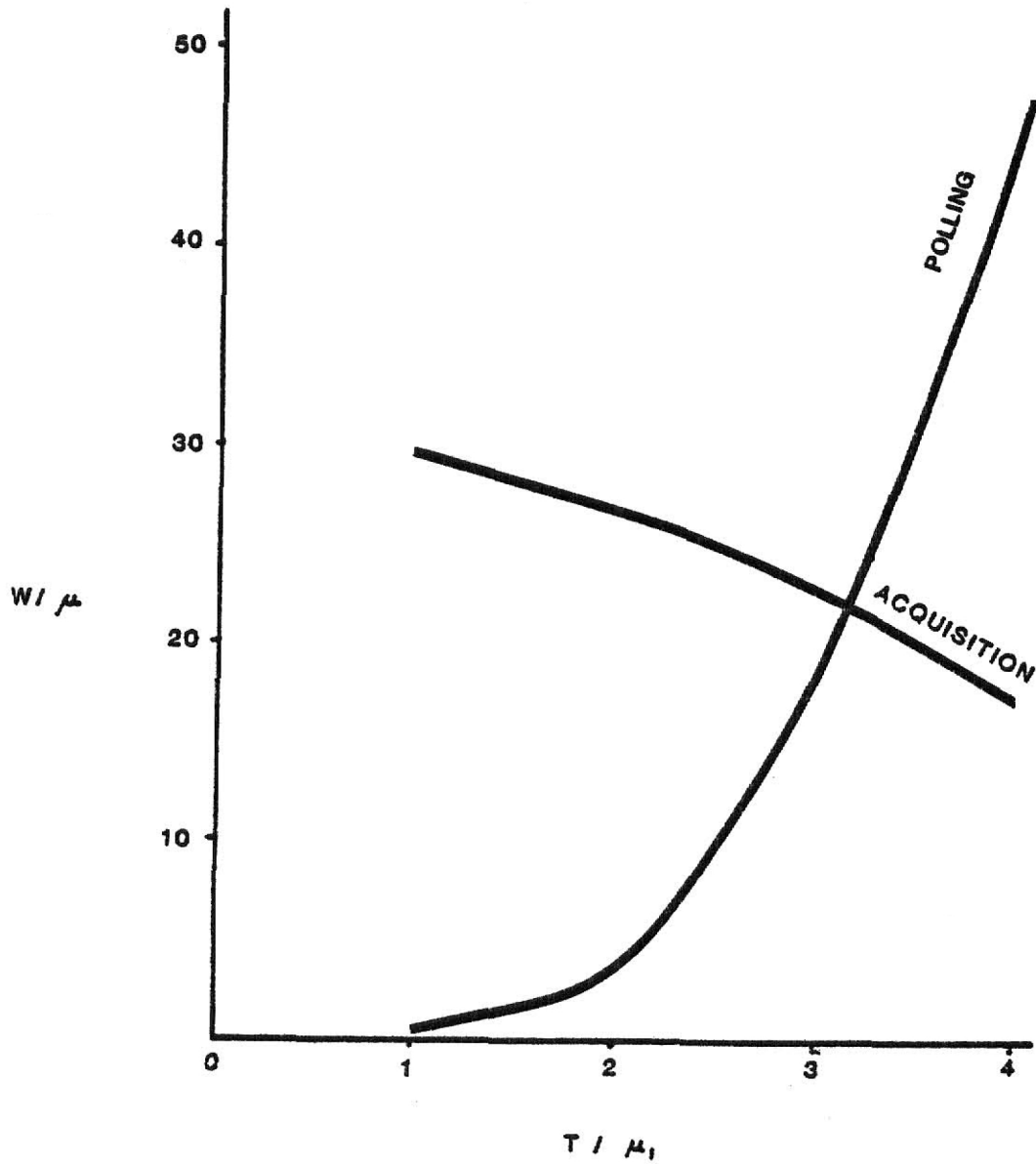


FIG 1.4 Waiting Times For Different Values of T_i

The simulation results obtained are as shown in Table 1.1 and Table 1.2. Results were obtained for various values of T_i , the limit on Polling Search Times.

The simulation results are discussed next.

Table 1.1

Simulation Results for Model Shown in Figure 2 with and without Multiclass Search

	Limits on Polling Search Time (T_i sec.)					
	0.5	1.0	2.0	20	1.0	20.0
Average waiting times						
Acquisition queue	56.17	50.4	49.18	74.25	200.15	183.4
Class 1 queue	467.0	427.5	78.5	118.95	---	---
Class 2 queue	80.89	271.0	34.5	35.45	---	---
Polling queue	0.03	0.91	22.57	23.70	0.73	23.0
Average Acquisition time	147.7	134.7	89.95	121.5	216.9	139.8
Average Polling time	.345	1.337	23.31	24.3	1.149	23.9
Average Polling queue lengths	0.023	1.6446	44.3	50.87	1.42	49.59
Percentage fall back from						
Acquisition service 1st search	37.44	39.8	40.19	33.33	0	0
Acquisition service 2nd search	0.42	2.5	3.9	8.33	0	0
Acquisition service 3rd search	0	0	0	0	0	0
Polling service	36	19.9	1.9	0	0	0

Table 1.2

Simulation Results for Two Acquisition Server Model

	Limits on Polling Search Times (Ti) for			
	Type A		Type B	
	1	20	1	20
Average waiting times:				
Acquisition queue	13.69	34.24	22.4	38.0
Class 1 queue	101.6	70.05	91.0	48.2
Class 2 queue	161.6	41.77	--	--
Polling queue	13.61	25.2	18.47	26.29
Average Acquisition Time	66.9	69.2	37.1	44.8
Average Polling Time	14.01	26.02	19.06	26.9
Average Polling queue length	33.1	54.07	40.14	55.1
Percentage fall back from				
Acquisition service 1st search	37	42	12	10
Acquisition service 2nd search	2.4	1.6	0	0
Acquisition service 3rd search	0	0	0	0
Polling service	13.34	0	14.1	0

1.4 CONCLUSION

The simulation results for the NTs average waiting times for the Multi-Class Search System and No-Multiclass Search System as shown in Table I were compared. As deserved there is no significant change in a) average polling queue waiting time and b) average polling cycle time, for the two models. The average acquisition times though shown an appreciable difference for the Multiclass Search System Model. Thus it is inferred that the Multiclass Queuing System Model significantly improve the NTS average acquisition times. Though the average polling queue waiting times and average polling cycle times are higher for the multiclass sytem, this increase is insignificant as compared to the improvement in the Average Acquisition Time.

The issue of importance now is that as to what value should the polling service time T_i be limited to optimize the multiclass queuing model. Fig 1.4 shows the variation of polling cycle waiting time and acquisition waiting times for different values of T_i . As observed from Fig 1.4 the average polling cycle time shows a gradual increase from T_i

$$\mu < T_i < 2\mu$$

For T_i greater than 2μ there is a rapid increase in the average polling cycle time which is because very few NTs now drop out of the polling cycle, and increasing T_i also increases the average holding time of NTs in the polling server, thus we have a longer queue and a longer average holding time. The average acquisition time though shows a number of NTs from the polling queue fall back to the acquisition queue. All optimal value of T_i would be to minimize the average polling cycle time and average acquisition time. As seen from Fig 1.4 for values of T_i between μ and 2μ the average cycle time is close to its minimum value and the average acquisition time is also within acceptable limits of its minimum value. The final value of T_i would depend upon the network and NTs behavior desired.

SECTION II

2.1 INTRODUCTION

In the last two decades there has been a rapid increase in the Land Mobile radio users. To meet this increase in demand the Federal Communications Commission (F.C.C.) announced a tentative allocation of the 40 MHz spectrum for the development of private cellular mobile telephone systems (Docket No. 18262).

This chapter discusses the signalling protocol specified by FCC for cellular mobile telecommunication systems. The performance of the signalling protocol has been studied by computer simulations. The cellular mobile system operation is as follows.

A mobile subscriber initiates a call by entering the area and/or directory digits into a storage register and then transmits them by activating a SEND button. the mobile base controller recognizes this as a request for service and initializes an access timer to 6 seconds. The mobile unit now attempts to seize an access channel. In the event it is not assigned an access channel it retries with a limit on the number of reattempts, if it fails to obtain an access channel within the limit on the number of attempts it is termed as "call failed." Once the mobile unit successfully obtains an access channel and transmits the initial seizure data it then waits for a maximum of 5 seconds for a voice channel designation. If it gains access to voice channel the mobile proceeds to successfully complete the call.

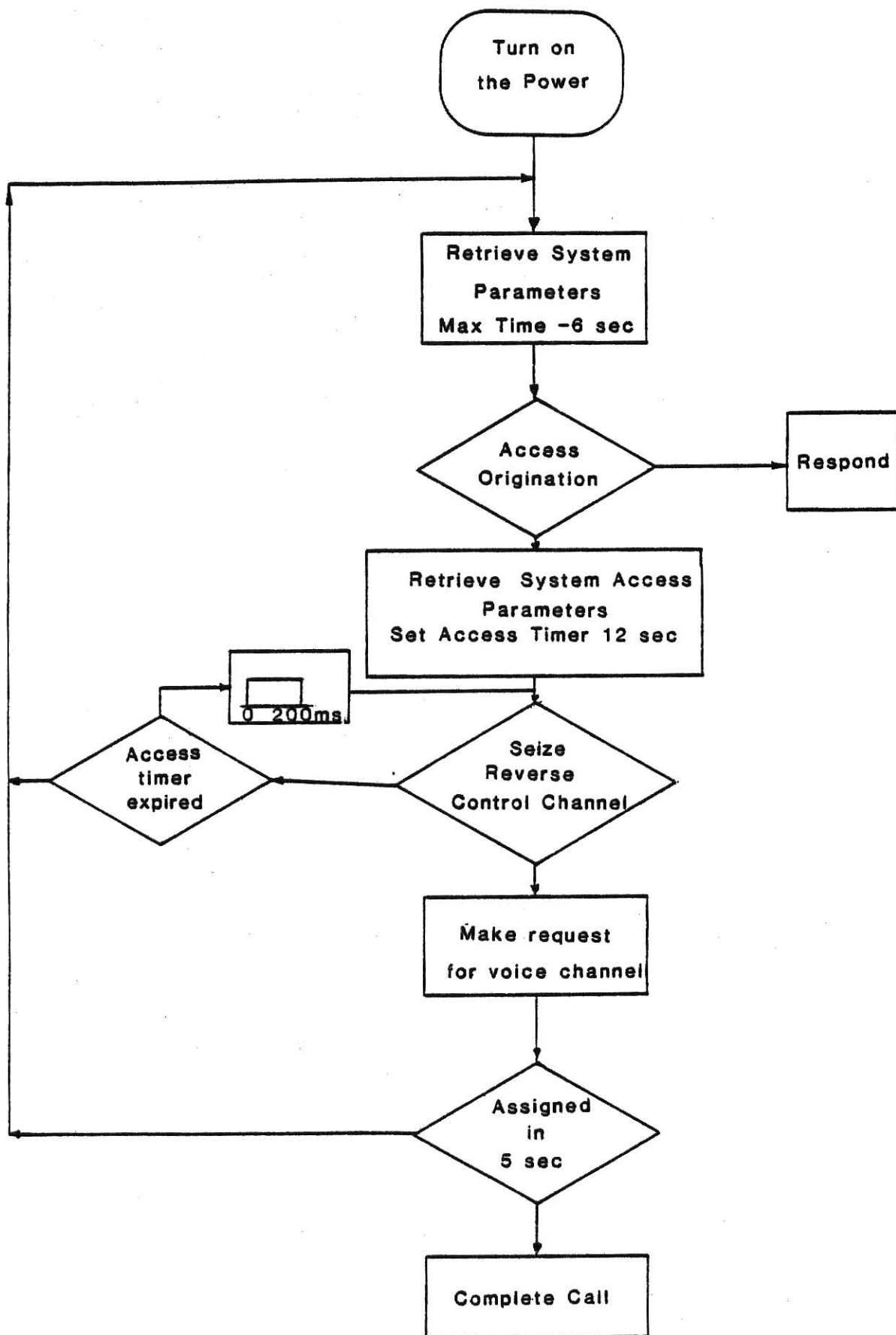


FIG 2.1 Simplified Flow Chart For Signalling Protocol

2.2 BACKGROUND ON CELLULAR SYSTEM

In a cellular mobile telephone system a geographic service area is divided into small regions known as cells. The boundary of a cell would be defined by the coverage area bound by a contour of constant signal level (39 dBu FCC standard). More than one cell can reuse the same frequencies (channels) if they are sufficiently apart to eliminate significant co-channel interference. The commonly used terms in a cellular system are discussed next.

Mobile Station: A mobile telephone unit in the Public cellular telephone system.

Home Mobile STation: A mobile station which operates in the cellular system for which service is subscribed also called HOMER.

Land Station: A station in the cellular system used for communication with mobile stations.

Control Channel: A channel (frequency) used for transmission of digital code information from a land to a mobile station or a mobile to land station.

Access Channel: A control channel used by a mobile station to access a cellular system to obtain service.

Forward Control Channel (FOCC): A control channel used from a land station to mobile station.

Forward Voice Channel (FVC): A voice channel used from a land station to a mobile station.

Reverse Control Channel (RECC): The control channel used from a mobile station to a land station.

Reverse Voice Channel (RVC): The voice channel used from a mobile station to a land station.

Paging Channel: A forward control channel which is used to page (the act of seeking a mobile station when an incoming call has been placed on it) mobile stations and send orders.

Voice Channel: A channel on which a voice conversation occurs and on which brief digital messages may be sent from a land station to a mobile station or from a mobile station to a land station.

Scan of Channels: The procedure by which a mobile station examines the signal strength of each forward control channel.

System Identification (SID): A digital identification associated with a cellular system, each system is assigned a unique number.

Signaling Tone: A 10 kilohertz tone transmitted by a mobile station on a voice channel to confirm orders, signal flash request, signal release request.

Release Request: A message sent from a mobile station to a land station indicating the user desires to disconnect the call.

Supervisory Audio Tone (SAT): One of three tones in 6-KHz region that are transmitted by a land station and transponded by a mobile station.

Roamer: A mobile station which operates in a cellular system other than the one from which service is subscribed.

Registration: The step by which a mobile station identified itself to a land station as being active in the system at the time the message is sent to the land station.

Mobile Identification Number (MIN): A 34 bit number which is a digital representation of the 10-digit directory telephone number assigned to a mobile station.

Busy-Idle Bits: The portion of the data stream transmitted by a land station on a forward control channel that is used to indicate the current busy-idle status of the corresponding reverse control channel.

Flash Request: A message sent on a voice channel from a mobile station to a land station indicating that a user requires to invoke special processing.

Numeric Information: Numeric information is used to describe the operation of the mobile station. The following subscript help describe them

"s" to indicate a value stored in a mobile station's temporary memory,

"sv" to indicate a stored value that varies as a mobile station processes various tasks,

"sl" to indicate the stored limits on values that vary,

"r" to indicate a value received by a mobile station over a forward control channel,

"p" to indicate a value set in a mobile station's

permanent security and identification memory, and
"s-p" to indicate a value stored in a mobile station's
semi-permanent security and identification memory.

The numeric indicators are:

ACCOLC_p - A four-bit number used to identify which overload
class field controls access attempts.

BIS_s - Identifies whether a mobile station must check for
an idle-to-busy transition on a reverse control channel
when accessing a system.

CCLIST_s - The list of control channels to be scanned by a
mobile station processing the Directed-Retry Task.

CMAX_s - The maximum number of channels to be scanned by a
mobile station when accessing a system.

CPA_s - Identifies whether the access functions are
combined with the paging function on the same set of
control channels.

DTX_s - Identifies whether the mobile station is permitted
to use the discontinuous transmission mode on the voice
channel.

E_s - The stored value of the E field sent on the forward
control channel. E_s identifies whether a home mobile
station must send only MIN2_p or both MIN1_p and MIN2_p
when accessing the system.

EX_p - Identified whether home mobile stations must send
MIN1 or both MIN1 and MIN1 when accessing the system.
EX differs from E in that the information is stored in

the mobile station's security and identification memory.

FIRSTCHA_s - The number of the first control channel used for accessing a system.

FIRSTCHP_s - The number of the first control channel used for paging mobile station.

LASTCHA_s - The number of the last control channel used for accessing a system.

LASTCHP - The number of the last control channel used for paging mobile stations.

LT_s - Identifies whether the next access attempt is required to be the last try.

MIN1_p - The 24-bit number which corresponds to the 7-digit directory telephone number assigned to a mobile station.

MIN2_p - The 10-bit number which corresponds to the 3-digit area code assigned to a mobile station.

MAXBUSY_{s1} - The maximum number of busy occurrences allowed on a reverse control channel.

MAXSZTR_{s1} - The maximum number of seizure attempts allowed on a reverse control channel.

N_s - The number of paging channels that a mobile station must scan.

NBUSY_{sv} - The number of times a mobile station attempts to seize a reverse control channel and finds the reverse control channel busy.

NSZTR_{sv} - The number of times a mobile station attempts to seize a reverse control channel and fails.

NXTREG_{s-p} - Identified when a mobile station must make its next registration to a system.

PL_s - The mobile station RF power level.

R - Indicates whether registration is enable or not.

RCF_s - Identifies whether the mobile station must read a control-filler message before accessing a system on a reverse control channel.

REGID_s - The stored value of the last registration number (REGID) received on a forward control channel.

REGINCR_s - Identifies increments between registrations by a mobile station.

S_s - Identifies whether the mobile station must send its serial number when accessing a system.

SCC_s - A digital number which is stored and used to identify which

SAT frequency a mobile station should be receiving.

SID_p - The home system identification stored in the mobile station's permanent security and identification memory.

SID_{s-p} - The system identification received on a forward control channel.

SIC_s - The stored system identification.

WFO_s - Identifies whether a mobile station must wait for

an overhead message train before accessing a system on a reverse control channel.

Orders

The following orders can be sent to a mobile station from a land station:

Alert. The alert order is used to inform the user that a call is being received.

Audit. The audit order is used by a land station to determine whether the mobile station is active in the system.

Change Power. The change power order is used by a land station to change the RF power level of a mobile station.

Intercept. The intercept order is used to inform the user of a procedural error made in placing the call.

Maintenance. The maintenance order is used by a land station to check the operation of a mobile station. All functions are similar to alert but the alerting device is not activated.

Release. The release order is used to disconnect a call that is being established or is already established.

Reorder. The reorder order is used to inform the user that all facilities are in use and the call should be placed again.

Send Called-Address. The send called-address order is used to inform the mobile station that it must send a message to the land station with dialed-digit information.

Stop Alert. The stop alert order is used to inform a mobile station that it must discontinue alerting the user. 2.3

2.3 SIGNALLING PROTOCOL FOR DOMESTIC PUBLIC CELLULAR RADIO TELECOMMUNICATION SERVICE

The following section describes the System Access Protocol for Domestic Public Cellular Radio Telecommunication Service as proposed by FCC (Ref 16). Each control function "task" is described as the mobile station attempts to access a cellular system. A flow chart illustrating the access protocol is shown in Fig 2.2.

2.3.1. SET ACCESS PARAMETERS

When a mobile station enters the System Access Task a timer, called the access timer is set as follows:

- a. If it is an origination (i.e. the mobile station is originating a call) to a maximum of 12 seconds.
- b. If it is a page response (i.e. the mobile is responding to page message) then to a maximum of 6 seconds.
- c. If it is an order response i.e. (the mobile is responding to an order message section), then to a maximum of 6 seconds.
- d. If it is a registration (i.e. the mobile is identifying itself to the land station as being in service), then to a maximum of 6 seconds.

After the access timer is set the mobile enters the Scan Access Channel Task.

2.3.2. SCAN ACCESS CHANNEL

The mobile station scans the signal strength on each of the channels FIRSTCHAS to LASTCHAS and chooses two channels with the strongest signals. The mobile station then tunes to the strongest access channel and enters the Retrieve Access Attempts Parameters Task.

2.3.3. RETRIEVE ACCESS ATTEMPT PARAMETERS

The mobile station must set the maximum-number-of-seizure-attempts allowed ($MAXSZTR_{sl}$) and maximum-number-of-busy-occurences ($NBUSY_{sv}$) and number-of-unsuccessful-seizure-attempts ($NSZTR_{sv}$) to zero.

The mobile station sets BIS_s to '1' and examines the $WFOM_s$ bit.

- If $WFOM_s = 1$, the mobile station enters the update Overhead Information Task (Section 2.3.4).

- If $WFOM_s = 0$, the mobile station encounters a random delay, uniformly distributed in the interval 0 to 92 m seconds and then enters the Seize Reverse Control Channel Task. (See Section 2.3.5).

2.3.4. UPDATE OVERHEAD INFORMATION

The mobile station must receive an overhead message train and respond to it within 1.5 seconds. Failing to complete the task within 1.5 seconds it exits this task and enters the Serving-System Determination Task. (Section 2.3.12). If completed it enters the Seize Reverse Control Channel Task.

2.3.5. SEIZE REVERSE CONTROL CHANNEL

The mobile station reads the busy-idle status of the channel.

If the channel is busy the mobile station increments $NBUSY_{sv}$ by 1.

- If $NBUSY_{sv}$ exceeds $MAXBUSY_{sl}$, then the mobile must exit this task and enter Serving-System Determination Task. (See Section 12).

- If $NBUSY_{sv}$ does not excess $MAXBUSY_{sl}$ then the mobile unit must exit this task and enter the Delay After Failure Task (See Section 6).

If the channel is idle, then the mobile station must set $NBUSY_{sv}$ to zero, turn on the indicated power level, wait till the transmitter is within 3dB of the required power level, and then start to send the message to the land station.

2.3.6. DELAY AFTER FAILURE

The mobile station examines the access timer. If the access timer has expired, the mobile station enters the Serving System Determination Task (See Section 2.3.12). If the access timer has not expired, the mobile station must wait a random time. Each time it enters this task it generates a random delay uniformly distributed in the interval 0 to 200 m seconds. The mobile unit then enters the Seize Reverse Control Channel Task (See section 2.3.5).

2.3.7. SERVICE REQUEST

The mobile station sends a message in a specified format identifying if it is an order response, registration, page response or an origination. When the mobile station has sent its complete message, it must continue to send unmodulate carrier for a nominal duration of 25 ms and then turn off the transmitter. If the access is an order confirmation, the mobile must enter the Serving System Determination Task (See Section 2.3.12) and if it is an origination or a page response, the mobile station enters the Await Message Task (See Section 2.3.8). If the access is a registration request the mobile station enters the Await Registration Confirmation Task (See Section 2.3.9).

2.3.8. AWAIT MESSAGE

If the Await Message Task is not completed within 5 seconds the mobile unit enters the Serving System Determination Task (See Section 2.3.12). The mobile unit attempts to match the MIN bits. If the MIN bits match it responds as follows:

If the access is an origination or page response:

- The mobile station updates the parameters set in the message. If equipped for autonomous registration it enters the Autonomous Registration Task (See Section 2.3.11), otherwise, the mobile station enters the Initial Voice Channel Confirmation Task.

- If the mobile station is equipped for directed retry, it responds to the directed-retry message, if it encounters

the start of a new message before it receives all four words of the directed-retry message, it must exit this task and enter the Serving System Determination Task (See Section 2.3.12). It then examines the Access Timer, if not expired it enters the Directed Retry Task (See Section 14), otherwise the Serving-System Determination Task (See Section 2.3.12).

2.3.9. AWAIT REGISTRATION CONFIRMATION

The mobile must attempt to match the MIN2 and MIN2 bits received in the message. The mobile then responds to the messages as follows:

- Release Order. The mobile station exits this task and enters the Action on Registration Failure Task (See Section 2.3.10).

- Order Confirmation. If the mobile station is equipped for autonomous registration and autonomous registration is enabled, the mobile station must exit this task and enter the Registration Update Task (see Section 2.3.11), supplying a "success" indication, the mobile station then enters the Serving System Determination Task. Otherwise the mobile station directly enters the Service System Determination Task.

2.3.10. ACTION ON REGISTRATION FAILURE

If the mobile station is equipped for autonomous registration and autonomous registration is enabled the mobile station enters the Autonomous Registration Update

Task (see Section 2.3.11), supplying a "failure" indication the mobile station enters the Serving System Determination Task (see Section 2.3.12). Otherwise the mobile directly enters the Serving System Determination Task.

2.3.11. AUTONOMOUS REGISTRATION UPDATE

If the first-registration ID status is enabled, return to the invoking task. Otherwise the mobile station updates the $NXTREG_{s-p}$ associated with the SID_{s-p} and then returns to the invoking task.

2.3.12. SERVING-SYSTEM DETERMINATION TASK

If the serving-system status does not correspond to the preferred system, the mobile station enters into utilization and reattempts to access the system. Otherwise the mobile reselects a paging channel and retires to access the system.

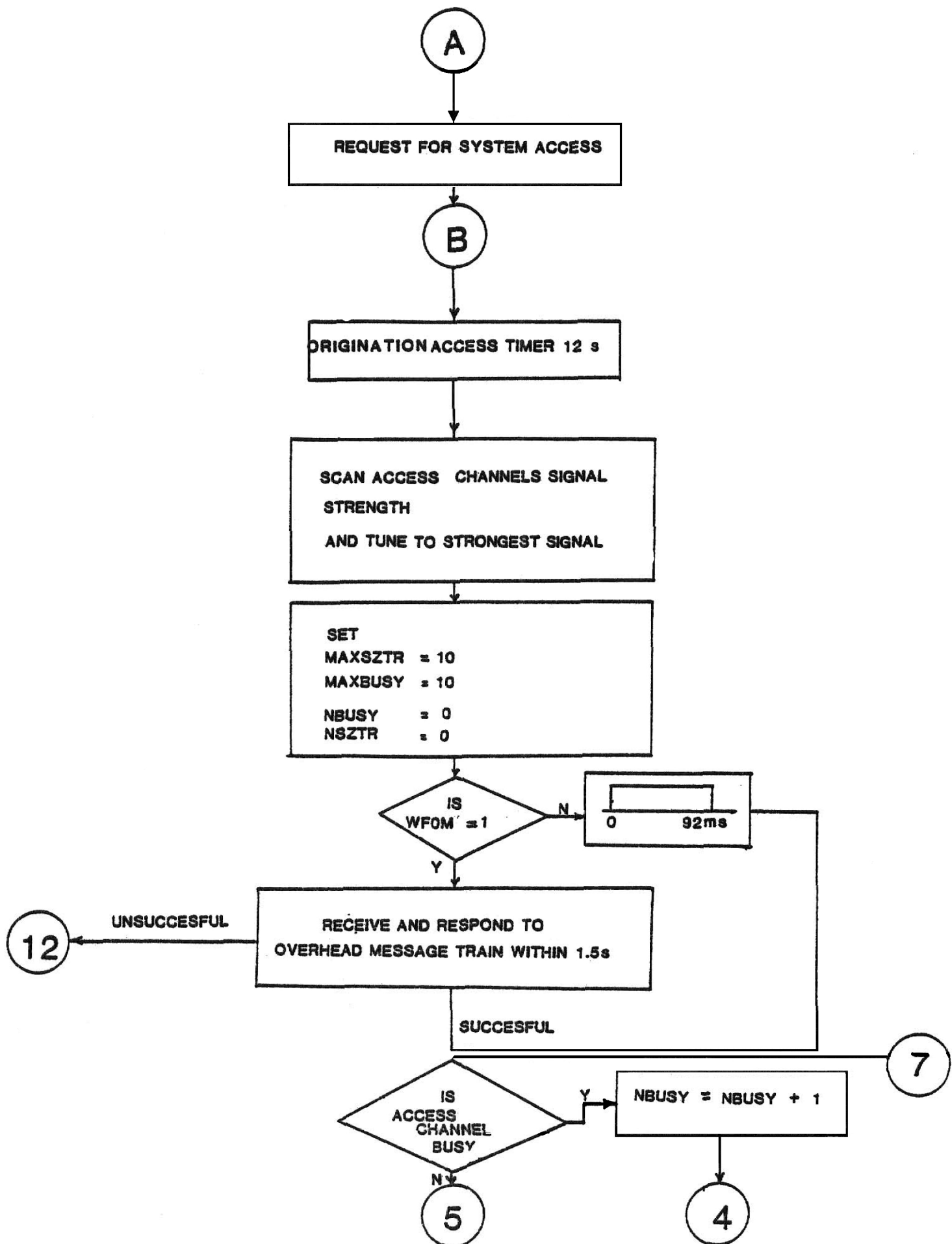
2.3.13. ALTERNATE ACCESS CHANNEL

If the mobile station is tuned to the strongest access channel, it may tune to the second strongest channel then enter the Retrieve Access Attempt Parameters Task (see Section 2.3.3). Otherwise it enters the Serving-System Determination Task (see Section 2.3.12).

2.3.14. DIRECTED RETRY

The mobile unit examines the signal strength on each of the channels listed in the $CCLIST_s$ and choose up to two channels with the strongest signals. The mobile station then tunes to the strongest access channel and enters the Retrieve Access Attempts Parameters Task (see Section 2.3.3)

FIG 2.2 Signalling Protocol



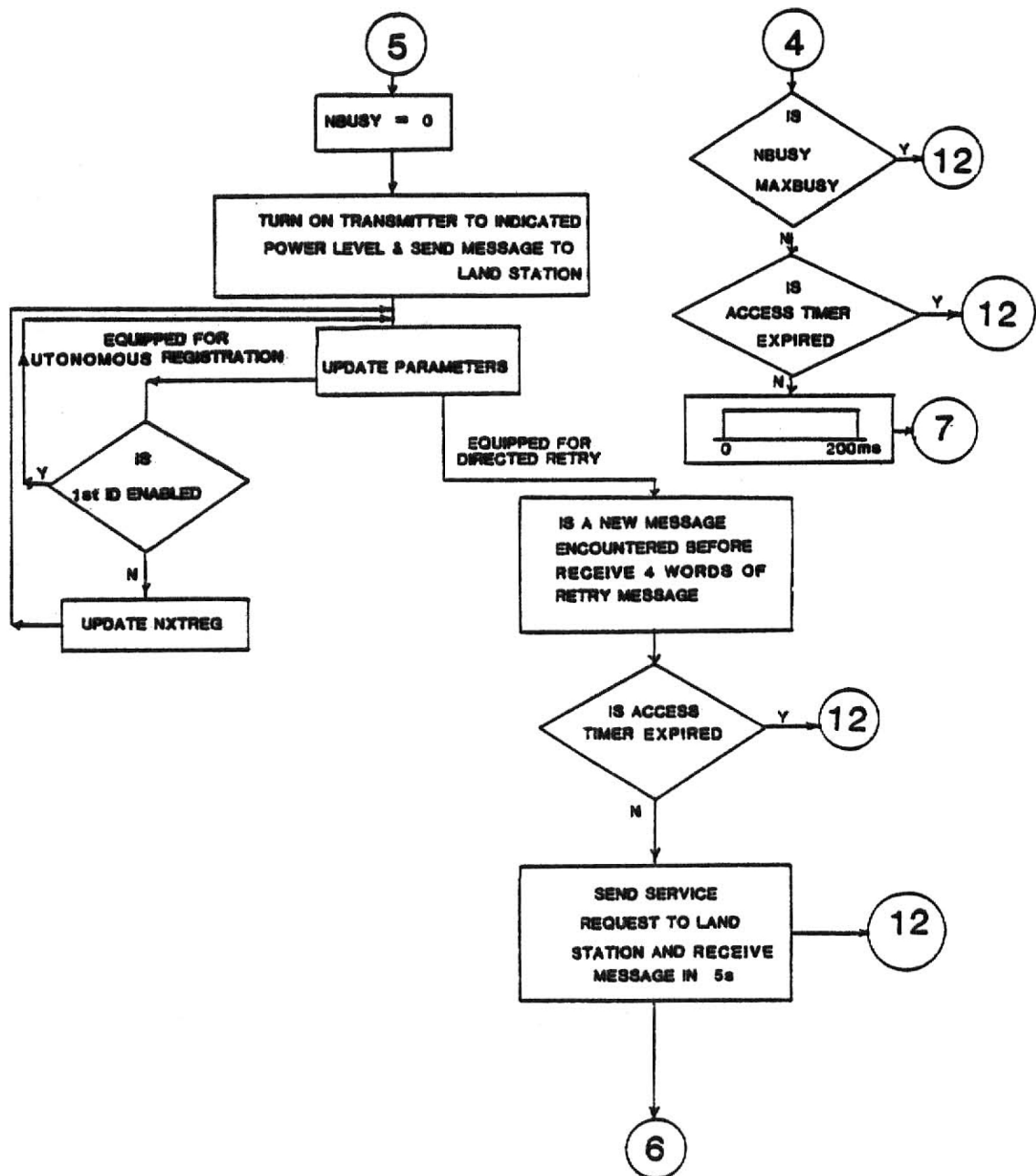


FIG 2.2 cont.

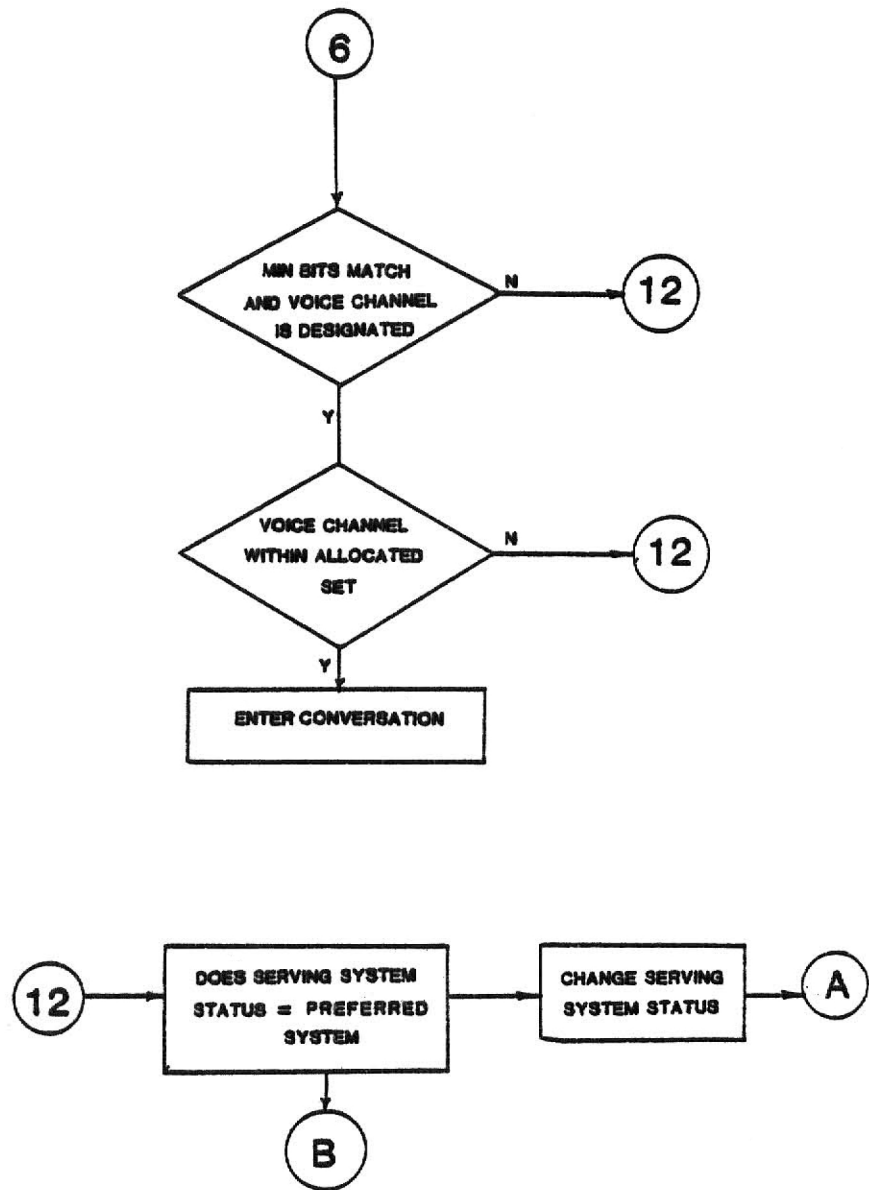


FIG 2.2 cont.

2.4. SIMULATION MODEL

The signalling protocol discussed in the previous section was simulated to study the system performance for different intensities of traffic. Figure 2.3 illustrates the simulation model and is discussed next.

A mobile station seeking service is simulated as an entity or customer arriving to the network. The interarrival times have been approximated by an exponential distribution. All initial arrivals undergo a random delay at A (Ref Fig 2.3). The random delay has been approximated by an exponential distribution and corresponds to the Retrieve System Parameters Task (see Section 2.3.2). As the call is an origination the Access Timer T_a is set at B (Ref Fig 3) to 12 seconds. The entities now attempt to seek an access server at D which represents access channels. If no access server is available the customer is immediately routed to I (Note: there is no queue at D). The number of seizure attempts NSZTR is checked, if NSZTR is less than the maximum number of seizure attempts allowed MAXSZTR the entities retry for an access server after a random delay which is uniformly distributed between 0 and 200 milliseconds and correspond to the Delay After Failure Task. If NSZTR has exceeded MAXSZTR the entities are then routed to A from where they start as new arrivals.

Entities which succeed in obtaining an access server join a random discipline queue at E where they wait for a voice channel server. The waiting times of the entities at E are limited to T_2 seconds. If an entity does not get access to a server within the T_2 seconds it is purged from the queue. The access timer of the purged entities is then examined, if the access timer has not expired, then the entities are routed to retry for an access server with NSZTR set to zero. If the access timer of the entities purged from the queue at E has expired then these entities retry access again from A as new arrivals. Entities which successfully obtain a voice channel server are processed with an exponentially distributed holding time with mean 120 seconds and are considered as successfully completed calls.

In the discussed simulation the following assumptions were made:

1. The interarrival times of the calls is exponentially distributed with a mean value seconds. The value of was varied for different intensities of traffic.

2. The access channel holding time was set to 100 m seconds based on 10 Kbit per second message rate and an average message length of 1000 bits (Ref. 1).

3. The voice channel holding time F (see Fig 2.3), is exponentially distributed with a mean value of 120 seconds.

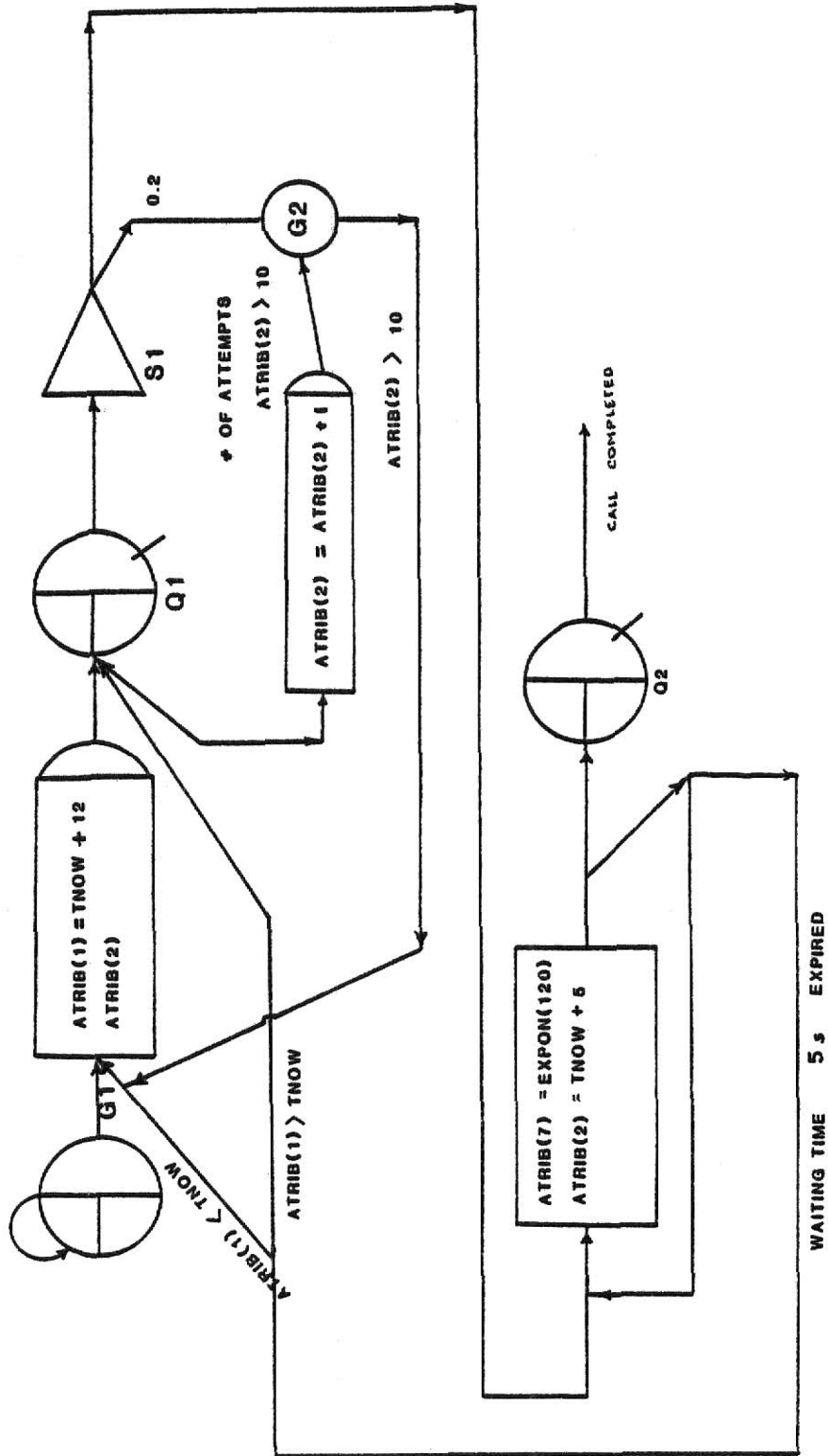


FIG 2.3 Simulation Model of Signalling Protocol

2.5 SIMULATION RESULTS AND CONCLUSION

The simulation model discussed in Section 2.4 was simulated using Simulation Language for Alternative Modeling (SLAM) the program is as in Appendix II and flow chart shown in Fig 2.4. Simulation results were obtained for different intensities of traffic and tabulated in Table 2.1.

It is observed from the results that the probability of a call failing because of being unable to obtain an access channel within MAXSZTR (MAXSZTR - 10) is negligible. For a 14 Erlangs traffic and 15 voice channels the call failure for NSZTR exceeding 10 is 0.05%.

Next, the probability of a mobile call being delayed because of all the voice channels being busy was determined for various traffic intensities and is as shown in Fig 2.5. The probability of delay under similar conditions for an Erlang C (block calls delayed) and Erlang B (block calls cleared) case is also considered as tabulated in Table 2.2 and shown in Fig 2.5. As observed from the plot for the simulation model and Erlang C (Fig 2.5) it is inferred that the subscriber behavior which normally would conform to Erlang B, but because the signalling protocol has provision for directed retry cause the subscriber behavior to be more like Erlang C.

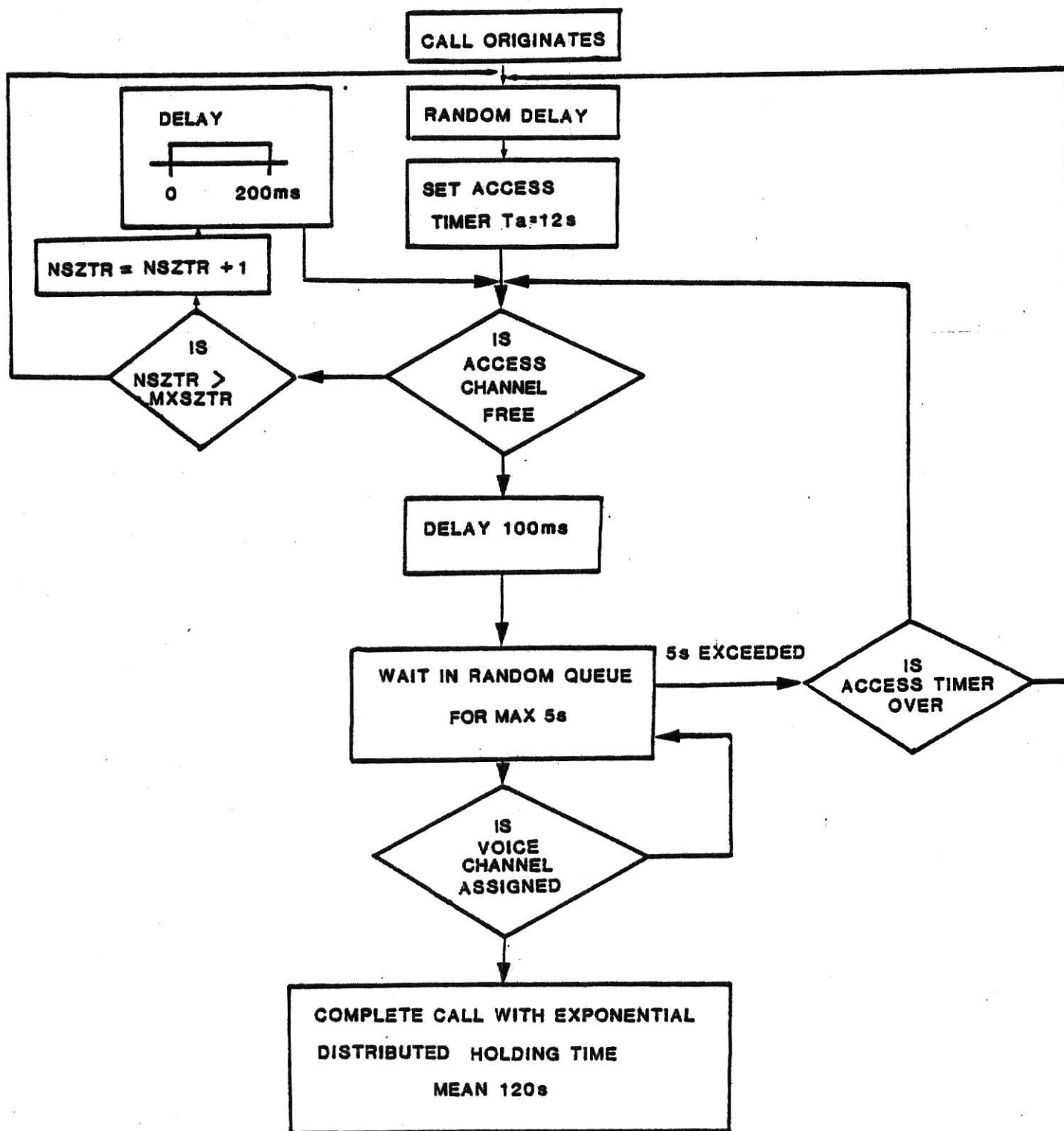


FIG 2.4 Simulation Flow Chart

Table 2.1
Simulation Results

PARAMETERS

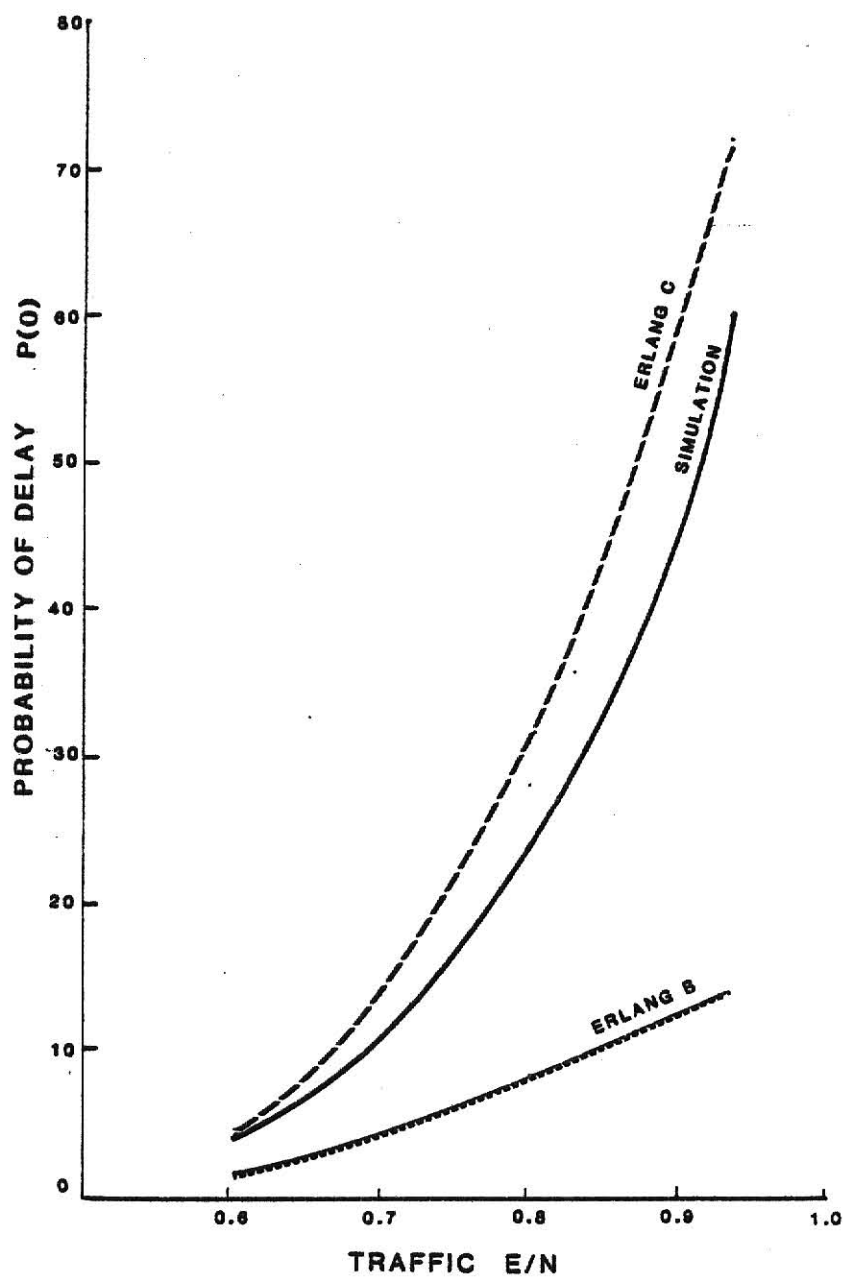
Number of Voice Channels = 15
Holding time for Voice Channels = 120 seconds
MAXSZTR = 10

RESULTS

Traffic in Erlangs	Average NSZTR	% Exceeded MAXSZTR	Average Waiting	
			time for Voice Channel	Probability of Delay
9	2.1	0	0.098	4.4
10.5	1.8	0	0.2653	11.1
12	2.25	0.01	0.6736	28.0
14	2.7	0.05	1.49	60.0.

Table 2.2
Comparison of Simulation, Erlang B and Erlang C

Traffic in Erlangs	Number of Voice Channels	Probability of Delay		
		Simulation	Erlang B	Erlang C
9	15	4.4	2.0	4.2
10.5	15	11.1	4.7	11.3
12	15	28.0	8.6	23.4
14	15	60.0	14.8	43.1



E-Traffic in Erlangs N-Number of channels

FIG 2.5 Probability of Delay V v/s Traffic

SECTION III

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3.1 INTRODUCTION

Signal attenuation due to precipitation is one of the most important factors in the design of satellite communication systems operating at frequencies above 20 GHz [2]. Early experiments were carried out to study the effect of rain fade on satellite systems operating at 4 GHz [1]. These results showed that the level of noise increased significantly due to the occurrence of rain in the vicinity of the receiving station and the noise increases at higher frequencies. With the saturation of frequency bands at 4 and 6 GHz and subsequent allocation of new common carrier band at 19 and 29 GHz, the rain attenuation becomes a serious design factor. To achieve a satisfactory performance of the satellite system, satellite systems must include a rain fade margin in its design. The provision of a rain fade margin on an individual basis to the earth stations would however lower the satellite system capacity to a level much lower than that which could have been provided in the absence of rain. Because of the low probability of earth stations to experience simultaneous fades, a small reserved pool of resources can be shared by a number of locations. This would increase the system capacity with more efficient use of the rain fade resources.

Earlier works have focused on the effect of the size of the reserved pool, the number of ground stations, the

correlation among attenuation events and satellites position on the utility of resource sharing [Ref. 4-6]. In this chapter various methods of resource sharing are discussed and their performances analyzed.

3.2 SATELLITE SYSTEM PARAMETERS

Satellites normally serve a number of earth stations, therefore some means of multiple access is necessary. The two commonly used methods for multiple access are by frequency division (FDMA) and time division (TDMA) schemes.

In the FDMA satellite system the earth stations are assigned different carrier frequencies within the available bandwidth. Due to the non-linearity of satellite transponders at high output power level, FDMA systems would experience intermodulation distortion at high output levels. This limits the output power level for FDMA systems. In single channel per carrier (SCPC) FDMA systems a discrete, modulated carrier represents a communication channel. These channels are assigned to the earth stations on a static or dynamic basis. The assignment of a fixed carrier frequency for each earth station is termed static assignment. In dynamic assignment channels are allocated to users based on their current needs, this is also termed demand assignment multiple-access (DAMA) system. During rain fades, the transmitted power level of the affected channel of a FDMA system has to be increased to maintain an acceptable signal to noise power ratio.

TDMA systems on the other hand allows the entire bandwidth to be shared by allocating the duration of time slots among the users. The time slots also can be assigned on a DAMA basis. During rain fades additional time slots can be

allocated to a earth station experiencing the fade. Error coding can be introduced in the additional time slots and thus maintaining the bit error rate. Resource sharing for rain fade margin can be implemented for both FDMA and TDMA systems. Resource in a FDMA system would imply bandwidth and power, and in a TDMA system time slots and power. A hybrid TDM/FDMA can use TDMA time slots, bandwidth and power simultaneously in an efficient manner. [Ref. 11]

3.2.1 RESOURCE UTILIZATION

Satellite resource sharing can include bandwidth, time slots and transmitted power. The efficiency of the satellite system would depend upon the efficient utilization of the satellite resources. To maintain service during rain fade periods the satellite needs to have reserved resources to back up the system. These reserved resources known as rain fade margin contribute to the resource utilization and the grade of service experienced by the satellite users. An optimistic or a pessimistic approach in determining the rain fade margin would cause the system to be utilized inefficiently. Keeping the high cost of satellite systems in consideration an efficient design would aim at efficient resource utilization while providing the additional required resource during most rain fade situations. Resource sharing is a technique which can improve the resource utilization while maintaining a low rain outage.

3.2.2 SIGNAL TO NOISE RATIO AND BIT ERROR RATE

A signal transmitted on a satellite down-link path is subjected to path attenuation which is enhanced during rain fade periods. To maintain reliability of the signal received at the earth station the signal to noise power level should have a minimum threshold value. In digital communication satellites this threshold is often determined by the specified bit error rate. Bit error rate is a measure of the rate at which bits received are lost or are in error. During rain fade periods additional resources are allocated to the affected link to maintain a desired signal to noise ratio or bit error rate.

3.3 RESOURCE SHARING FOR MULTIPLE CLASSES OF USERS

Satellite resources can be allocated to a multiple class of users by various schemes depending upon the priorities assigned to them. A satellite system with two classes of users, scheduled and dynamic will be considered. Scheduled users are those which have large holding times and their arrival and service rates are deterministic. On the other hand dynamic users have short holding times with random arrival and service distributions. Users such as T.V. and radio broadcasting which have a deterministic arrival and service rates can be classified under scheduled users. Telephone and telex service which have a random arrival and service distribution and relatively short holding times can be classified as dynamic users.

For the purpose of resource allocation, the satellite resources can be divided into several separate pools. The first one for the scheduled users normal requirements (i.e., non-rain fade and non-stress conditions). Due to the deterministic arrival and service rates of the scheduled users the utilization and performance of this pool can be considered as deterministic over time, therefore, this pool is not considered any further. Another resource pool can be reserved for the rain fade or stress requirements of the scheduled users. The arrival and service process for this pool are random and depend on the statistical properties of the rain intensity, rain occurrences and geographic

distribution of rain and the satellite terminals. Hence, this pool is taken into consideration in the queueing and simulation model. The next pool can be considered for the normal requirements of the dynamic users and the rain fade requirements of the dynamic users. The arrival and service process for this pool is also random and would depend upon the statistical properties of the dynamic users and the rain characteristics. This pool will also be considered for the queueing and simulation models. Therefore, now there are two resource pools under consideration, one for the scheduled users rain fade (SURF) requirements and the other for the dynamic users normal (DUN) requirements and the dynamic users rain fade (DURF) requirements. The cases are considered where these two pools are disjoint Fig. 3.1a, where these two pools are disjoint but users of the first pool have access to the second in pool Fig. 3.1b. Fig. 3.1c show the case where the two pools are essentially implemented in one pool with a class of users having priority access to the resources.

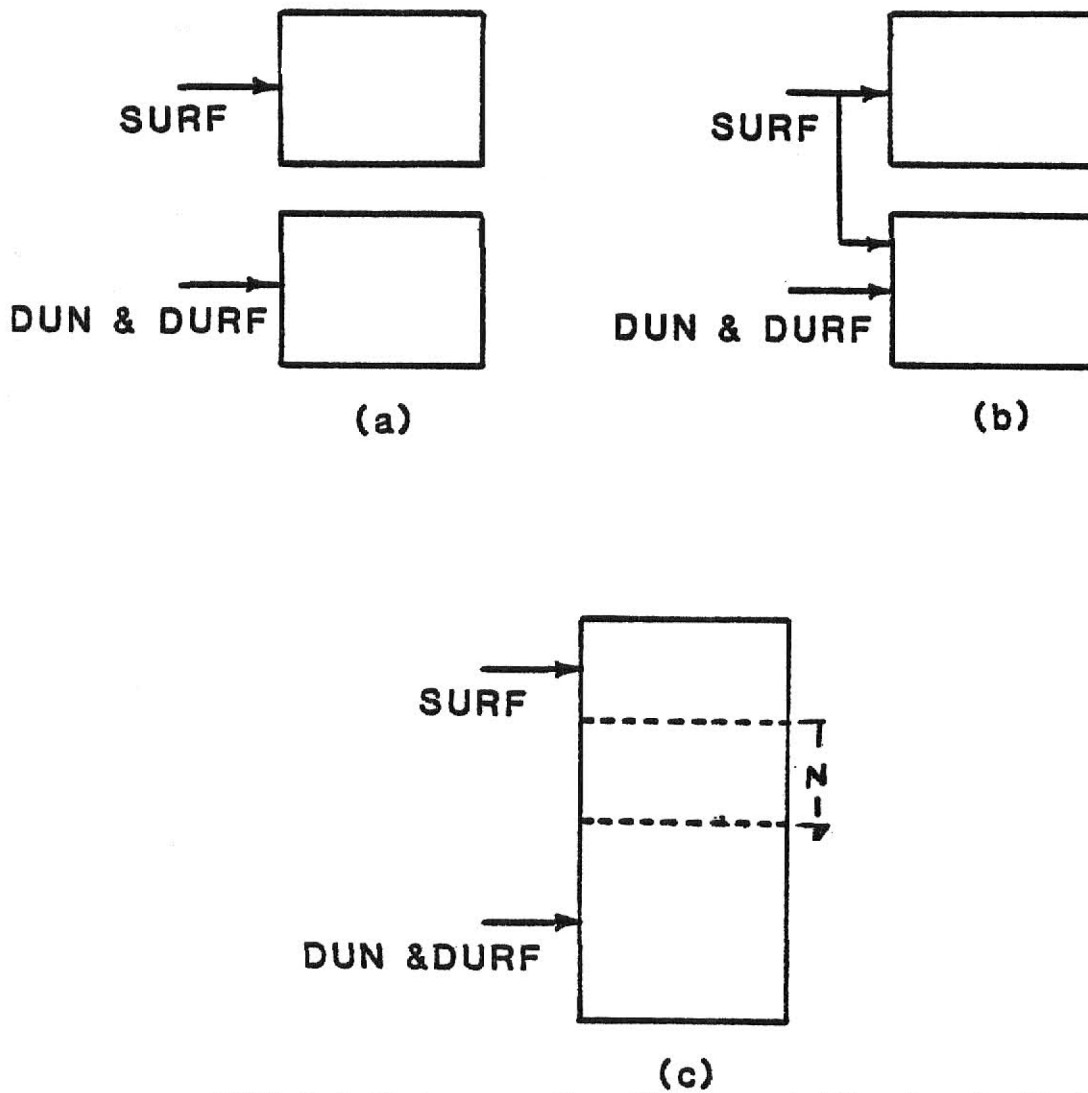


FIG 3.1 Schemes For Resource Sharing in Satellites

3.4 RAIN ATTENUATION MODEL

Rain attenuation in a satellite down link path depends upon the rain intensity, the path length and the carrier frequency. As rain occurrences follow a random pattern short-term measurement of rain rate are insufficient for use in the design of rain fade margins. Most available long-term data on rain rate statistics have been measured by a single rain gauge at a given geographical location. These statistics are known as point rate distributions. There is no unique relationship between the path attenuation and surface point rain rate because attenuation also depends upon the distribution of sizes and canting angles of the nonspherical raindrops whereas the point rate is not affected by them [Ref. 2]. Therefore, the prediction of path rain attenuation distribution from a point rain distribution is, meaningful only if the time base is sufficiently long to average these variations and yield a stable, unique, average relationship. A set of empirical formulas to calculate rain attenuation distribution from available long-term (20 yr) point rate distribution are as follows [Ref. 2].

$$\beta(R) = a + R^b$$

R is 5 minutes point rate in mm/hr a and b are functions of the radio frequency as shown in Fig 3.2

$$a(R,L) = \beta(R) \times L \times \frac{1}{1 + \frac{L}{\bar{L}(R)}} \text{ dB}$$

Another approach to estimate the rain attenuation statistic would be to extrapolate available rain attenuation statistics to other frequencies, geographical locations and path lengths. This approach is useful when ever long-term point rain rate distributions are not available. Further, as this approach uses rain attenuation statistics it disconcerts itself from the distribution of rain drop sizes and canting angles of the non-spherical rain drops.

$$L = (H-G) / \sin(\theta)$$

$$L(R) \approx \frac{2636}{R-6.2} \text{ km}$$

H $\approx$ 4km the level of clouds

G Height

θ Angle of elevation

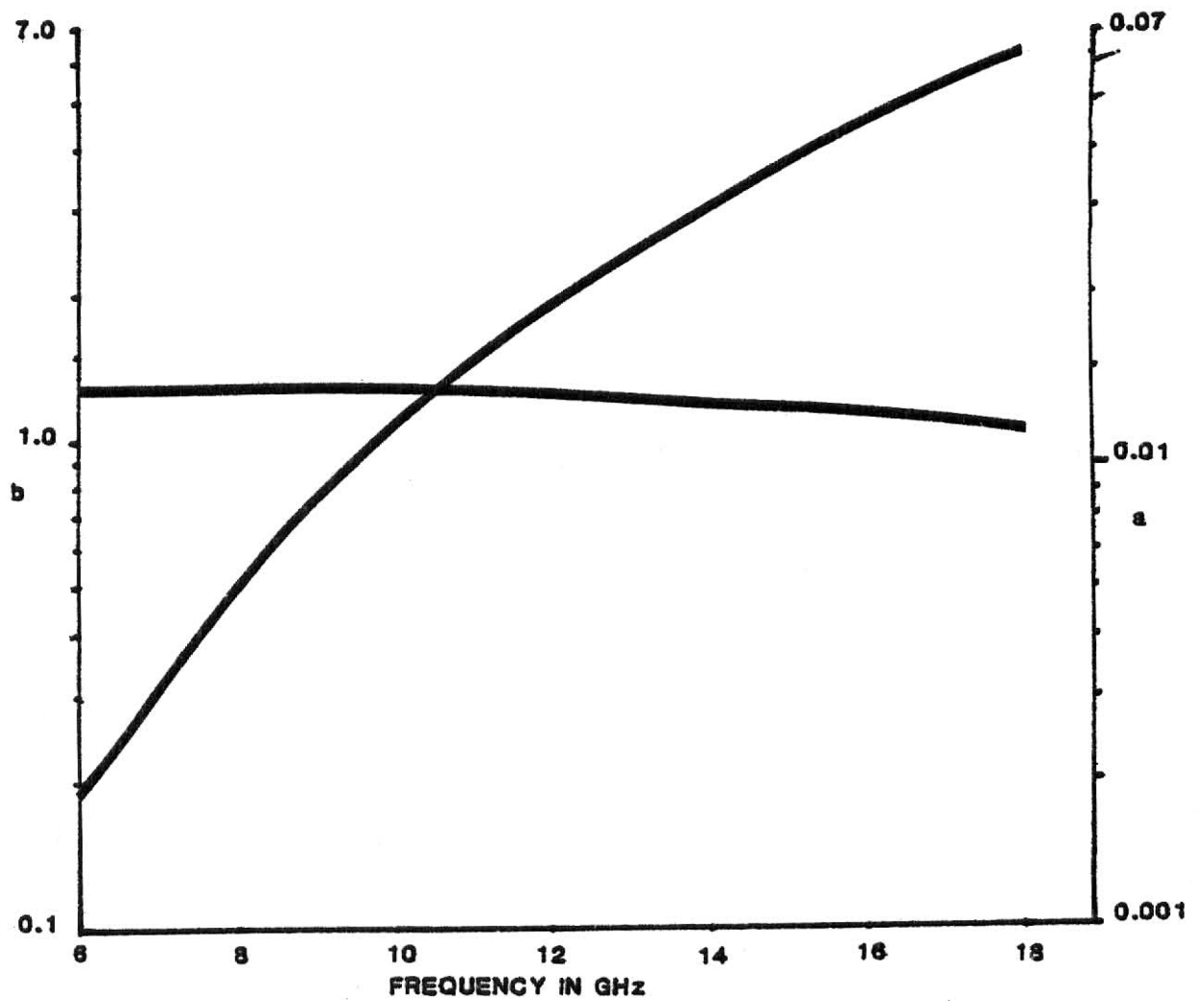


FIG 3.2 Variations of a and b With Carrier Frequencies

i. Frequency Scaling

Rain attenuation data collected simultaneously along collinear paths with identical polarization orientations at frequencies of 19.04 GHz and 28.56 GHz have been used for frequency scaling determination. The 19.04 GHz attenuation data has been scaled to 28.56 GHz by the assumption that attenuation is proportional to the square of the frequency. The comparison between the measured and scaled attenuation data at 28.56 GHz establishes the validity of the f^2 dependency of the rain attenuation. [Ref. 3].

ii. Path Length Scaling

The path elevation angle determines the path length of the rain medium (is the distance over which the signals will experience rain attenuation). The attenuation medium can be considered as a horizontal homogeneous slab of constant height. The path length will be proportional to the cosecant of the angle of elevation. As attenuation is proportional to the path length the attenuation would be a function of the cosecant of the angle of elevation. [Ref. 3].

iii. Geographic Location Scaling

The average rainfall at different geographic locations is as shown in Fig. 3.3 [Ref. 7]. The terrain and climate are important factors in approximating the rain characteristics of the region. A rough values to scale the

probability of fade to exceed a given margin is shown in Table 3.1. [Ref. 7].

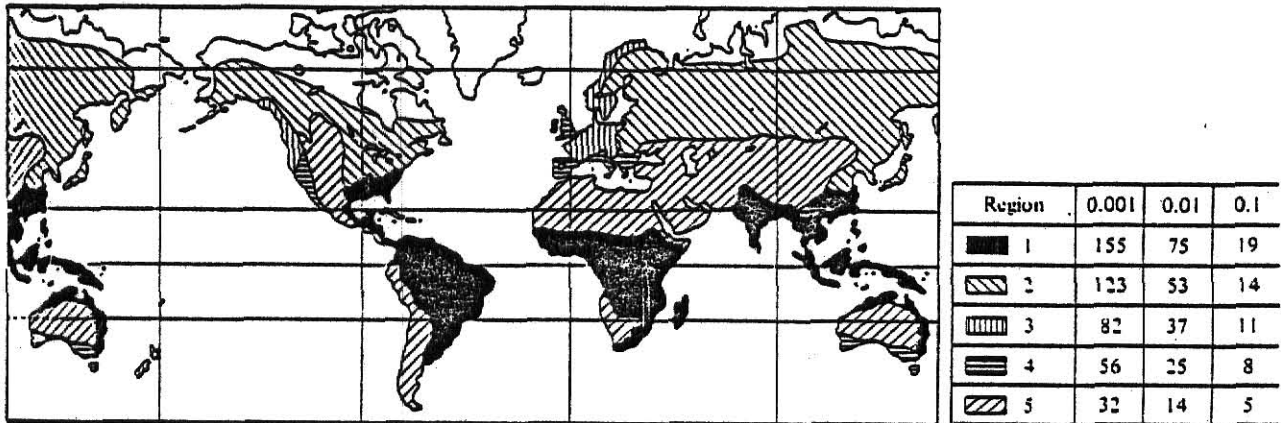


Fig. 3.3 - Percentage of an average year for which rainfall rate (mm/hr) is exceeded in the indicated climatic regions

PARAMETER	SCALING FACTOR
Terrain/Climate	
a. Average	x 1
(Some roughness, inland/temperature)	
b. Worst	x 10
(Smooth/hot and humid)	
c. Best	x 0.1
(Very rough, mountainous/dry)	

Table 3.1

The described methodology for estimation of the rain attenuation distribution is useful for the determination of

rain fade margins required in a satellite system. In this chapter the discussions are focused on a general satellite system, and attention is drawn on the usefulness of resource sharing under general rain fade conditions. For the purpose of analysis of the resource allocation schemes, rain characteristics are modeled as seen by the satellite as a whole. This approach avoids modeling of each location individually. The rain attenuation distribution is approximated to a lognormal distribution equation 3.4.(1)

$$P(\alpha) = \frac{1}{\sqrt{2\pi} D_1 \alpha} \exp \left[- \frac{(\ln \alpha - \mu_1)^2}{2D_1^2} \right]$$

μ_1 is the mean of $\ln \alpha$

D_1^2 is the standard deviation of $\ln \alpha$

$\ln \alpha$ is the attenuation in db's

3.5. QUEUEING AND SIMULATION MODEL

The satellite resources are considered as multiple servers, each server representing one unit of resource. The scheduled and dynamic users are modeled as bulk arrivals. The bulk sizes corresponding to the resources requested by the user. When a user experiences rain fade it would request for additional resources, this is simulated by a corresponding increase in the bulk size. Thus we would have a bulk arrival process for scheduled users rain fade (SURF) requirement and another arrival for dynamic users normal requirements and dynamic users rain fade requirements (DUN and SURF). Scheduled users normal requirements are not considered as mentioned in Section 3.3. The holding times of the SURF arrivals would correspond to the duration of the rain fade. As the holding times of the DUN arrivals are relatively short it can be assumed that a dynamic user starting service during a rain fade period would experience the same fade intensity during its entire service time. Thus the holding times for the DUN and DUNF arrivals would be the service time of the dynamic users. In the next section the bulk sizes and the holding times are estimated for the SURF and DUN-DUNF arrivals.

3.5.1 ESTIMATION OF BULK SIZES AND HOLDING TIMES

A. Scheduled Users Rain Fade Arrivals

The SURF bulk arrival process corresponds to extra resources required by the scheduled users experiencing rain fades. The extra resources required would depend upon the intensity of rain fade being experienced by the user. The rain attenuation distribution can be modeled approximated to a longnormal distribution as discussed in Section 3.4. As high intensity rains are normally of short durations, therefore, it is assumed that the durations of rain fades to be inversely proportional to their intensity. This in turn establishes an inverse relation between the bulk sizes and their holding times. Considering the worst months for rain attenuation the average duration of rain is 6 hrs./day. [Ref 6] The holding times for the bulk arrivals are calculated as follows:

$P(K)$ Probability of arrival of a bulk of size B_k

The mean holding time

The holding time of bulk B_k

$$\Phi_k \propto \frac{1}{B_k}$$

$$\Phi = \sum_{k=1}^M P(k) \Phi_k \quad \Phi = c \sum_{k=1}^M P(k) / B(k)$$

Using the values of $P(k)$ and $B(k)$ from Table 2.

We have $C = 13.6$

$$\text{Hence } \Phi_k = \frac{13.6}{B_k} \quad 3.5(3).$$

The values of ϕ_k are also shown in Table 3.2.

Consequently the rain attenuation distribution in decibels would be a normal distribution.

$$P(\bar{A}) = \frac{1}{\sqrt{2\pi} D_1} \exp \left[\frac{-(\bar{A} - \mu_1)^2}{2D_1^2} \right]$$

A Attenuation in dB's

The normal distribution is discretised into steps of equal size. Corresponding to the mean of each step a bulk size B_k is determined. According to the probability of the occurrence of each step the probability of the corresponding bulk arrival is determined, this is as shown in the following equations:

$$P(A_1 < A < A_2) = \int_{A_1}^{A_2} \frac{1}{\sqrt{2\pi} D_1} \exp \left[\frac{-(A - \mu_1)^2}{2D_1^2} \right] dA$$

Let $y = (A - \mu_1)/D_1$ hence $dA = D_1 dy$

$$P(A_1 < A < A_2) = \frac{1}{\sqrt{2\pi} D_1} \int_{\frac{A_1 - \mu_1}{D_1}}^{\frac{A_2 - \mu_1}{D_1}} \exp(-y^2/2) D_1 dy$$

$$P(A_1 < A < A_2) = \text{erf} \left(\frac{A_2 - \mu_1}{D_1} \right) - \text{erf} \left(\frac{A_1 - \mu_1}{D_1} \right)$$

Table 3.2

K	Mean of Step K	P(k)	B(k)	Mean Holding Time Sec.
1	2	0.25	1	13.6
2	6	0.38	3	4.53
3	10	0.25	5	2.72
4	14	0.09	7	1.94
5	20	0.05	9	1.51

B. Dynamic Users Arrivals

A dynamic user bulk arrival would correspond to the DUN requirements and the DURF requirements. The rain attenuation distribution would again be a normal distribution (attenuation in dB's) as for scheduled users with the exception that there would be an impulse of height $P(1)$ at the origin corresponding to a no rain-fade condition.

$$P(A) = \frac{1}{\sqrt{2\pi} D_1} \exp \left[\frac{-(A-\mu_1)^2}{2D_1^2} \right] + P(1)\delta(1)$$

The bulk sizes which represent the DUN and DURF arrivals are shown in Table 3.3. In accordance with the assumption that a dynamic user starting service during a rain fade and would experience the same fade during its entire service the holding times of the dynamic users bulk size would not be a function of the bulk size, but will depend on the characteristics of the dynamic users.

Table 3.3

K	Mean of Step K	P(K)	B _k
0	No fade	0.9	1
1	2	0.025	3
2	6	0.038	7
3	10	0.023	11
4	14	0.009	15
5	18	0.005	19

3.5.2 MODEL I: RESOURCE SHARING WITH OVERFLOW

The satellite resources which are represented by multiple servers in the queueing model are divided into two pools, the first for SURF arrivals and the second for DUN and DURF arrivals. If the SURF requirements exceeds the capacity of the first pool allocated to them, they would then have access to the resources in the second pool reserved for the dynamic users (i.e., they overflow to the second pool as shown in Fig. 3.1(b).) Thus, SURF arrivals first attempt to seek service from the servers reserved for SURF arrivals. If all the servers in SURF pool are busy then SURF arrivals attempt to access the second pool of servers reserved for DUN and DURF arrivals. In the event all the servers in the first and second pool are busy, the SURF arrivals would wait for a server to get free for a

maximum duration which is equal to the rain fade duration. As and when servers are free in the first or second pool they are allocated to the waiting SURF arrivals, if any, for the remainder of rain fade duration (i.e., the difference of the rain fade and waiting time). DUN and DURF arrivals have access only to the servers in the second pool. These arrivals wait indefinitely for service if all the servers in the second pool are busy. Whenever servers in the second pool become free they are allocated to SURF arrivals or DUN and DURF arrivals, on a first come first serve (FCFS) basis. DUN and DURF arrivals service times are independent of their waiting time in the queue and balking of the dynamic users is not considered. The queuing model flow chart describing the above process is shown in Fig. 3.4. The exact mathematical analysis of the this model becomes very intractable; hence computer simulation techniques are used to study the systems behaviour. The simulation model is as shown in Fig. 3.5 and results discussed in sections 3.6. (For simulation program refer to Appendix II).

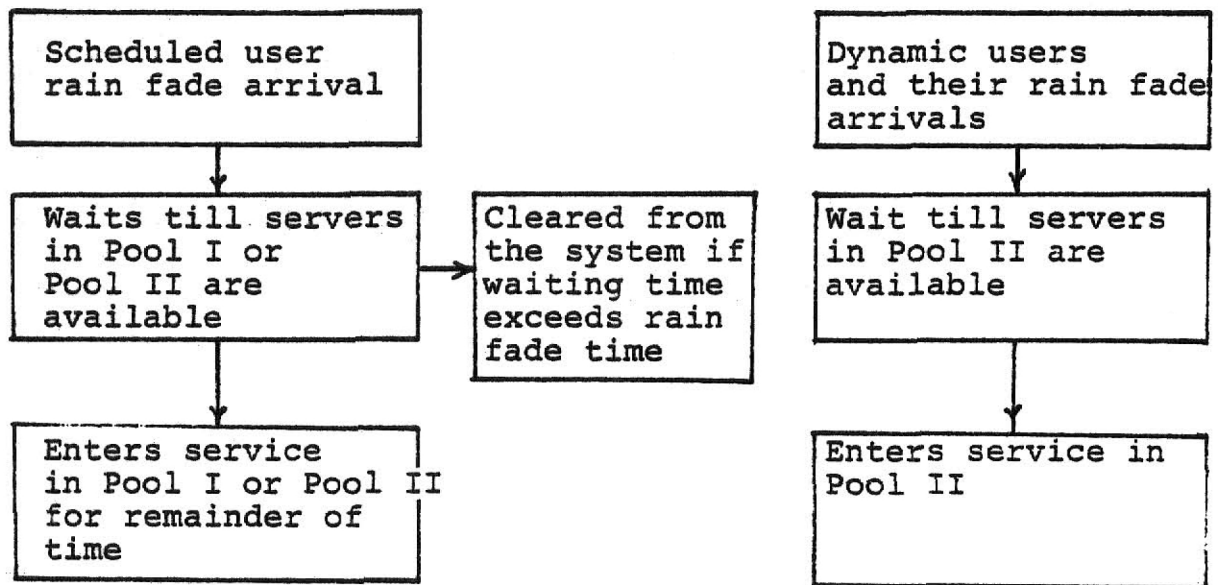


Fig. 3.4

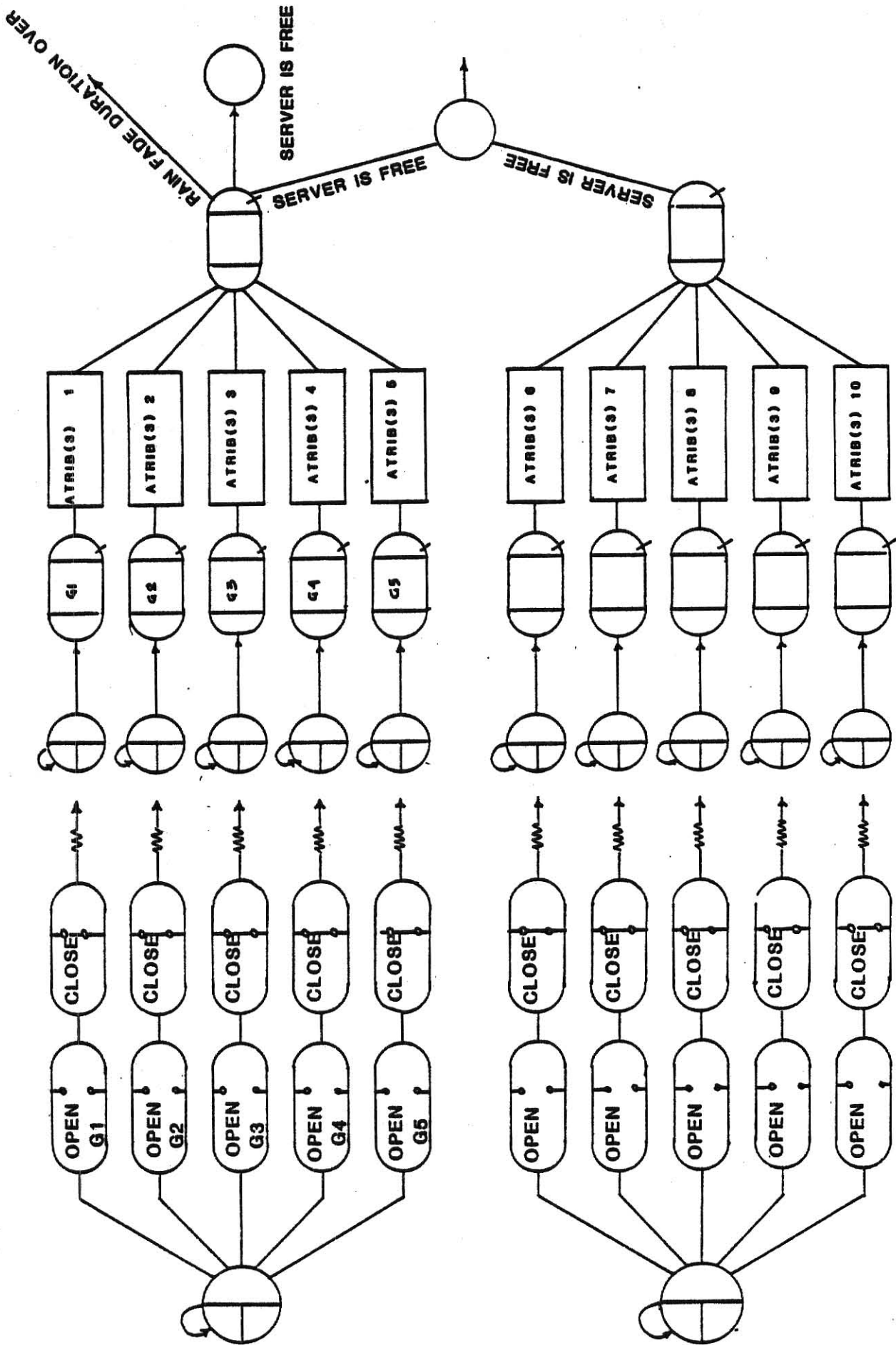


FIG 3.5 SLAM Simulation Model For Resource Sharing With Over Overflow

3.5.3 MODEL II: RESOURCE SHARING WITH CUT-OFF PRIORITY

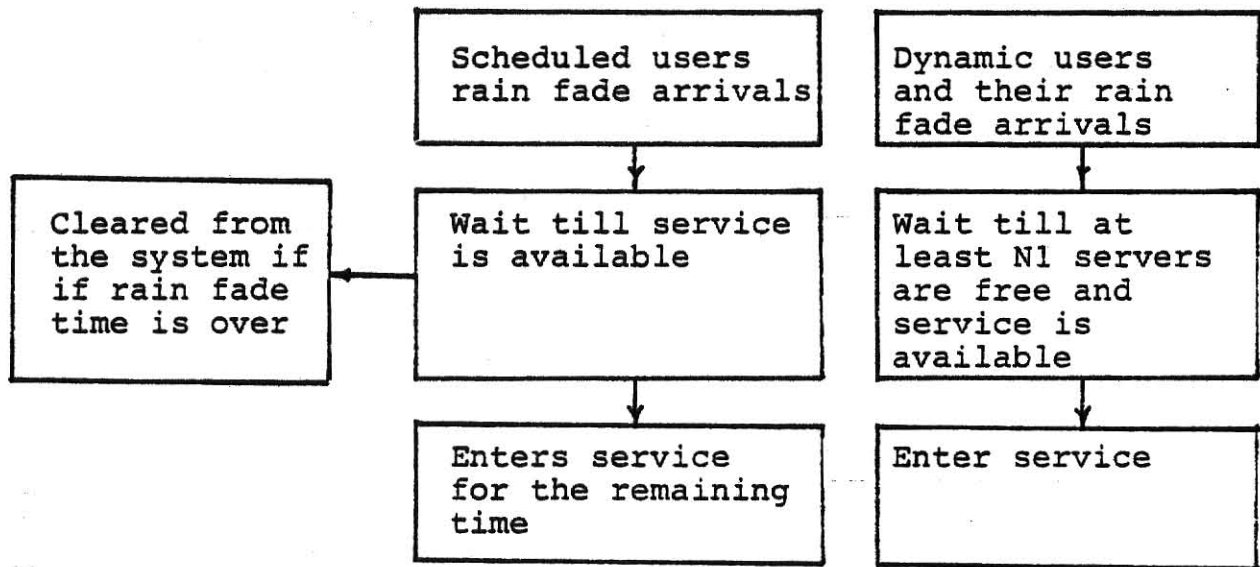
Cut-off priority for a system of servers is defined as, if more than or equal to N_1 ($N_1 > N$) servers are busy then the ordinary or non-priority arrivals do not have access to service. These non-priority arrivals wait for service till less than N_1 servers are busy. The priority arrivals have access to all of the N servers. If all of the N servers are busy then priority arrivals wait for a server to be free. The SURF arrivals are priority arrivals in the problem under consideration. If all of the N servers are busy, the SURF arrivals wait for service up to a maximum of the rain fade duration. As and when a server is available they receive service for the remaining duration of the rain fade period. Dynamic users are the non-priority arrivals and only have access to servers if less than N_1 servers are busy. If more than or equal to N_1 servers are busy they wait for service with no upper limit on their waiting time. The flow chart describing the above is shown in Fig 3.6.

The analysis of a cut-off priority system itself is quite involved, and with the addition of the arrivals process being bulk arrivals of different sizes and holding times with a limit on the waiting times makes the analysis intractable. Hence, the systems behavior has been studied using computer simulation. The computer simulation model

(Fig 3.7) and the results are discussed in Section 3.6.

(Simulation program is given in Appendix II).

Fig 3.6



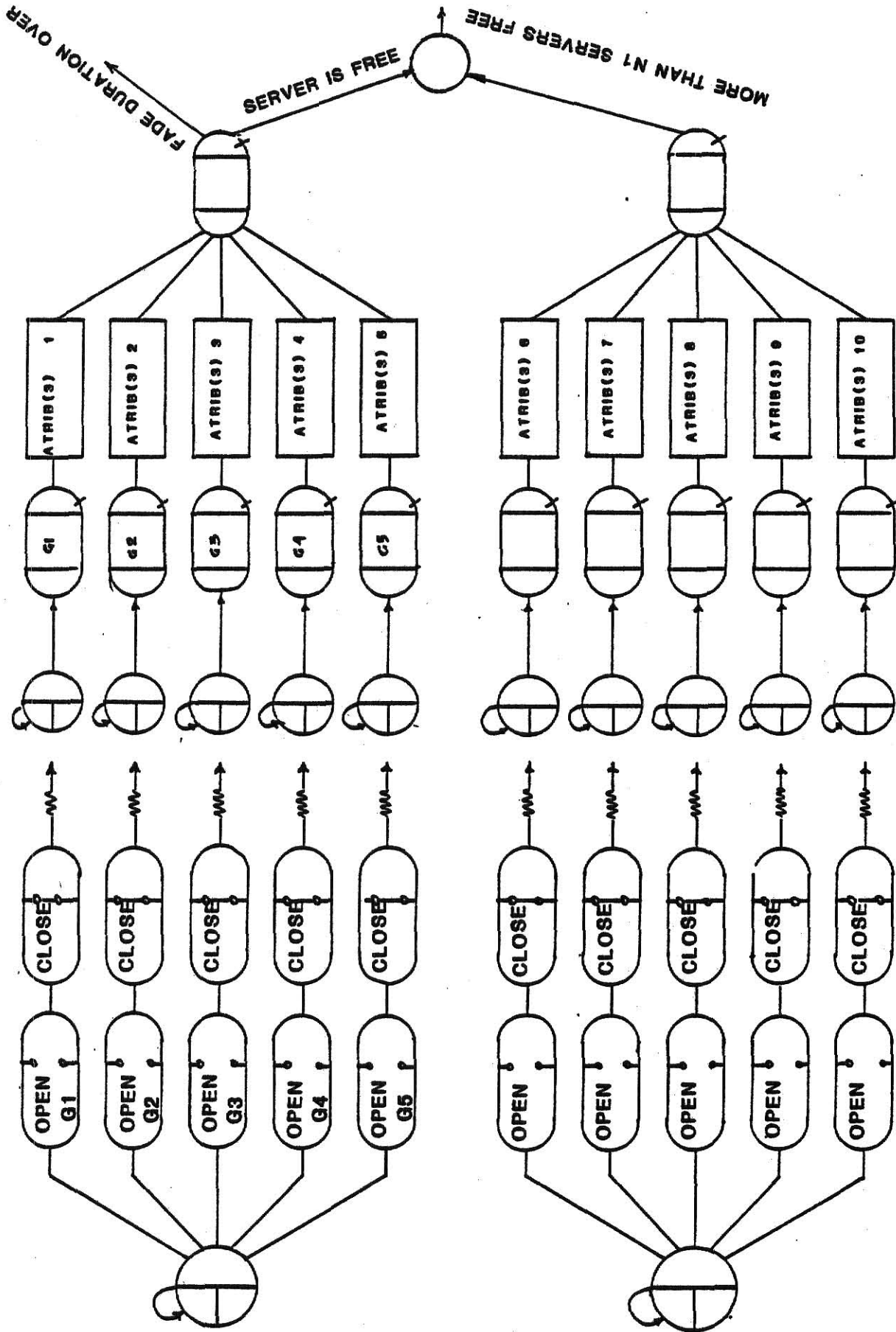


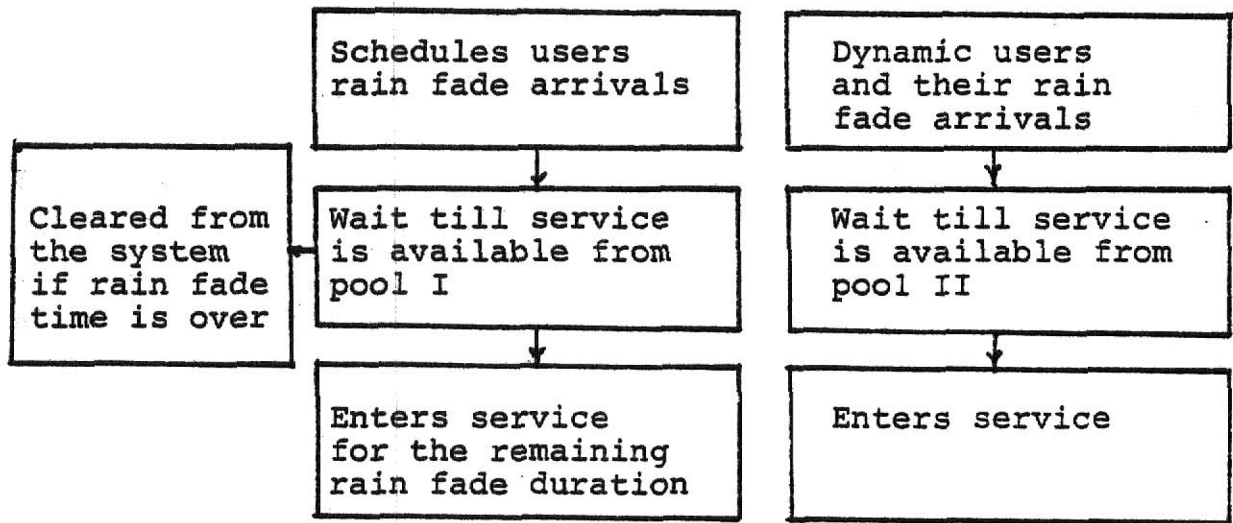
FIG 3.7 SLAM Simulation Model For Resource Sharing With Cut-Off Priority

3.5.4 MODEL III: NO RESOURCE SHARING

The servers (which represent the satellite resources) are divided into two pools, the first for SURF arrivals and the second for DUN and DURF arrivals. The SURF arrivals in this case do not overflow or share the DUN and DURF servers pool. The SURF arrivals attempt to gain access to the servers in the first pool. If all the servers in the first pool wait for service with the maximum limit on their waiting time being equal to the rain fade period. When servers in the first pool are free, waiting SURF arrivals would receive service for the remaining duration of the rain fade period. DUN and DURF arrivals would seek service from the second pool. If all the servers in the second pool are busy, they will wait for service with no upper limit on their waiting time. The flow chart in Fig 3.8 describes the above model.

As the overflow and cut-off priority system model performance was determined by computer simulations, the scheme with resource sharing is also studied using simulation techniques. The simulation model is shown in Fig 3.9, and results discussed in the next section 3.6.

Fig 3.8



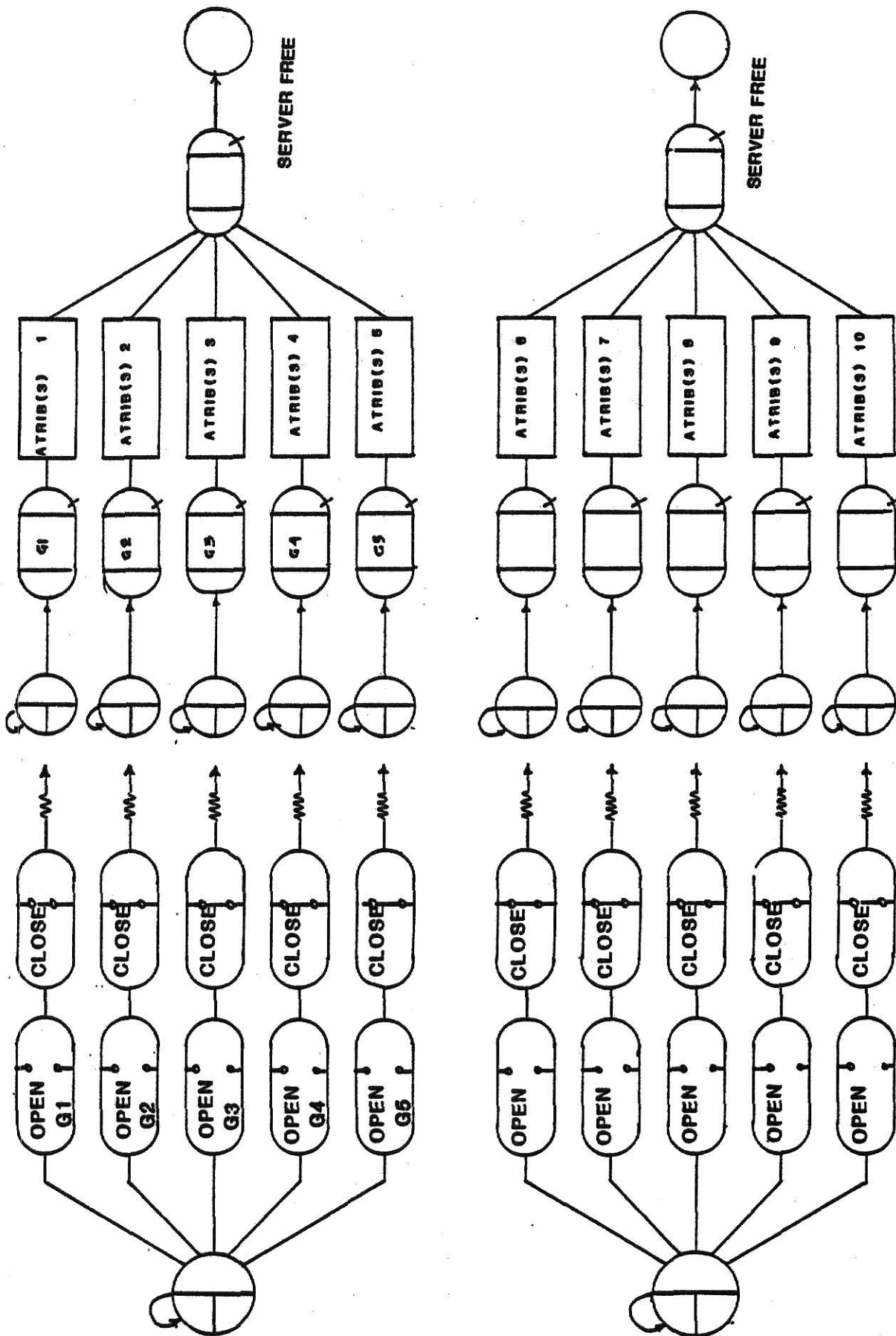


FIG 3.9 SLAM Simulation Model For No Resource Sharing

3.6 SIMULATION RESULTS

The factors which determine the performance of a satellite communication system are resource utilization, grade of service experienced by the users and the quality of signal received at the earth station. The high cost of a satellite communication system necessitates the efficient utilization of the available satellite resources to a maximum. Resource utilization is a measure of the fraction of time the satellite resources are busy for a given grade of service. An ideal situation would require all the satellites resources to be utilized at all times, but in reality due to the dynamic nature of users (i.e., random arrival and departure) and the necessity of having rain fade margins, reduces the efficient resource utilization. Grade of service is defined as the probability of a user upon request for service (i.e. resources) is refused service due to the unavailability of resources at that time. The acceptable grade of service is normally determined by the nature of users. For a very reliable communication system (i.e., normally used for emergency broadcasting, exchange of information where time is an important factor) the system design would aim at a very low grade of service, for commercial users like telephone, telex customers a higher grade of service would cause loss of customers.

The satellite resources are represented by servers in the simulation model. Therefore, the servers utilization is a direct measure of the satellites resource utilization. Rain fade periods have been simulated by a bulk arrival process. In actuality there are no additional arrivals corresponding to a rain fade requirement, but the earth stations experiencing rain fade request for more resources. If additional resources are not available on earth station will experience a degradation in the quality of signal (i.e., lower S/N power ratio or higher bit error rate). In the simulation model the waiting process describes the situation when the system can not meet the users additional resource requirements. Hence, the average queue length is indicative of the degradation of signal received by the users, and the average waiting time is a direct measure of duration of this degradation. Because this study is focused on comparison of the various resource sharing schemes discussed earlier, the average queue lengths are not translated to the corresponding signal to noise power ratio or the bit error rate. In terms of the simulation model an efficient system design would aim at efficient utilization, of the servers to reduce the average waiting times of SURF and DUN and DURF arrivals. The simulation results obtained are discussed next.

3.6.1 MODEL I: RESOURCE SHARING WITH OVERFLOW

The resource sharing with overflow technique as described earlier in Section 3.5.2 was simulated to study the systems behavior to an increase in the SURF traffic, DUN and DURF traffic and change in fraction of resource allocated to Pool I and II. The results obtained for an increase in SURF arrival rate is as shown in Table 3.4.

Table 3.4

Scheduled Arrival Rate	Normalized Waiting Times in %		Resource % Utilization
	Scheduled	Dynamic	
1.0	4.08	26.47	70.17
1.3	5.32	30.6	76.3
1.5	11.9	41.3	80.8

It is observed that for a 33% increase in SURF arrival rate the increase in the waiting times of SURF arrivals and DUN and DURF arrivals is within acceptable limits. This is because of the SURF arrivals which overflow to the second pool and thus cause the effect of the increase in the SURF arrivals to be shared by the scheduled users and dynamic users. The effect of a 32% increase in the DUN and DURF arrival rate on the SURF waiting times is negligible, as shown in Table 3.5. (the decrease in SURF waiting times seen in Table 3.5 is within the statistical approximations in the

simulation). The fraction of resources allocated to the first and second pool were varied to observe their effect on the system, the results are as shown in Table 3.6. The SURF arrivals waiting time and DUN and DURF arrivals waiting times versus the fraction of resources reserved for Pool II curves are shown in Fig 3.10. As observed from the curves the DUN and DURF arrivals waiting times decrease and SURF arrivals waiting times increase as the fraction of resources allocated to Pool II is increased. The best operating point would be determined by the nature of dynamic users and scheduled users and the reliability desired for them, thus would vary from system to system.

Table 3.5

By Users		Waiting Times	
<u>Arrival Rate</u>	<u>Sch Users</u>	<u>Dyn Users</u>	<u>Res Utilization</u>
.25	4.42	21.42	62.0
.33	4.08	26.47	70.17
.40	3.65	37.3	77.6

Table 3.6

% Allocate to Waiting Times				
Pool I	Pool II	Scheduled Users	Dynamic Users	Resource
33	67	4.08	26.47	70.17
25	75	4.61	20.27	70.0
16	84	5.25	16.06	69.7
10	90	5.7	13.07	69.5

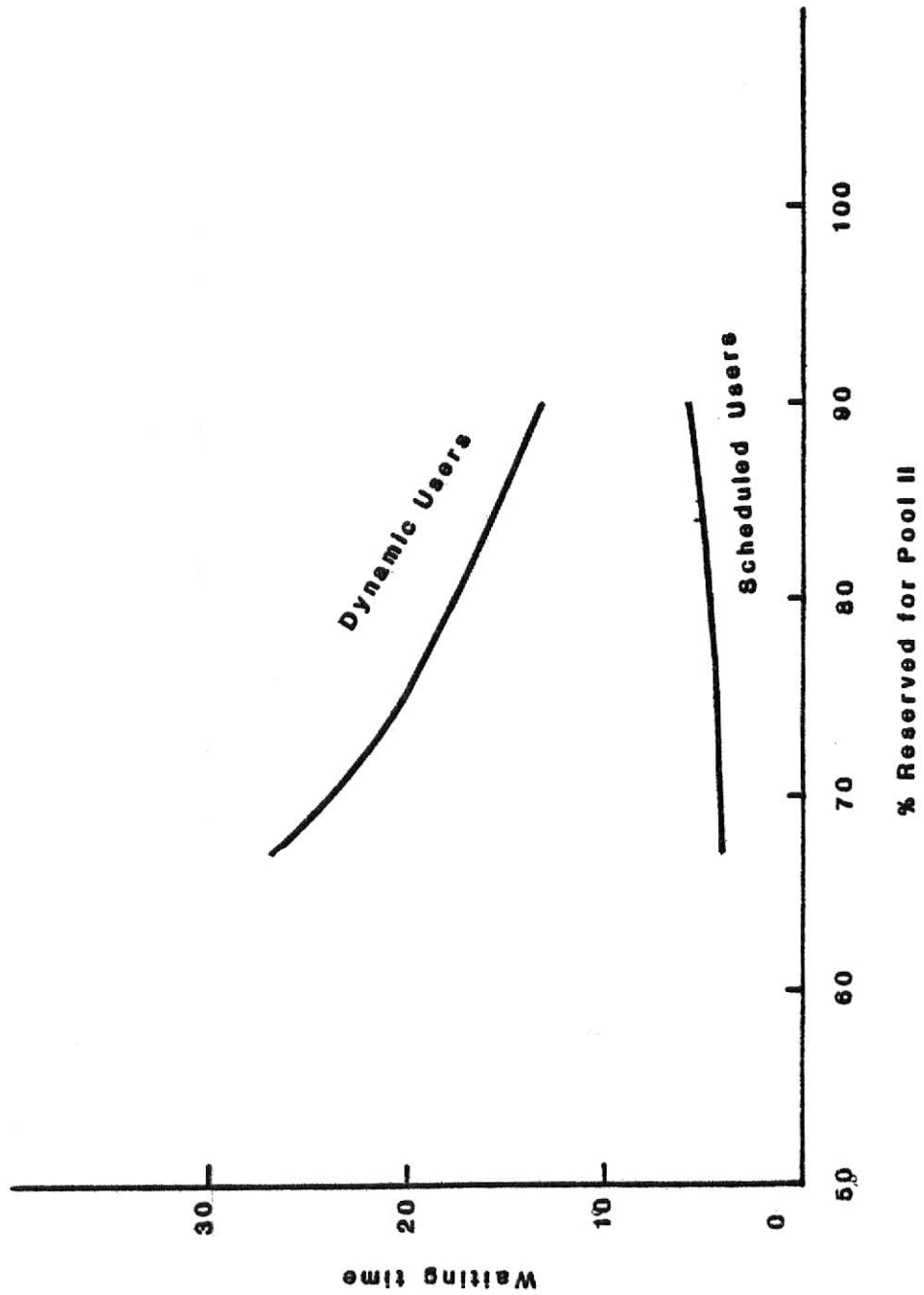


FIG3.10 SURF and DUN-DURF Times For Different Resource Allocation
For Pool I and Pool II

3.6.2 Model II: Resource Sharing with Cut-Off Priority

The SURF arrivals are the priority arrival in the cut-off priority model (discussed earlier in Section 3.5.3). The results obtained for an increase in the SURF arrival rate are as shown in Table 3.7. It is observed that for a 33% increase in the SURF arrival rate the DUN and DURF arrivals are very adversely affected. For simplicity in understanding the model we can consider the servers to be in a stack as shown in Fig 3.11(a).

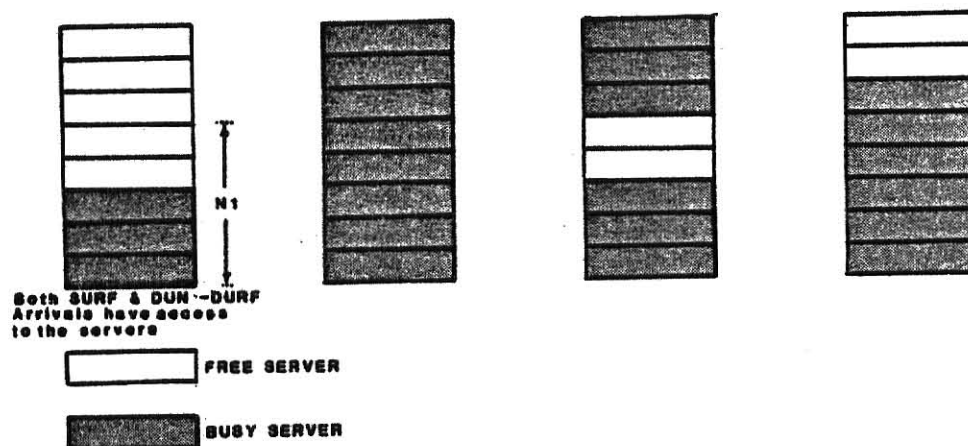


FIG 3.11 Resource Allocation in a Cut-Off Priority Resource Allocation Scheme

Table 3.7

Scheduled User Arrival Rate	Waiting Times		
	Sch Users	Dyn Users	Res Utilization
1.0	0.071	208	63.6
1.3	0.933	776	74.0
1.5	1.36	2696	76.3

The arrivals would start occupying the servers from the bottom of the stack, whenever a server completes service it moves to the top of the stack. The DUN and DURF arrivals do not have access to the servers till the number of busy servers is less than N_1 (as discussed in Section 3.5.3). Once the number of busy servers is more than N_1 the DUN and DURF arrivals will practically not get access to the server till all the waiting SURF arrivals receive service. This is because once all the servers are busy and a service completion occurs, and as the number of busy servers would yet be more than N_1 only a SURF arrival will have access to the server. In this manner all the waiting SURF arrivals would gain access to a service before the number of busy servers would drop below N_1 . This cycle is shown in Fig 3.11. Thus it explains the increase in the DUN and DURF arrivals waiting times for the increase in SURF arrival rate. An increase in the DUN and DURF arrival rate would also adversely affect their waiting time but to a lesser degree, the results

obtain for an increase in DUN and DURF arrival rates are shown in Table 3.8.

Table 3.8

Dynamic Users Arrival	Waiting Times		Resource Utilization
	Scheduled	Dynamic	
Rate			
0.25	0.071	208	63.6
0.33	0.09	512	70.6
0.40	0.0	1669.0	70.9

The cut-off limit (n1) was varied to observe the system sensitivity to it, the results obtained are shown in Table 3.9. The SURF arrivals and DUN and DURF arrivals waiting times are versus the percentage of servers representing N1 plots are as in Fig. 3.12. The best operating cut-off point would be best determined by a knowledge of the scheduled users and dynamic users characteristics.

Table 3.9

N1 as a % of Total Resource	Waiting Times		Resource
	Scheduled	Dynamic	Utilization
66	.01	512	70.6
75	.08	138	71.5
84	.17	72	71.5
90	.36	46	71.6

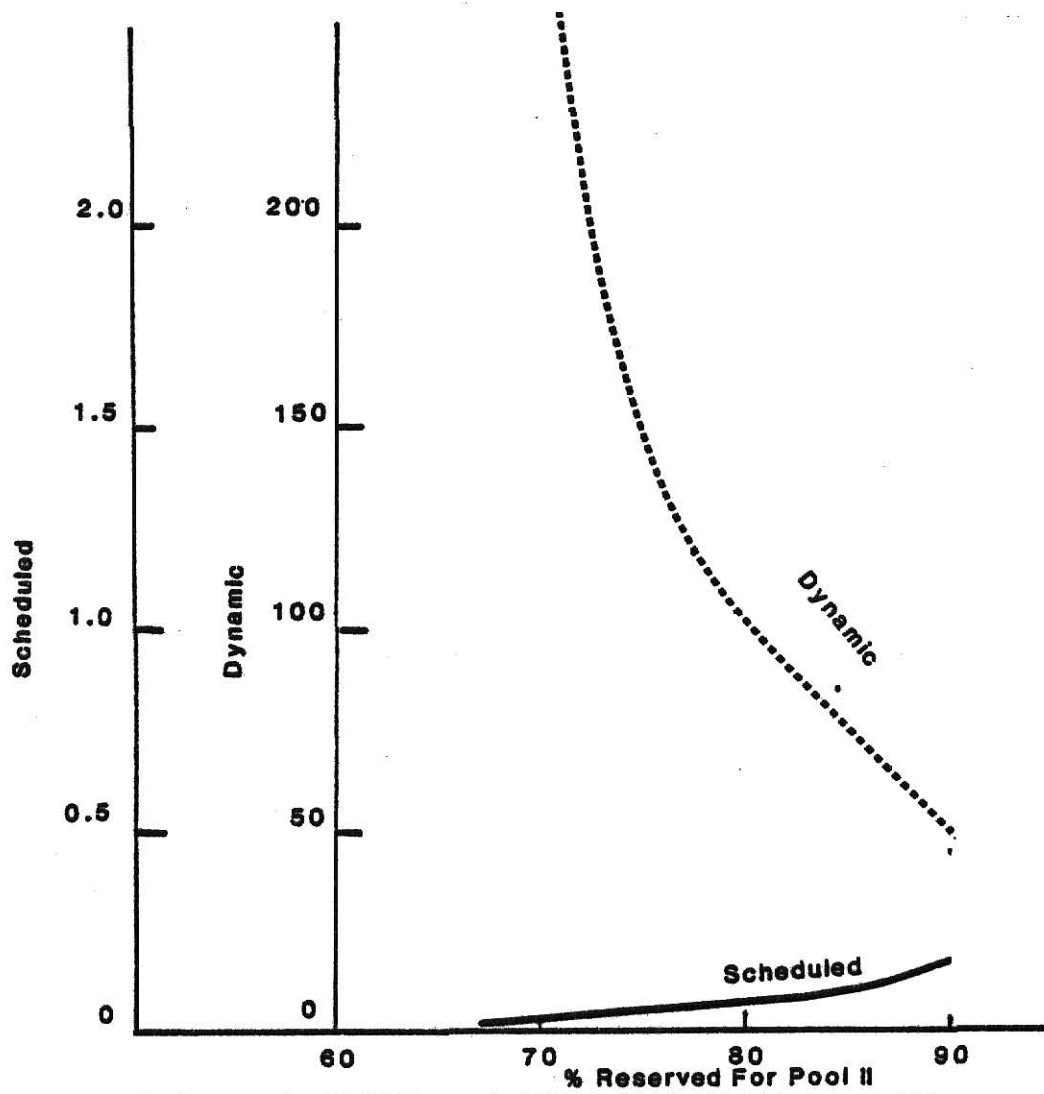


FIG 3.12 SURF and DUN-DURF Waiting Times
For Various Cut Off Limits

3.6.4 MODEL III: NO RESOURCE SHARING

The purpose of studying behavior of this model is to compare the results with the previous model (i.e., overflow and cut-off priority models). As the two pools in this model are disjoint and there is no overflow of arrivals, the SURF arrival rate would not affect the DUN and DURF waiting times and the DUN and DURF arrival rate would not affect the SURF arrivals waiting time. The system was simulated and results obtained to observe the effect of an increase in SURF arrivals rate on its waiting time and the effect of an increase in DUN and DURF arrivals on their waiting time, the results are as in Table 3.10.

Table 3.10

<u>Scheduled</u>		Waiting Times	
<u>Arrival Rate</u>	<u>Scheduled</u>	<u>Dynamic</u>	<u>Res Utilization</u>
1.0	14.12	2.34	57.16
1.3	36.48	2.6	59.8
1.5	41.6	2.5	65.0
 <u>Dynamic</u>			
0.25	14.12	2.34	57.16
0.33	14.30	8.09	59.5
0.40	23.0	60.0	68.0

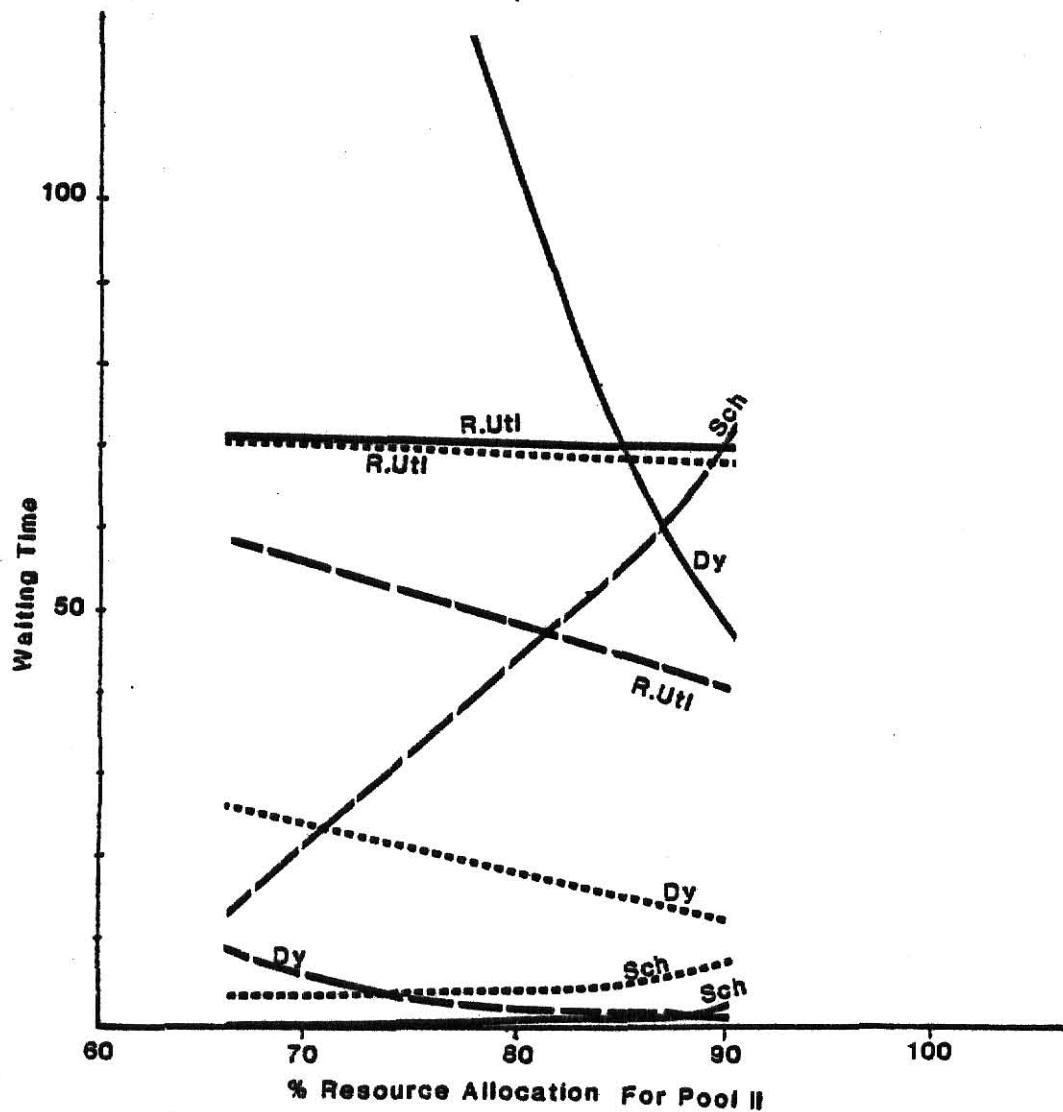


FIG 3.13 Waiting Times and Resource Allocation
For Model I II & III

Model I
Model II
Model III

3.7 CONCLUSION

The performance of the models discussed in the previous sections is compared for the same SURF and DUN and DURF arrivals. The SURF arrivals waiting times, DUN and DURF arrivals waiting times and the resource utilization are compared for different values of the percentage of resources allocated to Pool II (the cut-off point in the case of Model II). There is little difference in resource utilization for Model I and II, though there is a definite improvement over Model III, as seen in Fig 3.13. The waiting times of SURF arrivals is the least for Model II and increases for Model I and increases very rapidly for Model III. On the other hand the DUN and DURF arrivals waiting time are maximum for Model II and decreases for Model I with a further drop for Model III.

Thus, we see that no one model can be generalized as the best model. The best model would depend upon the scheduled user and dynamic users characteristics, and the degree of reliability required for each. Model I would be a preferred choice for a system where the scheduled and dynamic user are of near the same priority. Model II would be more suitable for a system where the scheduled users need to have very reliable service.

APPENDIX I

Commonly used SLAM statements and symbols

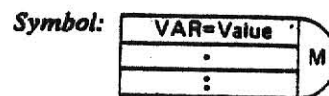
Node Type: ALTER



Function: The ALTER node changes the capacity of resource RLBL by CC units. In the case where the capacity is decreased below current utilization, the excess capacity is destroyed as it becomes freed. The capacity can be reduced to a minimum of zero with additional reductions having no effect. At each release, a maximum of M emanating activities are initiated.

Input Format: ALTER, RLBL/CC, M;

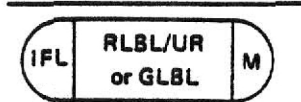
Node Type: ASSIGN



Function: The ASSIGN node is used to assign values to SLAM variables (VAR) at each arrival of an entity to the node. A maximum of M emanating activities are initiated.

Input Format: ASSIGN, VAR = value, VAR = Value, M;

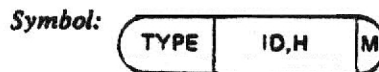
Node Type: AWAIT



Function: The AWAIT node operates in two modes. In the resource mode, the AWAIT node delays an entity in file IFL until UR units of resource RLBL are available. The entity then seizes the UR units of RLBL. In the gate mode, the AWAIT node releases the entity if the gate status is open and delays the entity in file IFL if the gate status is closed. At each release of the node a maximum of M activities are initiated.

Input Format: WAIT A (IFL), RLBL/UR or GLBL, M;

Node Type: COLCT

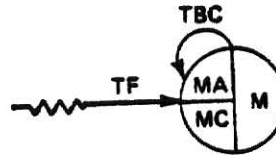


Function: The COLCT node is used to collect statistics that are related to: either the time an entity arrives at the node (TYPE); or on a VARIABLE at the entity arrival time. ID is an identifier for output purposes and H is a histogram specification for the number of cells (NCEL), the upper limit of the first cell, (HLOW) and the cell width (HWID). A maximum of M emanating activities are initiated.

Input Format: COLCT, TYPE or VARIABLE, ID, NCEL/HLOW/HWID,
M;

Node Type: CREATE

Symbol:



Function: The CREATE node is used to generate entities within the network. The node is released initially at time TF and thereafter according to the specified time between creations TBC up to a maximum of MC releases. At each release, a maximum of M emanating activities are initiated. The time of creation is stored in ATRIB(MA) of the created entity.

Input Format: CREATE, TBC, TF, MA, MC, M;

Node Type: GOON

Symbol:



Function: The GOON node provides a continuation node where every entering entity passes directly through the node. It is a special case of the ACCUMULATE node with FR and SR set equal to one. A maximum of M emanating activities are initiated.

Input Format: GOON, M;

Node Type: QUEUE

Symbol:

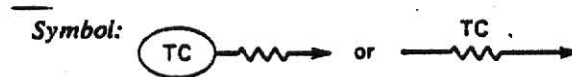


Function: The QUEUE node is used to delay entities in file IFL until a server becomes available. The QUEUE node initially contains IQ entities and has a capacity of QC entities. The specification of blocking causes incoming servers to be blocked whenever the queue is at capacity. The specification of balking causes arriving entities to balk whenever the queue is at capacity.

Input Format: QUEUE (IFL), IQ, QC, BLOCK or BALK (NLBL), SLBL;

Node Type: TERMINATE

Symbol:



Function: The TERMINATE node is used to destroy entities and/or terminate the simulation. All incoming entities to a TERMINATE node are destroyed. The arrival of the TCth entity causes a simulation run to be terminated.

Input Format: TERMINATE, TC;

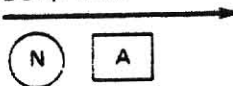
Block Type: RESOURCE

Function: A RESOURCE block defines a resource by its label RLBL and its initial capacity or availability IRC. The file numbers, IFLs, associated with AWAIT and PREMPT nodes are where entities requesting units of the resource are queued. The IFLs are listed in the order in which it is desired to allocate the units of the resource when they are made available.

Input Format: RESOURCE/RLBL (IRC), IFLs;

Activity Type: SERVICE

Symbol: DUR, PROB



Function: The service activity is any activity emanating from a QUEUE or SELECT node. The service activity is used in conjunction with the QUEUE node to model single channel queues or queues with N identical servers. The service activity is used in conjunction with the SELECT node to model

multiple channel queues with non-identical servers. Statistics are collected on all service activities. If the activity is numbered, the server status (number of busy or blocked servers) and total entity count are maintained as SLAM variables $NNACT(A)$ and $NNCNT(A)$, respectively.

Input Format: ACTIVITY(N)/A, duration, PROB, NLBL;

Activity Type: REGULAR

Symbol: DUR, PROB or COND

A

Function: A REGULAR activity is any activity emanating from a node other than a QUEUE or SELECT node. The REGULAR activity is used to delay entities by a specified duration, perform conditional/probabilistic testing, and to route entities to non-sequential nodes. If the activity is numbered, statistics are provided on the activity utilization, and the number of active entities and the total entity count are maintained as SLAM variable $NNACT(A)$ and $NNCNT(A)$, respectively.

Input Format: ACTIVITY/A, duration, PROB or COND, NLBL;

BIBLIOGRAPHY

1. D. C. Hogg and Ta-Shing Chu - "The Role of Rain in Satellite Communications." IEEE Proceedings Vol. 63, No. 9, September 1971.
2. H. Sing-Lin - "Emprical Rain Attenuation Model for Earth Satellite Paths." IEEE Transactions on Communication, Vol. COMM-37, No. 5, May 1979.
3. H. W. Arnold, D. C. Cox, A. J. Ruskako, Jr. - "Rain Attenuation at 10-30 GHz Along Earth Space Path: Elevation Angle, Frequency, Seasonal and Diurnal Effects." IEEE Transactions on Communication, Vol. COMM-29, No. 5, May 1981.
4. A. S. Acampora - "Rain Margin Improvements Using Resource Sharing in 12 GHz Satellite Downlinks." Bell Systems Technical Journal Vol. 60, No. 2, February 1981.
5. A. S. Acompora - "The Use of Resource Sharing and Coding to Increase the Capacity of Digital Satellites." IEEE Vol. SAC-1, No. 1, January 1983.
6. Wushow Chou - "Computer Communications." Prentice Hall, Inc., 1983.
7. Kamilo Feher - "Digital Communications." Prentice Hall, Inc., 1981.
8. A. Alper and C. Arleak - "Capacity Allocation and Reservation in Common-User Satellite Communication Systems with Reconfigurable Multi-Beam Antenna and a Non Liniar Repeater." IEEE Transaction on Communication, Vol. COM-28, No. 9, September 1980.
9. T. M. Aein, O. S. Kosouych - "Satellite Capacity Allocation." IEEE Proceedings, Vol. 65, No. 3, March 1977.
10. R. S. Lunayach, E. B. Knick, G. Kowalski - "User Capacity of a Demand-Assigned Satellite Communication System with a Hybrid TD/FDMA Up-link and a TDMA Down Link." IEEE Vehicular Technology, March 1983.
11. "A Unified Analysis of Psedonoise Synchronization by Envelop Correlation." IEEE Transactions on Communication, Vol. COM-25, No. 8, August 1977.

12. J. K. Holmes and C. C. Chen - Acquisition Time Performance of PN Spread Spectrum Systems." IEEE Transactions on Communication, Vol. COM-25, No. 8, August 1977.
13. D. Gross and C. M. Harris - "Fundamentals of Queueing Theory." John Wiley and Sons, 1974.
14. "EIA Interim Standards C15-3" July 1981.
15. R. S. Lunayach - "Spectral Efficiency of Mobile Radio Communication Systems"
16. "Predictions of Rain Effects on Satellite Communication Systems." Proceeding IEEE Vol. 65., No. 3.
17. "Some Measurements of Attenuation by Rainfall at 18.5 GHz" Bell Systems Technical Journal, Vol. 48.
18. Roy D. Rosner - "Packet Switching" Wadsworth, Inc., 1982.
19. R. C. Dixon - "Spread Spectrum Systems" John Wiley and Sons, Inc., 1976
20. Vyay Ahuja - "Design and Analysis of Computer Communication Networks." McGraw-Hill, Inc., 1982.
21. Federal Communication Commission, "Private Land Mobile Radio Service" Federal Register, Vol. 43, No. 226, November 1978.
22. M. Schawartz, W. R. Bennett, and S. Stein, "Communication Systems and Techniques," McGraw Hill, New York, 1965.
23. Roger I. Wilkinson, "Theories for Toll Traffic Engineering in the U.S.A.," Bell Systems Technical Journal, March, 1956.
24. Martin M. Peritsky, "Traffic Engineering of Combined Mobile Telephone and Dispatch System," IEEE Transaction on Vehicular Technology, November, 1973.
25. R. S. Lunayach, S. Elnoubi and S. C. Gupta, "Performance of Frequency Channel Assignment Schemes in Combined Mobile Telephone and Dispatch Systems," ICC 1980, Seattle, Washington, June 1980.
26. R. W. Nettleton and G. R. Cooper, "Error Performance of a Spread Spectrum Mobile Communication System in a Rapid Fading Environment," National Telecommunication Conference, Los Angeles, December 7.

**THIS BOOK
CONTAINS
NUMEROUS PAGES
THAT WERE
BOUND WITHOUT
PAGE NUMBERS.**

**THIS IS AS
RECEIVED FROM
CUSTOMER.**

```

DIMENSION NSET(20000)
COMMON/SCOM1/ATTRIB(100),DD(100),DDL(100),DTNOW,II,MFA,MSTOP,
1NCNLR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),TNEXT,TNOW,XX(100)
COMMON QSET(2000)
EQUIVALENCE (NSET(1),QSET(1))
NNSET=20000
NCRDR=5
NPRNT=6
NTAPE=7
CALL SLAM
STOP
END
//LKED.SYSIN DD DSN=DS4H3.SLAM.LINKLIB(SLAMNET),DISP=(OLD,KEEP)
//GO.SYSIN DD *
GEN,SUNIR KOCHHAR,RAIN FADE SIMULATION,05/21/83;
LIMITS,14,3,2500;
NETWORK;
#####
;
DECLARING THE RESOURCES AND GATES
#####
RESOURCE/SER(60),6,12;
GATE/G1,CLOSE,1;
GATE/G2,CLOSE,2;
GATE/G3,CLOSE,3;
GATE/G4,CLOSE,4;
GATE/G5,CLOSE,5;
GATE/DG1,CLOSE,7;
GATE/DG2,CLOSE,8;
GATE/DG3,CLOSE,9;
GATE/DG4,CLOSE,10;
GATE/DG5,CLOSE,11;
GATE/DG6,CLOSE,14;

CREATE,EXPON(1.0),1,,1;          CREATS A BULK ARRIVAL

ACT,,0.25,01;                     !
ACT,,0.38,02;                     !
ACT,,0.23,03;                     ! CHOOSES THE BULK SIZE
ACT,,0.09,04;                     !
ACT,,0.05,05;                     !

CREATE,0.01,,,2,1;
ACT,,,W2;
CREATE,0.01,,,4,1;
ACT,,,W3;
CREATE,0.01,,,6,1;
ACT,,,W4;
CREATE,0.01,,,8,1;
ACT,,,W5;

```

```

;
C1      CREATE;
        ACT,,,W1;
C2      CREATE;
        ACT,,,W2;
C3      CREATE;
        ACT,,,W3;
C4      CREATE;
        ACT,,,W4;
C5      CREATE;
        ACT,,,W5;
;*****
;*****
;*****      CREATING THE DYANAMIC ARRIVALS      *****
;*****
;*****
;
        CREATE,EXPON(.20),1,,,1;
;
        ACT,,,0.9,D01;
        ACT,,,0.025,D02;
        ACT,,,0.038,D03;
        ACT,,,0.023,D04;
        ACT,,,0.009,D05;
        ACT,,,0.005,D06;
;
        CREATE,0.01,,,1,1;
        ACT,,,DW1;
        CREATE,0.01,,,3,1;
        ACT,,,DW2;
        CREATE,0.01,,,7,1;
        ACT,,,DW3;
        CREATE,0.01,,,11,1;
        ACT,,,DW4;
        CREATE,0.01,,,15,1;
        ACT,,,DW5;
        CREATE,0.01,,,19,1;
        ACT,,,DW6;
;
DC1      CREATE;
        ACT,,,DW1;
DC2      CREATE;
        ACT,,,DW2;
DC3      CREATE;
        ACT,,,DW3;
DC4      CREATE;
        ACT,,,DW4;
DC5      CREATE;
        ACT,,,DW5;
DC6      CREATE;
        ACT,,,DW6;
;*****
;*****
;*****      OPENING AND CLOSING GATES FOR SCH      *****

```

```

; *****
; *****
01      OPEN, G1, 1;
        ACT, .01;
        CLOSE, G1, 1;
        TERM;
02      OPEN, G2, 1;
        ACT, .01;
        CLOSE, G2, 1;
        TERM;
03      OPEN, G3, 1;
        ACT, .01;
        CLOSE, G3, 1;
        TERM;
04      OPEN, G4, 1;
        ACT, .01;
        CLOSE, G4, 1;
        TERM;
05      OPEN, G5, 1;
        ACT, .01;
        CLOSE, G5, 1;
        TERM;
* * * * *
;      OPENING AND CLOSING GATES FOR DYANAMIC USERS
; * * * * *
D01     OPEN, DG1, 1;
        ACT, .01;
        CLOSE, DG1, 1;
        TERM;
D02     OPEN, DG2, 1;
        ACT, .01;
        CLOSE, DG2, 1;
        TERM;
D03     OPEN, DG3, 1;
        ACT, .01;
        CLOSE, DG3, 1;
        TERM;
D04     OPEN, DG4, 1;
        ACT, .01;
        CLOSE, DG4, 1;
        TERM;
D05     OPEN, DG5, 1;
        ACT, .01;
        CLOSE, DG5, 1;
        TERM;
D06     OPEN, DG6, 1;
        ACT, 0.01;
        CLOSE, DG6, 1;
        TERM;
; *****
; *****

```

```

; ***** AWAIT NODES FOR SCH SERVERS *****
; *****
; *****

W1      AWAIT(1),G1,1;
        ASSIGN,  ATRIB(1)=TNOW, ATRIB(2)=6, ATRIB(3)=1,2;
        ACT, .01,,C1;
        ACT,,,WT;
W2      AWAIT(2),G2,1;
        ASSIGN,  ATRIB(1)=TNOW, ATRIB(2)=6, ATRIB(3)=2,2;    THE ATRI
BS      ACT, .01,,C2;
        ACT,,,WT;
W3      AWAIT(3),G3,1;
        ASSIGN,  ATRIB(1)=TNOW, ATRIB(2)=6, ATRIB(3)=3,2;    THE ATRI
BS      ACT, .01,,C3;
        ACT,,,WT;
W4      AWAIT(4),G4,1;
        ASSIGN,  ATRIB(1)=TNOW, ATRIB(2)=6, ATRIB(3)=4,2;    THE ATRI
BS      ACT, .01,,C4;
        ACT,,,WT;
W5      AWAIT(5),G5,1;
        ASSIGN,  ATRIB(1)=TNOW, ATRIB(2)=6, ATRIB(3)=5,2;    THE ATRIB
S      ACT, .01,,C5;
        ACT,,,WT;
*****

;      WAITS FOR A SERVER TO BE FREE
;
*****

;
WT      AWAIT(6),SER/1,1;
        ASSIGN, ATRIB(1)=TNOW-ATRI(1),
        ATRIB(2)=ATRI(2)-ATRI(1),1;
        ACT,, ATRIB(2).LE.O,LOST;
        ACT,, ATRIB(2).GT.O,WTME;
WTME    COLCT, ATRIB(2),ACTUAL SER TIME,30/0/0.1,1;
        COLCT, ATRIB(1),WAITING TIME SCH,30/0/1,1;
        ACT,,,QUE;
; *****
; *****
; ***** AWAIT NODES FOR DYANAMIC SERVERS *****
; *****
; *****

```

```

DW1      AWAIT(7),DG1,1;
RIBS     ASSIGN,  ATRIB(1)=TNOW, ATRIB(2)=EXPON(3),2;    MARKING THE AT
        ACT,0.1,,DC1;
        ACT,,,DWT;

```

```

DW2      AWAIT(8),DG2,1;
RIBS     ASSIGN,  ATRIB(1)=TNOW,ATRI(2)=EXPON(3),2;  MARKING THE AT
          ACT,0.1,,DC2;
          ACT,,,DWT;
DW3      AWAIT(9),DG3,1;
RIBS     ASSIGN,  ATRIB(1)=TNOW,ATRI(2)=EXPON(3),2;  MARKING THE AT
          ACT,0.1,,DC3;
          ACT,,,DWT;
DW4      AWAIT(10),DG4,1;
RIBS     ASSIGN,  ATRIB(1)=TNOW,ATRI(2)=EXPON(3),2;  MARKING THE AT
          ACT,0.1,,DC4;
          ACT,,,DWT;
DW5      AWAIT(11),DG5,1;
RIBS     ASSIGN,  ATRIB(1)=TNOW,ATRI(2)=EXPON(3),2;  MARKING THE AT
          ACT,0.1,,DC5;
          ACT,,,DWT;
DW6      AWAIT(14),DG6,1;
          ASSIGN,  ATRIB(1)=TNOW,ATRI(2)=EXPON(3),2;
          ACT,0.1,,DC6;
          ACT,,,DWT;
*****
;         WAITS FOR 5 SERVERS TO BE FREE
;
*****
DWT      AWAIT(12),SER/6,1;
          FREE,SER/5,1;
          ASSIGN,ATRI(1)=TNOW-ATRI(1),1;
          COLCT,ATRI(1),DY WAIT TIME,30/0/1,1;
          ACT,,,QUE;
;=====
;
;         THE SERVICE
;=====
;
QUE      QUEUE(13);
          ACT(60)/1,ATRI(2);
          FREE,SER/1,1;
E        COLCT,ATRI(1),WAITING TIME,30/0/1;          THE OVERALL WAITING TIM
E        COLCT,ATRI(2),AVG SERVICE,30/0/1;          THE OVERALL SERVICE TIM
E
          ACT,,,ATRI(3).EQ.1,C01;
          ACT,,,ATRI(3).EQ.2,C02;
          ACT,,,ATRI(3).EQ.3,C03;
          ACT,,,ATRI(3).EQ.4,C04;

```

```
      ACT, , ATRIB(3).EQ.5, C05;  
      TERM;  
C01   COLCT, ATRIB(1), BLK 1 WAIT;  
      TERM;  
C02   COLCT, ATRIB(1), BLK 2 WAIT;  
      TERM;  
C03   COLCT, ATRIB(1), BLK 3 WAIT;  
      TERM;  
C04   COLCT, ATRIB(1), BLK 4 WAIT;  
      TERM;  
C05   COLCT, ATRIB(1), BLK 5 WAIT;  
      TERM;  
LOST  COLCT, BETWEEN, LOST;  
      FREE, SER/1, 1;  
      TERM;  
      ENDNETWORK;  
INIT, 0, 500;  
MONTR, CLEAR, 1;  
FIN;
```


RESOURCE SHARING FOR SATELLITE COMMUNICATION AND MOBILE COMMUNICATION NETWORKS

by

**SUNIR KOCHHAR
B.S. Birla Institute of Technology, India**

**AN ABSTRACT OF
A MASTERS THESIS**

**Submitted in Partial fulfillment of the
requirements for the degree**

MASTER OF SCIENCE

Department of Electrical Engineering

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1983

RESOURCE SHARING FOR SATELLITE COMMUNICATION AND MOBILE RADIO COMMUNICATION NETWORKS

Abstract

This thesis deals with the efficient resource utilization in satellite communication and mobile communication systems. Network response times are calculated for a spread spectrum satellite system with a large number of network terminals and a small number of network control terminals. Various aiding strategies are discussed and studies analytically and by computer simulations.

Signalling protocol for mobile radio communication systems is simulated to study the effect of mobiles behavioral pattern on spectral efficiency.

Schemes for resource sharing for a satellite communication system under raid fade situations are proposed and studies. Two classes of user, scheduled and dynamic are considered. Their performances have been studies using computer simulation techniques. The different schemes are compared with each other to show the advantages of the proposed schemes.