EFFICIENT SUPPORT OF CIRCUIT-MODE AND PACKET-MODE SERVICES IN MICRO-VSAT NETWORKS

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This paper studies the provision of low data rate services in Micro-VSAT networks such as the bandlimited quasi-synchronous CDMA VSAT system currently being developed by ESA. It presents the results of a simulation study intended to evaluate the performance impact of several system design choices. The simulated network (which is a generalization of the first-generation system planned by ESA) is required to support voice, fax, electronic mail, and other data services, both in circuit and packet mode, which have different requirements in terms of data rate, symmetric or asymmetric data flow, etc. These services have to be supported with a very limited number of communication channels, resulting in a potentially high call blocking probability. In this context, the paper evaluates the call blocking redwction that can be obtained, firstly by sending user packets and acknowledgements via signalling channels instead of via traffic channels, and secondly by dynamically sharing traffic channels among several networks coordinated by a central control station. The impact of these design choices on other performance indicators, for example the call setup delay and the signalling channel load, is also evaluated.

INTRODUCTION

This paper studies the provision of low and medium data rate services (below 64 Kbit/s) in Micro-VSAT networks. The reduced data rate allows significant economies in service and equipment cost compared to conventional VSAT networks, making these systems a cost-effective solution for some applications. In this context, the European Space Agency (ESA) has started the development of a Ku-band VSAT network based on an access technique called bandlimited quasi-synchronous (BLQS) CDMA, see De Gaudenzi et al (**?**), which in a first step will offer a voice service with in-band fax and data transmission capabilities. The first system generation is presently scheduled to be completed in 1995. The portable VSATs will utilize a 45 cm dish providing 16 Kbit/s toll-quality and half-rate voice. QS-CDMA allows for low power flux density emissions and robustness against co-frequency broadcasting satellite services (e.g. TV). See (**?**). At 16 Kbit/s, in-band fax and data services will also be provided. The Hub station will allow connections to the PSTN. Additional services will be included in the second system generation.

The paper presents the results of a simulation study, made on behalf of ESA during the initial phase of the system design, intended to evaluate the performance impact of different design choices. The reference network considered in our study, which is more general than the first system generation mentioned above, is required to support a mixture of teleservices, including voice, fax, electronic mail, and other data services, both in circuit and packet mode, and with different requirements in terms of data rate, symmetric or asymmetric data flow, etc. These services have to be supported with a very limited number of communication channels, e.g. frequencies or signature codes in the case of CDMA, so the mapping of services to channels is a critical design issue. For example, sometimes the user information can be sent in packet mode via the signalling channels of the system, see figure 1, without using the traffic channels, see figure 2. This would decrease the probability of a call being blocked due to lack of resources, at the cost of increasing the load in the signalling channels and, possibly, the call setup delay.

The simulation study described in this paper compared different channel assignmenv strategies and other related design choices, evaluating their influence on the system performance. (A companion paper in this Conference, see Azcorra et al (**?**), describes in more detail the service aspects and the protocol architecture of the VSAT network considered here.) In particular, the simulation compared two options for the support of asymmetric services such as fax or file transfer, namely: allocating traffic channels for both communication directions, versus allocating traffic channels only for the direction of the main data flow, and sending the information of the return direction (mainly acknowledgements) via the signalling channels. In the latter case, the effect of setting priorities for accessing the signalling channels, for example signalling messages with higher priority than user messages, was also evaluated. Some services, such as the transfer of short messages, are assumed to use the signalling channels in all cases.

The simulation considered also the possibility of sharing communication channels among several VSAT networks coordinated by a central control station. (In the real system there is already a central station which performs synchronization and general management functions.) Different schemes for the dynamic sharing of channels among networks were proposed and compared.

The paper is organized as follows. The next section describes in more detail the design alternatives introduced above, and formulates the objectives of the simulation study. The following section presents the simulation re-

FIGURE NOT AVAILABLE

Figure 1: Signalling Channels

FIGURE NOT AVAILABLE

Figure 2: Traffic Channels

sults and their implications for the system design. The last section summarizes the conclusions of the study.

DESIGN ISSUES AND SIMULATION OBJECTIVES

The simulations reported in this paper study the networking aspects of the BLQS-CDMA VSAT system with two objectives:

> First, to evaluate the performance impact of design choices such as the mapping of teleservices to carriers, the use of packet-mode teleservices, and the policy followed to allocate carriers to Mini-Hubs (MHs).
>
> Second, to optimize the system parameters, for example the number of carriers required for a given grade of service, the maximum packet traffic that may be admitted in the signalling carriers, etc.

The BLQS-CDMA VSAT network simulator, called CKN, has been developed with the simulation tool TOPNET, described in Ajmone et al (**?**). It models the calls and the packet traffic generated by the different teleservices supported by the system (see below), including the exchange of signalling messages required to establish and release these calls, as well as the allocation and deallocation of traffic carriers to the calls in progress. The simulator allows the user to study the behavior of one subnetwork (i.e. a group of VSATs linked to one Mini-Hub), or several subnetworks supervised by a central station (called NMS). In the latter case, the traffic carriers available in the system can be shared dynamically among the subnetworks. The control of the shared carriers is centralized in the NMS.

The topology of the system with the names of the different traffic and signalling carriers is shown in figures 1 and 2. The figures show only the VSAT users, but the system includes also *local users* which are connected to the MH via terrestrial networks.

The traffic load generated by the different teleservices, the number of MHs, and the number of carriers are part of the simulation parameters defined by the user. For a given configuration of parameter values, the simulator provides information about the system performance, for example the call setup delay, the call blocking probability, and the utilization of the signalling and traffic carriers. Where relevant, separate results are provided for each class of service class and each type of call: from a local to a VSAT user (MH-to-VSAT) or vice versa (VSAT-to-MH), and between two VSAT users via hub (VSAT-to-VSAT). A complete list of the simulation parameters and results is given in Alvarez and Vázquez (**?**). The parameter values selected in the present simulation study are defined in the next section.

Two main system design issues are investigated in the simulation study:

> Mapping of teleservicgs to bearer services
>
> Dynamic sharing of carriers among subnetworks

Mapping of Teleservices to Bearer Services

Azcorra and Vázquez (**?**) define the teleservices and bearer services available in the CKN system. There are several unidirectional and bidirectional bearer services, supported by traffic carriers (FCC and/or rCC), signalling carriers (PSC, CAC), or a combination of both. See table 1. The mapping of teleservices to bearer services can be defined in several ways. See table 2. This has an important impact on the usage of the system resources, and, therefore, on the system performance.

As indicated by the tables, voice and symmetric data services must use one or two dedicated traffic carriers for each direction of the communication. The short message teleservice T3 uses the signalling carriers in packet mode (provided that the total T3 traffic is low). However, there are two possible bearer services for the bidirectional asymmetric teleservices, namely fax, electronic mail, and other asymmetric data applications. These teleservices may use the bearer service B23, that is, traffic carriers, FCC or RCC, for its main traffic flow, and signalling carriers, CAC or PSC, for the acknowledgements sent in the opposite direction. Alternatively, the asymmetric teleservices may use B21 in the same way as the symmetric data applications. This second choice implies that traffic carriers are used both for the main traffic flow in one direction, and for the acknowledgements in the opposite direction.

The best solution in a particular system configuration will depend on the trade-off between using more traffic carriers per service, which increases the call blocking probability, and raising the load in the signalling carriers, which increases the call setup delay. This trade-off is investigated for different traffic loads and number of available traffic carriers in the simulation experiments presented in the next section.

Dynamic Sharing of Carriers Among Subnetworks

The second design aspect evaluated in the simulations is the possibility of sharing traffic carriers among several subnetworks. If the number of available FCCs/RCCs is limited, the probability of a call being blocked due to lack of carriers can be reduced if some of the available carriers are assigned dynamically to MHs during peaks of traffic. When the traffic is low, the carriers are returned to a common pool managed by the NMS. By using dynamic carrier assignment, each MH does not need to have a relatively high number of carriers permanently assigned to it in order to achieve a low call blocking probability.

There is a trade-off between the performance improvement and the implementation complexity of the dynamic carrier assignment mechanism. In particular, this mechanism requires a exchange of signalling messages between the MHs and the NMS, via the CRC and MSC carriers, in order to request additional carriers in periods of high traffic, and return them when the traffic decreases.

The CKN simulator implements a simple algorithm to decide when to request and return traffic carriers. The algorithm works independently for the FCCs and the RCCs, because the total traffic load supported by each type of carriers may be different. The algorithm is explained for the FCCs; the RCCs are handled in exactly the same way. Each MH has a number of FCCs initially allocated for its exclusive use. When the number of unused FCCs in a MH is below a certain minimum threshold, the MH requests a number of extra FCCs from the common pool managed by the NMS. Conversely, when the number of unused FCCs is above a certain maximum threshold in a MH, this MH returns part of the unused FCCs to the common pool.

The simulation experiments reported in the next section study the performance effects of this mechanism for a variable number of subnetworks and different values of the parameters that control the dynamic assignment procedure: minimum and maximum threshold of unused FCCs, number of carriers requested, and time interval between requests. As noted above, the parameter values may be different for the FCCs and for the RCCs.

SIMULATION EXPERIMENTS

The simulation experiments considered in this study are divided in two groups, corresponding to the two main system design aspects mentioned above, i.e. the mapping of teleservices to bearer services, and the dynamic sharing of traffic carriers among subnetworks. In the experiments of the first group, only one subnetwork is simulated. The performance of the system is evaluated for two configurations:

> Asymmetric teleservices mapped to bearer service B23. This means that the acknowledgements are sent via the signalling carriers PSC/CAC.
>
> Asymmetric teleservices mapped to B21. This means that the acknowledgements are sent via the traffic carriers FCC/RCC.

The impact of selecting different priorities for PSC/CAC access is evaluated in each configuration. The number of available FCCs/RCCs varies between 10 and 30. The traffic offered to the system varies from the nominal load values defined below up to 4 times that nominal load.

In the experiments of the second group, up to 4 subnetworks are simulated. The performance of the system is evaluated in the following scenarios:

> Sharing carriers among an increasing number of subnetworks (1, 2, and 4).
>
> Fixed number of subnetworks (4), but variable thresholds in the dynamic carrier assignment algorithm.

The number of FCC/RCC carriers initially available for the whole network varies between 10 and 20 FCC/RCC pairs per MH. Initially, each MH is assigned a number of carriers between 3 and 5. The number of FCCs or RCCs that can be requested or released in a single interaction MH–NMS is 2. Additional details are discussed later.

TABLE 1 - Bearer Services Simulated

Bearer service	Mode	Configuration	Carriers Used		
			MH VSAT	VSAT MH	VSAT VSAT
B11/B21	circuit	P-to-P symm.	1 FCC/1 RCC	1 RCC/1 FCC	2 FCCs/2 RCCs
B23	circuit	P-to-P asymm.	1 FCC/CAC	1 RCC/PSC	1 RCC/1 FCC/CAC/PSC
B12	circuit	P-to-Multip. unidir.	1 FCC	1 RCC	1 RCC/1 FCC
B32	packet	P-to-Multip. unidir.	PSC	CAC	CAC/PSC

TABLE 2 - Teleservices Simulated

Teleservice	Code	Mode	Configuration	Bearer
Voice	T1	circuit	point-to-point symmetric	B11
Fax	T2	circuit	point-to-point asymmetric	B21 or B23
Short messages	T3	packet	point-to-point symmetric	B32
Electronic mail	T4	circuit	point-to-point asymmetric	B21 or B23
Asymmetric data	T5A	circuit	point-to-point asymmetric	B21 or B23
Symmetric data	T5S	circuit	point-to-point symmetric	B21
Voice multicast	T6	circuit	point-to-multipoint unidirectional	B12

Parameter Values

There are several parameters that take the same values in all the simulation cases considered. By default, each MH has 25 local users and 100 VSATs. The *nominal* traffic load of the system is defined as follows. See Alvarez and Vázquez (**?**). The teleservices voice and symmetric data generate a total traffic load of 3 Erlang per MH each. This total traffic is divided into 1 Erlang for MH-to-VSAT calls, 1 Erlang for VSAT-to-MH calls, and 1 Erlang for VSAT-to-VSAT calls. The remaining circuit-mode, point-to-point teleservices, namely fax, electronic mail and asymmetric data, are assumed to generate 0.6 Erlang per MH each. As in the previous case, the traffic is split into three equal parts, one for each call type. The voice multicast traffic is 0.1 Erlang for MH-to-VSAT calls and 0.1 Erlang for VSAT?to-VSAT calls. (There are no multicast calls directed to the MH local users.) The call interarrival times follow an exponential distribution. The call durations are assumed to be uniformly distributed between 60 and 140 s. The resulting average call duration, 100 s, may correspond, for example, to a short voice call, a fax transmission with 4-5 pages, or the transfer of a file of 50 Koctets approximately.

Concerning the packet traffic due to the user applications and the signalling protocols, the short message service generates 0.2 packet/s for each of the three call types mentioned above. The message lengths are uniformly distributed between 10 and 90 octets. The acknowledgements of the asymmetric data services are 8 octets long. Each active call of any of these services generates acknowledgements with an interarrival time uniformly distributed between 0.25 and 0.75 s. (The acknowledgement traffic is only simulated when it is transmitted via the signalling carriers.)

The layer 3 signalling messages exchanged between the MH and the VSATs are short. The SETUP message, which initiates the call establishment procedure, has 44 octets. The remaining messages have between 14 and 20 octets. These lengths are incremented by the layer 2 protocol headers (8 octets), and, in the case of the CAC, by an acquisition preamble of 5 octets. Additionally, in each call, the first signalling message sent to a VSAT includes an extra overhead of 18 octets. See (**?**). The retransmission time-out for lost signalling messages is a uniform variable between 1 s and 1.5 s. The establishment and release of multicast calls use different signalling procedures. In this case, the signalling messages are not acknowledged by the multiple destinations. Therefore, each message is preventively repeated 2 times, with an interval between transmissions of 0.5 s, in order to increase the probability of correct message reception by all the destination users. The carrier allocation/deallocation messages exchanged between the MHs and the NMS have 7 octets, including the layer 2 protocol overhead. The minimum time between consecutive carrier reqwests from the same MH is 1 s. The details of the signalling protocols simulated in this study can be found in (**?**).

The capacity of each of the four signalling carriers is 4800 bit/s and the bit error rate is fixed at . When access priorities are used, the highest priority is assigned to the signalling messages, followed by the acknowledgements, and, at the lowest priority, by the short message service.

Support of Asymmetric Services

If the asymmetric teleservices fax (T2), electronic mail (T4), and asymmetric data (T5A) are mapped to bearer service B23, the main data flow of each call is sent via traffic carriers, and the acknowledgements are sent via the signalling carriers PSC/CAC. Alternatively, if the asymmetric teleservices are mapped to B21, both the main data flow and the acknowledgements use traffic carriers. Qualitatively, the former alternative should produce a reduction of the FCC/RCC utilization and the call blocking probability with respect to the latter, at the expense of an increase of PSC/CAC utilization and call setup delay (due to the higher load in the signalling carriers).

Call Blocking. The call blocking probabilities obtained by simulation in each of the two cases cited above are compared in figure 3 for 1 MH with nominal traffic load and using a variable number of traffic carriers. The reduction of call blocking obtained with B23 is significant for a small number of traffic carriers only.

FIGURE NOT AVAILABLE

Figure 3: Average Call Blocking vs Number of Traffic Carriers

The blocking probability is different depending on the direction of the call (VSAT to MH, MH to VSAT, or VSAT to VSAT), and the teleservice considered, because the number of traffic carriers required to establish a call is different in each case. Symmetric teleservices, namely voice (T1) and symmetric data (T5S), require one FCC and one RCC per call in the VSAT-to-MH and MH-to-VSAT directions, and two FCCs and two RCCs in the case of VSAT-to-VSAT calls. Therefore, the probability of a VSAT-to-VSAT call being blocked due to lack of traffic carriers is higher than in the other two cases. For example, in this case, the VSAT-to-VSAT call blocking probabilities are approximately 50 % higher than the average values displayed in figure 3.

With the asymmetric teleservices there are two possibilities. If they are supported by the bearer service B21, they use exactly the same number of FCC/RCC carriers as teleservices T1/T5S, so their blocking probabilities are the same. (White bars in figure 3.) However, if they are supported by the bearer service B23, they use only half of the traffic carriers required in the previous case, so their blocking probability is smaller than that of T1/T5S. (Compare the light and dark grey bars in figure 3.) The blocking probability for voice multicast calls (teleservice T6) is not shown in the figure, but it is similar to that of the asymmetric teleservices T2/T4/T5A when they use the bearer service B23.

It can be seen from figure 3 that, with the traffic values considered, it is necessary to have at least 15 or 20 FCC/RCC pairs to obtain a reasonably low call blocking probability. With more than 20 carriers the blocking reduction is very small. This is due to the fact that the MH returns unused traffic carriers to the NMS (according to the parameters of the dynamic carrier allocation mechanism). Therefore, even if the number of FCC/RCC carriers is very high, there is always the possibility of having a burst of call arrivals that makes the MH run out of free traffic carriers before it can receive more from the NMS.

The solid line curves in figure **??** show the average and 95-percentile of the number of FCC/RCC carriers *in use* by calls as a function of the total number of available FCCs/RCCs. The dotted line curves give the same statistics for the number of FCC/RCC carriers *allocated* to the MH.

As indicated by the call blocking statistics previously discussed, it can be seen that 20 FCC/RCC carriers is enough for the traffic load considered. (Although it is not shown in the figure, there is a slightly higher average utilization of FCC versus RCC carriers, due to the voice multicast traffic. This teleservice introduces a small asymmetry in the system, because multicast calls can only be established from a MH or a VSAT to a set of VSATs, but not from a VSAT to the MH.) The report (**?**) provides estimations of the probability distribution functions of the two variables considered in figure **??**.

Figure **??** corresponds to the case where the asymmetric services are mapped to the B23 bearer service. If B21 is used instead of B23, the number of traffic carriers allocated to the MH and the number of traffic carriers effectively used by calls increase by 10 % approximately.

FIGURE NOT AVAILABLE

Figure 4: Traffic Carrier Utilization. (Asymmetric Services Mapped Over B23.)

Figure **??** shows the increase of the call blocking probability versus the traffic load for VSAT-to-VSAT calls. In this case, there are 30 FCC/RCC pairs available to the MH. The values in the X axis indicate the traffic increase factor with respect to the nominal traffic load.

Call Setup Delay. As mentioned above, the bearer service used for asymmetric teleservices has an impact on the call setup delay. Figure **??** compares the delay obtained for each bearer service (B21 and B23) as a function of the traffic load. When B23 is used, the signalling messages have higher priority than the rest of the PSC/CAC traffic.

The call setup delay is measured since the signalling message SETUP is sent by the calling party until an ALERTING or CONNECT message is received. The lower call setup delay with B21 compared to B23 is caused by the PSC/CAC load reduction allowed by the use of bearer service B21 for asymmetric teleservices. The setup delay reduction, however, is relatively small, because even in the worst case (B23 and high traffic) the PSC/CAC load values are low. To illustrate this point, figure **??** compares the PSC and CAC utilizations for the bearer services B21 and B23.

In addition the the PSC/CAC utilization, (**?**) provides simulation results also for the number of retransmissions

FIGURE NOT AVAILABLE

Figure 5: VSAT-to-VSAT Call Blocking vs Traffic Load

FIGURE NOT AVAILABLE

Figure 6: Average Call Setup Delay vs Traffic Load

in the PSC and in the CAC. For example, for the highest traffic load, approximately 35 % of the messages have to be transmitted more than once when asymmetric services use B23. If they use B21 instead, this percentage is reduced to 24 %.

FIGURE NOT AVAILABLE

Figure 7: Signalling Carrier Utilization vs Traffic Load

Due to the low PSC/CAC carrier load in the system configurations simulated, the effect of giving a higher priority to the signalling messages is almost negligible. Consequently, the call setup delays without access priorities are very similar to the values shown in figure **??**. If priorities are suppressed, the worst-case delay increment, which occurs for VSAT-to-VSAT calls and high traffic values, is only 15 % approximately.

The utilization of the NMS signalling carriers (CRC and MSC) is below 5 % in all cases simulated. See (**?**).

Dynamic Sharing of Carriers

The second group of simulation experiments evaluated the reduction of call blocking probability allowed by the dynamic sharing of traffic carriers among several MHs. As explained in the preceding section, the carrier sharing algorithm is based on two thresholds. Initially, each MH has a certain number of carriers (FCCs and RCCs) allocated to it. When the number of unused carriers in a MH is below the minimum threshold *Min*, the MH requests additional carriers to the NMS. When that number is above the maximum threshold *Max*, some of the unused carriers are returned to the common pool.

Two simulation experiments are described below. In the first one, the parameters of the sharing algorithm are fixed. Each MH has 5 FCC/RCC pairs initially allocated to it. The minimum and maximum thresholds for the number of unused carriers are 2 and 5 respectively. FCCs and RCCs are requested or returned to the NMS in blocks of 2 carriers. In this situation, the expected behaviour is that the call blocking probability reduction will be more noticeable when there is a large number of MHs sharing carriers, or when the total number of traffic carriers in the system is small. This behaviour is confirmed by the results shown in figure **??**.

FIGURE NOT AVAILABLE

Figure 8: Call Blocking Reduction with Dynamic Carrier Sharing (parameters Min=2, Max=5)

As expected, 4 MHs gives the lowest call blocking, but note that with only 2 MHs there is already a significant call blocking reduction with respect to the case of 1 MH only. The call blocking values of figure **??** correspond to the symmetric teleservices voice (T1) and symmetric data (T5S) averaged for the three types of call (VSAT to MH, MH to VSAT, and VSAT to VSAT). The blocking probability values for each call type considered separately, as well as for the other teleservices, are similar to the ones presented here.

In the second experiment, the case of 4 MHs is taken as the reference to test different threshold values for the dynamic carrier allocation algorithm. See table **??**.

TABLE 3 - Parameters of the Carrier Sharing Algorithm

Minimum unused FCC/RCC	Maximum unused FCC/RCC
2	5
2	3
4	5

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Each combination of values has been simulated for 10, 15, and 20 FCC/RCC pairs per MH. Figure **??** shows the results obtained. As in the previous figure, the blocking probabilities shown correspond to the teleservices T1 and T5S, and are averaged over the three call origin-destination cases.

FIGURE NOT AVAILABLE

Figure 9: Comparison of Carrier Sharing Strategies with 4 MHs

In the first case listed in table **??**, the parameter values are the same as in the previous experiment. It is an intermediate situation between the two strategies listed below it. Qualitatively, the second case corresponds to an *altruistic* strategy where each MH keeps only a few unused FCCs/RCCs (between 2 and 3), returning the rest to the NMS for possible allocation to other MHs. In this way, the traffic carriers are shared more efficiently, but a given MH may easily run out of free traffic carriers if several calls arrive in a burst. In the third and last case, called the *egoistical* strategy, each MH is allowed to keep more unused FCCs/RCCs (between 4 and 5). This allows the MHs to keep a reserve of unused carriers to cope with call bursts; however, these carriers may remain unused in one MH while another one needs them.

According to the results obtained, see figure **??**, it seems that the altruistic strategy, i.e. returning unused FCCs/RCCs to the common pool as soon as possible, is better in terms of call blocking when the total number of shared carriers is small. If the number of carriers is bigger, the egoistical strategy, i.e. keeping a certain reserve of unused carriers, performs better.

CONCLUSIONS

The simulation experiments presented in this paper have investigated the performance of the BLQS-CDMA VSAT network for different traffic conditions and system configurations. Results have been provided both for external quality-of-service parameters (e.g. call blocking probability, call establishment delay), and for internal resource utilization indicators (e.g. wtilization of traffic carriers, load in the signalling carriers). Table **??** summarizes the system performance indicators evaluated in the study, indicating with an **x** the system parameters or design choices on which they depend.

One of the main design choices considered is which bearer service should be used to support asymmetric teleservices such as fax, e-mail, or file transfer. If bearer service B21 is chosen, traffic carriers are used for both communication directions. If B23 is used, traffic carriers are used only for the direction of the main data flow, and the acknowledgements transmitted in the opposite direction use the signalling carriers. In summary, opting for B23 instead of B21 gives lower call blocking probability and traffic carrier utilization, at the cost of higher call setup delay and PSC/CAC utilization. In the former case, B23, the effect of using priorities in the access to the signclling carriers is only a small reduction of call setup delay. Thus, the implementation of the priority mechanism seems to be justified only if the traffic in the PSC or CAC is very high, or there are bursts of T3 packets (or long packets of any kind) that cause too long queueing delays to the signalling messages.

The other important design choice evaluated in this study is the dynamic sharing of traffic carriers among several MHs coordinated by the NMS. This can be done with very little signalling traffic between the MHs and the NMS, and may provide significant call blocking reductions if the number of available FCC/RCC carriers is small. The last experiment presented in the paper, served to tune the parameters of the dynamic carrier sharing algorithm. It has been shown that the optimum parameter values depend on the total number of available FCC/RCC carriers.

TABLE 4 - Dependencies between Performance Indicators and System Parameters

	Quality of Service		Internal Performance Indicators			
System Parameters	Call Blocking	Setup Delay	PSC/CAC Load	Transfer delay in PSC/CAC	CRC/MSC Load	FCC/RCC utiliz
Circuit-Mode Traffic	x	x	x	x	x	x
T2/T4/T5A over B21/B23	x	x	x	x	x	x
Packet-Mode Traffic (T3)		x	x	x		
Priorities in CAC/PSC		x		x		
Dynamic carrier assignment	x				x	x
Number of FCC/RCC	x				x	x

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