Control Data Flow within the Analogue Concentrator of the IFS[1]

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1 The IFS Concept

IFS stands for 'Integrated Telecommunication System'. This PCM system is jointly developped in Switzerland by the PTT administration and its three manufactures of public telephone exchanges. As a SPC-switching system with centralized control, this communication system shall provide switched telephone and data service.

Transmission, switching and control are based on the 32 channel PCM system.

Figure 1 shows the IFS network configuration of one plane. Five different areas are to be distinguished:

- The *peripheral field*. It consists of analogue and digital subscriber stations together with their interconnecting lines, as well as analogue or digital trunks.
- The *concentration field* performs the traffic concentration (analogue concentrator AKT and digital concentrator DKT) of the subscriber lines, analogue to digital conversion by means of the terminals T. The concentrators perform functions for call establishment and clearing which are discussed later.
- The *switching network* performs the interconnection of 64 kbps PCM channels by means of the digital switching units (DE).
- The *processor field* consists of the central processor (ZS) and so called telegram units (TE) for control data interchange with all controlled units. The register unit WE is for the processing of signalling information.
- The *service field* is for maintenance and operating functions.

To secure operation and to achieve a high degree of availability the so called multi-plane principle *(Fig. 2)* is introduced. This principle means that four planes, one of which is Figure 1, are completely equipped and are working according to a load sharing mode with respect to originated calls. Therefore, each concentrator is connected to these four planes.

More details about IFS can be found in [1...7].

This paper presents a study on the flow of control information and the performance of the control of the analogue concentrator AKT of the IFS.

2 Structure and Operating Mode of the Concentrator

21 Structure of the AKT

Figure 3 shows the basic structure of the concentrator and its environment. Subscribers are connected to the analogue switching array via subscriber circuits (SC). The switching array performs a concentration of the subscriber lines to the outgoing trunks, which are connected to the switching array via line circuits (LC). The trunks are partitioned into four groups, leading to four switching fields within the four planes of the IFS. The subscriber and line circuits are scanned by the concentrator control.

All switching and control functions within the concentrator are performed by the concentrator control CC, which consists for reasons of reliability of *two* microprocessors (PR0, PR1) and *two* signalling units (SU0, SU1), also microprocessor controlled for control information interchange with the central control units in the processor fields of the four planes.

22 Operating Mode of the Concentrator

The concentrator control handles three different types of requests, which are listed in order of priority:

- *Connect requests (CN).* For call attempts, who need a connection to a called (B) subscriber, connected to the considered concentrator, the central control unit, responsible for this call, sends control information (connect request) via the control information channel to a SU. For the following it is assumed that signalling unit SU0 is responsible for control data channels from planes 1+2, and SU1 for planes 3+4. The SU preprocesses this information and fills it into the storage location of the input buffer (IB) of the considered plane.

The CC tries to find a path through the switching array from the free SC of the called subscriber to a free trunk (LC) leading to the appropriate plane. The connect request is acknowledged either positive if the throughconnection is possible or negative if congestion occurs.

- *Clear requests (CL).* Clear requests are generated if a connection terminates and the occupied paths and trunks have to be released. The clear request is indicated within the LC and detected by means of scanning the LC under control of the CC.

The mechanism for scanning LC's can be seen in *Figure 4.* If a clear request has been detected during the last scan cycle at LC x, scanning starts at LC x+1. As-

[1] This article is based on investigations carried out while Dr. Wizgall and Dr. Kraemer had been with the Institute of Switching and Data Technics of the University of Stuttgart. With reference to the Paper presented at the '9th International Teletraffic Congress' on 1979 in Torremolinos, Spain.

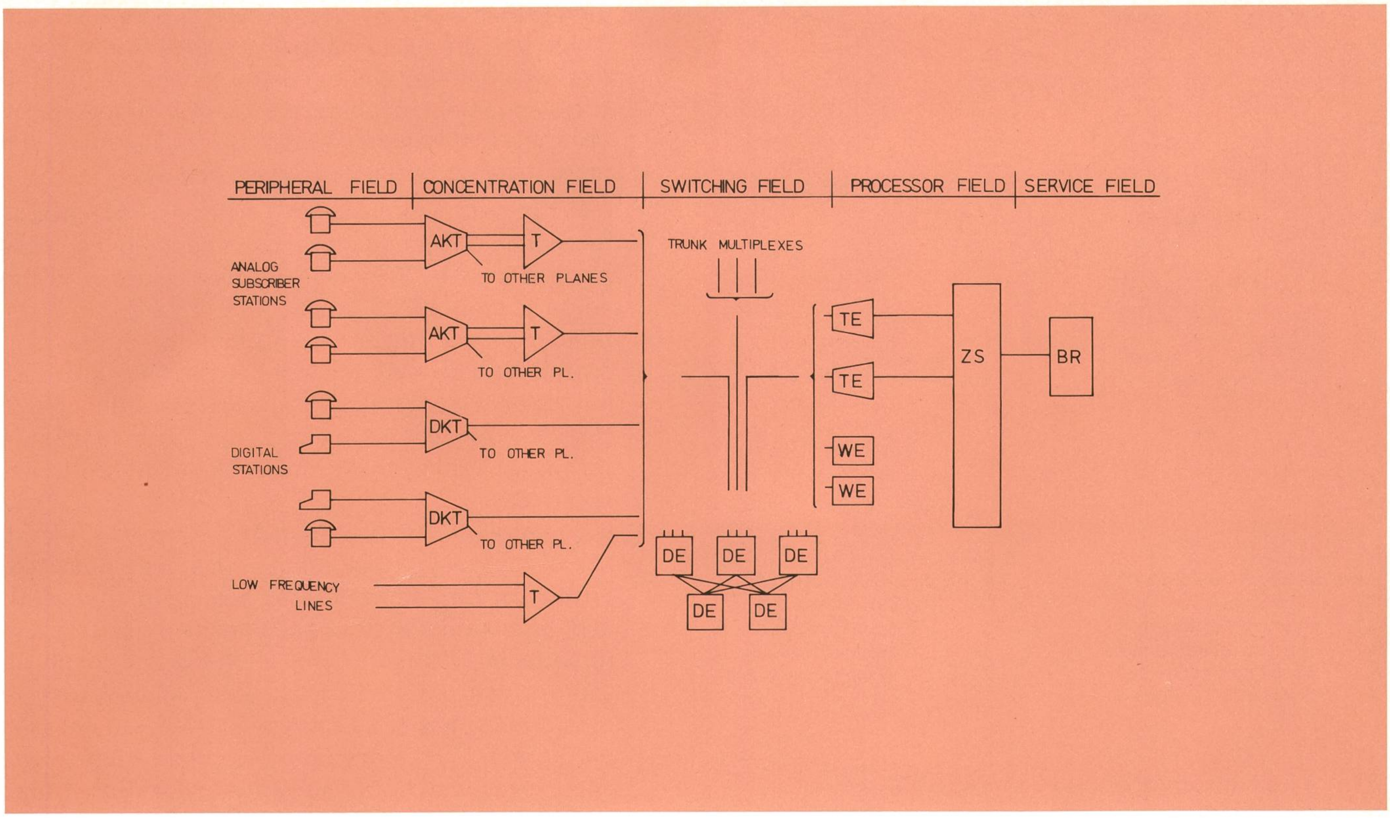

Fig. 1
IFS Network Structure of one Plane

AKT	Analog concentrator
T	Terminal
DKT	Digital concentrator
TE	Telegram unit
ZS	Central processor
BR	Maintenance center computer
WE	Register unit
DE	Digital switching unit

sume that at LC y the first clear request with respect to the scan direction is waiting, then the scanning stops at the LC y. The next scan-cycle will then start at y+1. Therefore, the time needed by the CC for scanning, which is a linear function of the scan-distance [in this case $[N+y-(x+1)+1]_{\mathrm{modN}}$], is not constant.

- *Call requests (CA).* Call requests are generated by subscribers, connected to the considered AKT, which want to place a call. The call request is indicated within the SC and also detected by means of scanning.

The mechanism for scanning SC's can be seen in *Figure 5.* This mechanism is very similar to that of the LC scanning, but the scan distance, and, therefore, also the scan time is constant, as always all SC's are scanned. This is necessary for technical reasons. The first detected call request is stored for later processing. The CC tries, similar to the case of connect requests, to find a path and a free outgoing trunk. In contrast to the case of connect requests, the trunk can be choosen arbitrarily from *all* trunks connected to the AKT. By cyclic testing, a balance of occupied trunks to all planes can be achieved.

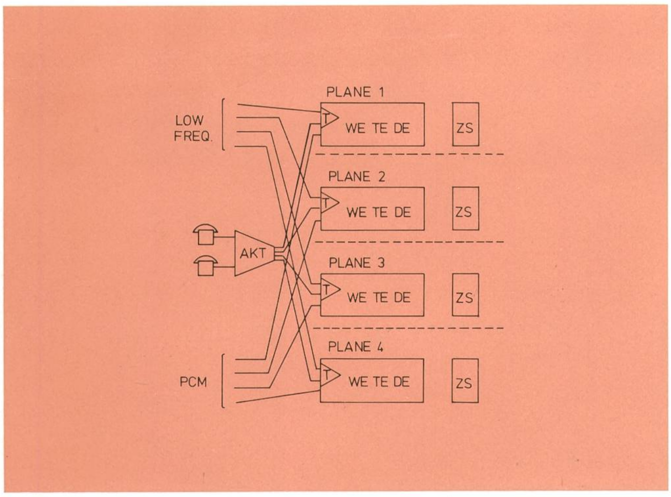

Fig. 2
The Multiplane Structure of the System IFS

T	Terminal
WE	Register unit
TE	Telegram unit
DE	Digital switching unit
ZS	Central processor
AKT	Analog concentrator
PCM	Pulse code modulation

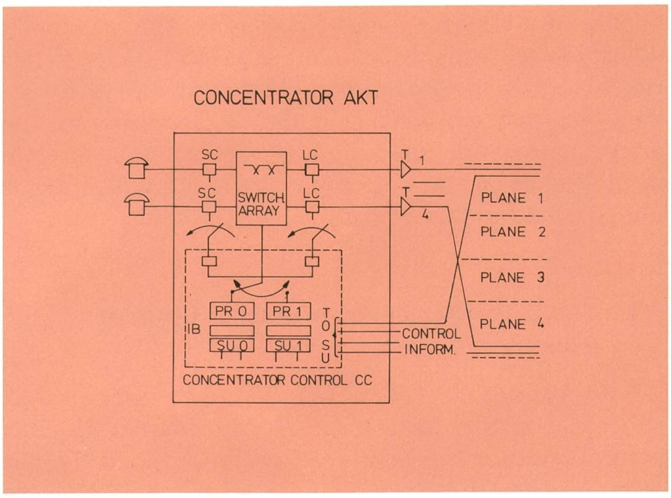

Fig. 3
Basic Structure of the Concentrator AKT

SC	Subscriber circuit
LC	Line circuit
PR	Processor of CC
IB	Input buffer
SU	Signalling unit
CC	Concentrator control
T	Terminal

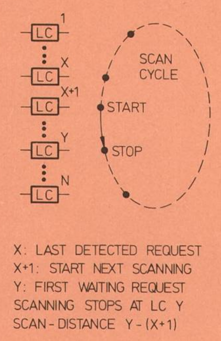

Fig. 4

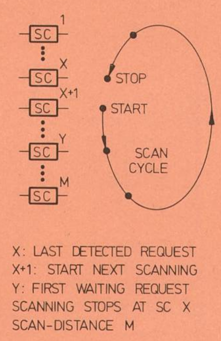

Fig. 5

Fig. 4
Principle of LC Scanning
LC Line circuit
SC Subscriber circuit
X Last detected request
X+1 Start next scanning
Y First waiting request

Fig. 5
Principle of SC Scanning
SC Subscriber circuit
X Last detected request
X+1 Start next scanning
Y First waiting request

23 The Control Concept of the AKT

231 The Principle of the Control Phase

Each of the two processors of the concentrator control can be in an 'active' or 'passive' control phase *(Fig. 6)*. If one processor is active, the other has to be passive. Access to the switching array is only possible within an active control phase. During an active control phase a sequence of tasks, as described in chapter 232, is performed. The other processor, being in the passive status, looks for connect requests in his input buffer IB. This mode of operation with two working processors will be denoted as normal operation mode (NOM). In this mode processor 0 (PR0), as assumed previously, is only able to process connect requests from planes 1+2, PR1 from planes 3+4. In case of failure of one processor, the error operation mode (EOM) is set up.

The error-free processor (PR0 in Fig. 6) performs the normal functions during his active control phase. The next active control phase starts after the end of the preceding control phase, plus a short constant time, during which the processor is set into the passive status. In this passive phase the processor tests, among others, if connect requests are waiting in the IB. Furthermore, the working processor can now serve connect requests from *all* planes, as control data channels from the four planes are switched to this processor.

232 The Different Types of Active Control Phases

Four types of control phases have to be distinguished according to the tasks to be performed *(Fig. 7)*. Each control phase starts with a selftesting program (T), this lasts t_T. Then subscriber circuit scanning (SS) takes place, lasting t_{SS}.

a) If a connect request from one of the two planes for which the active processor is responsible is waiting, this request will be served. During the time t_{PS} a path search program is running. This program is finished with an acknowledgement (positive or negative) which is sent to the central processor. This acknowledgement enables the central processor to send a new request if necessary. Therefore not more than one request per plane can wait.

If the path searching (PS) has been successful, the switching function for the connect request takes place during t_E. This type of control phase is denoted as type 'CN'.

b) If no connect request is waiting (or if the path search for a connect request has not been successful), line circuit scanning (LS) takes place during t_{LS}.

b1) If a clear request is detected, that clear request is processed during t_C. The type of this phase is denoted 'CL'.

b2) If no clear request is detected, it is tested if during the SC scanning a call request has been detected. In this case a path and trunk searching starts (PS) and afterwards a throughconnecting takes place (time t_E) or in case of congestion the control phase is terminated. This control phase is denoted 'CA'.

c) If no request has to be served, an overhead phase is performed. This is necessary for technical reasons and causes, that an active phase is not shorter than a given minimal time. This phase is denoted 'NOP'.

These different types of active control phases will be further clarified in the following.

3 Investigations by Means of Simulation

31 The Simulation Model

Figure 8 shows the model of the concentrator control as a queuing model. As in the normal operation mode NOM only one processor is active during a control phase, only one processor has been depicted.

This processor represents

- for the NOM the momentarily active processor
- for the EOM the only active processor

The already mentioned tasks of the processor are represented by square boxes in Figure 8. Furthermore, the four control channels to the central processors of the four planes are modelled. The model of *one* control channel consists of an output buffer into which requests from the central processor are filled with rate $\lambda_{CN,i}$. The

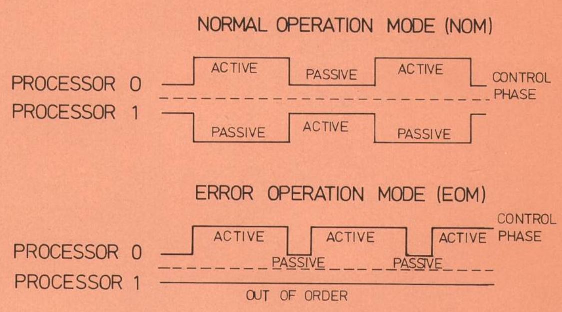

Fig. 6
The Control Phase Principle

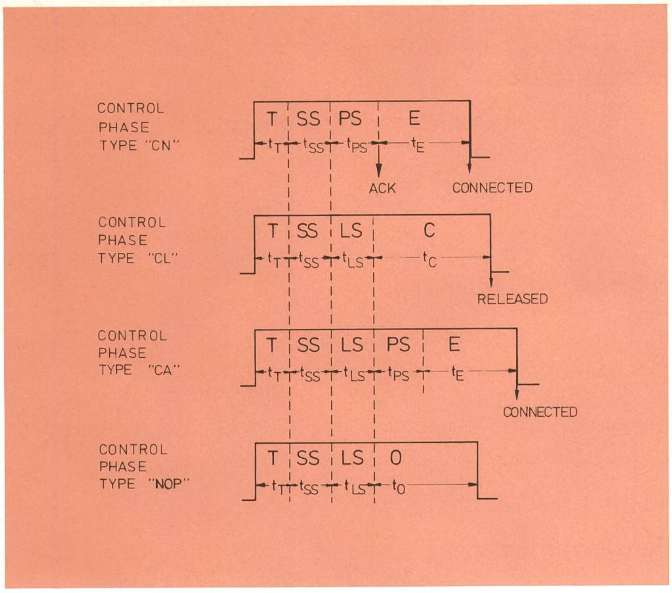

Fig. 7
The Different Types of Active Control Phases

T	Self testing program	O	Overhead
SS	Subscriber circuit scanning	CN	Connect request
PS	Path search	CL	Clear request
E	Throughconnecting	CA	Call request
ACK	Acknowledgement	NOP	No-operation
LS	Line circuit scanning		
C	Clear of a connection		

transmission delay of control information from the output buffer to the buffers IB of the concentrator is modelled by means of the constant delay time t_{TD}. Only one request is allowed to wait in the buffers IB for each plane until an acknowledgement is sent to the central processor of the pertinent plane via a backward control channel. This acknowledgement has also the constant delay time t_{TD}.

The operation of the control within the model is in accordance to that described in chapter 23.

LC and SC scanning is modelled in detail. In contrast to the real system, only the trunks are modelled with respect to free or busy, having holding times of t_h after each seizure. The switching network is assumed to be non-blocking and has therefore not to be modelled here.

32 The Simulation Program

The simulation program has been written in ALGOL and comprises 13k statements and appr. 1k data array, together about 42 kbyte main store. The program uses code procedures for time consuming simulation functions. Run time is about one hour CPU time on a computer with a typical execution time for a statement of 6 µs for a large number of test calls.

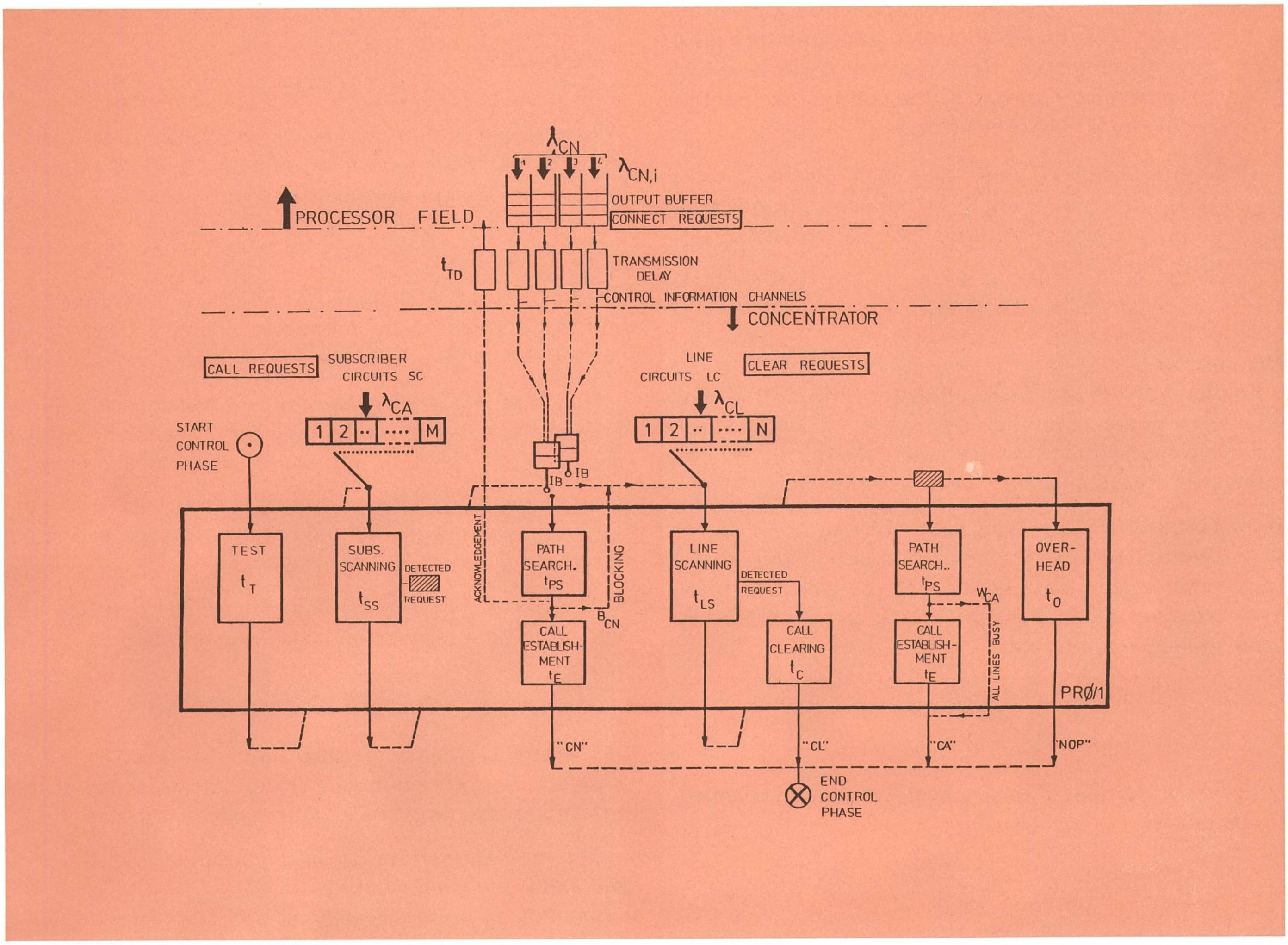

Fig. 8
The Simulation Model of the Concentrator AKT

PR0/1	Processor	CN	Connect request
W_{CA}	Probability that the control has to perform another attempt to serve a call request	CL	Clear request
IB	Input buffer	CA	Call request
LC	Line circuit	NOP	No-operation

33 Definition of Characteristic Traffic Parameters

The aim of the investigation is to obtain characteristic traffic parameters of the control. The following values, among others, are obtained.

Waiting Times:

$t_{w,CN}$ Mean waiting time of all connect requests. This time starts with entering of a request into input buffer IB and ends with sending the acknowledgement.

$t_{w,CL}$ Mean waiting time of all clear requests. This time starts with the originating of a clear request within the LC and ends with the release of the LC. The time from going on-hook until the clear request is generated within the LC is $t_{D,C}$. This time can be considered as constant.

The release of the SC, belonging to this connection, has to be done during a SC-scan routine. For technical reasons this is only possible after a time $t_{RS,MIN}$. The actual time between release of LC and release of the pertinent SC is t_{RS}. Therefore, the total time from being on-hook until LC and SC are released is

$$t_{D,R} = t_{D,C} + t_{w,CL} + t_{RS}$$

$t_{w,CA}$ Mean waiting time for call requests. This is the time, a SC is occupied until a path to a free LC is throughconnected. This time may enclose several unsuccessful attempts of the control [in case that no idle trunk (LC) is available].

With these waiting times and their pertinent rates (λ_{CN}, λ_{CL}, λ_{CA}) the queue length or the mean number of simultaneously waiting requests can be calculated according to the formula

$$\text{mean queue length} = \lambda \cdot t_w$$

Occupancy

The load of the processors PR0 and PR1 is of special interest. It depends on the rates λ_{CN}, λ_{CL}, λ_{CA} and on the following parameters, which are determined by the number of trunks and their carried traffic load:

B_{CN} Probability of loss for connect requests.

W_{CA} Probability, that the control has to perform another attempt to serve a call request (due to all trunks busy). It is assumed, that call attempts wait until they are served.

In the stationary case it holds

$$\lambda_{CL} = \lambda_{CA} + (1 - B_{CN}) \cdot \lambda_{CN}$$

The mean number of unsuccessful attempts to serve a single call is

$$\frac{W_{CA}}{1 - W_{CA}}$$

If t_{DC} denotes the mean duration of an active control phase, then $1/t_{DC}$ is the (a priori unknown) rate, with which control phases are started. Therefore, the rate of LC-scanning is

$$\lambda_{LS} = 1/t_{DC} - (1 - B_{CN}) \cdot \lambda_{CN}$$

because call establishment for connect requests [rate $(1 - B_{CN}) \cdot \lambda_{CN}$] excludes LC-scanning within the same control phase.

The rate with which a control phase of the type CA occurs is

$$\lambda_{CA,TOT} = [1/(1 - W_{CA})] \cdot \lambda_{CA}$$

Therefore the number of control phases of the type NOP within a given time is

$$\lambda_{NOP} = \lambda_{LS} - \lambda_{CL} - \lambda_{CA,TOT}$$

The occupancy Y of the processor is defined as the processor time necessary for a certain task related to the length of an active control phase:

Testing $\quad Y_T = t_T / t_{DC}$

Subscriber scanning

$$Y_{SS} = t_{SS} / t_{DC}$$

Connect requests

$$Y_{CN} = \lambda_{CN} \cdot [B_{CN} \cdot t_{PS} + (1 - B_{CN}) \cdot (t_{PS} + t_E)]$$

Clear requests

$$Y_{CL} = \lambda_{CL} \cdot t_C$$

LC-scanning

$$Y_{LS} = \lambda_{LS} \cdot g \cdot t_{LS} \cdot$$

$g \cdot t_{LS}$ is the traffic dependent mean time for LC-scanning

Call requests

$$Y_{CA} = \lambda_{CA} \cdot [t_E + (1 + W_{CA}/(1 - W_{CA}))t_{PS}]$$

In contrast to that, the overhead phase is not considered as real load, so that the effective load of an active processor during a control phase is

$$Y_{PR} = Y_T + Y_{SS} + Y_{CN} + Y_{LS} + Y_{CL} + Y_{CA} = 1 - \lambda_{NOP} \cdot t_O = 1 - Y_O$$

After having described the structure and operating mode of the model, the stochastic characteristics of the arrival and service processes have to be characterized.

It is assumed, that all service and transmission times are constant, excluding the time for LC-scanning, which is calculated within the simulation program by means of the scan distance.

The arrival process for call requests is assumed to be a poissonian process with rate λ_{CA}.

The arrival process for connect requests is also assumed to be a poissonian process with rate

$$\lambda_{CN} = \sum_{i=1}^{4} \lambda_{CN,i} \text{ with } \lambda_{CN,1} = \lambda_{CN,2} = \lambda_{CN,3} = \lambda_{CN,4}$$

The arrival process for clear requests (rate λ_{CL}) is also a poissonian process because the holding times of the trunks are also negative exponentially distributed.

The momentary rate $\lambda_{CL,MOM}$ is a function of the momentarily occupied trunks Z:

$$\lambda_{CL,MOM} = Z \cdot 1/t_h$$

with t_h = mean holding time of a trunk after seizure.

The carried traffic on the trunks is

$$Y_{TR} = [\lambda_{CA} + (1 - B_{CN}) \cdot \lambda_{CN}] \cdot t_h$$

Table I. List of Input Parameters

Input Parameter	Maxi	Mini
Number of subscriber circuits M	8192	1024
Number of line circuits N	2048	128
Mean holding time t_h	150 s	150 s
Time for testing t_T	5 ms	5 ms
Time for scanning all SC t_{SS}	15 ms	3 ms
Time for path search t_{PS}	8 ms	8 ms
Time for call establishment t_E	25 ms	25 ms
Time for scanning all LC, t_{LS}	8 ms	1 ms
Time for clearing t_C	26 ms	26 ms
Overheadtime t_0	12 ms	31 ms
Time to set clear request $t_{D,\,C}$	178 ms	178 ms
Minimal time to release SC $t_{RS,\,MIN}$	50 ms	50 ms
Mean transfer time t_{TD}	16 ms	16 ms
Time for passive phase in case of EOM	1 ms	1 ms

Table I gives a list of the input parameters together with values for two sizes of the concentrator (MAXI, MINI).

34 Results

Waiting times

Figure 9 shows the mean waiting times for connect requests $t_{w,CN}$ for the concentrator sizes MAXI and MINI as a function of the request rate for call establishments

$$\lambda = \lambda_{CN} + \lambda_{CA} \quad \text{with } \lambda_{CN} = \lambda_{CA}$$

Figures 10 and 11 show the mean waiting times for clear requests $t_{w,CL}$ and the mean waiting times for call requests $t_{w,CA}$, respectively.

As expected, the waiting times increase for the size MAXI with the request rate λ.

Due to the priorities for the different kinds of requests, the waiting times for connect requests (CN) are

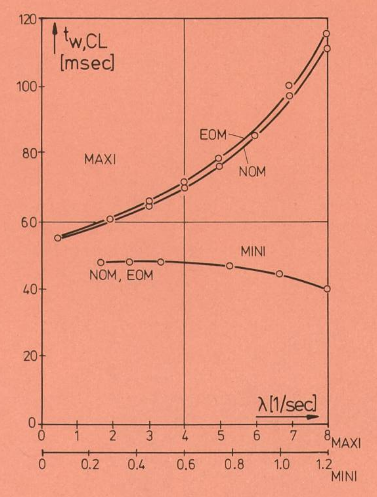

Fig. 10
Mean Waiting Time for Clear Request
EOM Error operation mode
MAXI Maximal
NOM Normal operation mode
MINI Minimal
$t_{w,CL}$ Mean waiting time of all clear requests

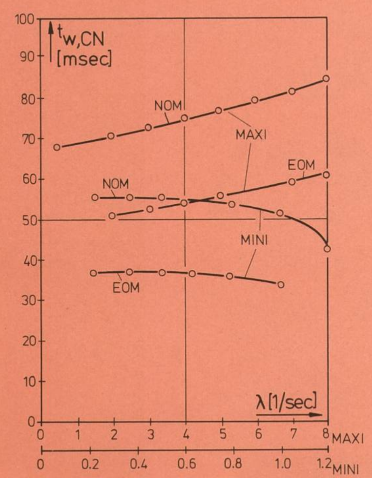

Fig. 9
Mean Waiting Time for Connect Requests
$t_{w,CN}$ Mean waiting time of all connect requests
NOM Normal operation mode
MAXI Maximal
EOM Error operation mode
MINI Minimal

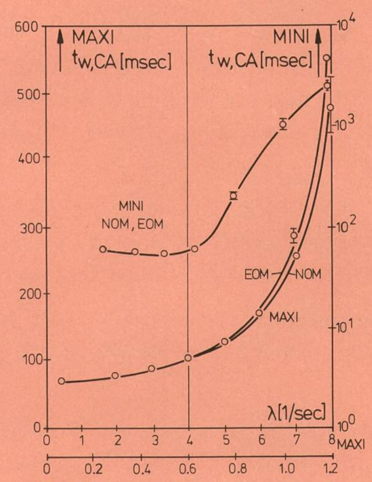

Fig. 11
Mean Waiting Time for Call Requests
MAXI Maximal
MINI Minimal
$t_{w,CA}$ Mean waiting time of all call requests
NOM Normal operation mode
EOM Error operation mode

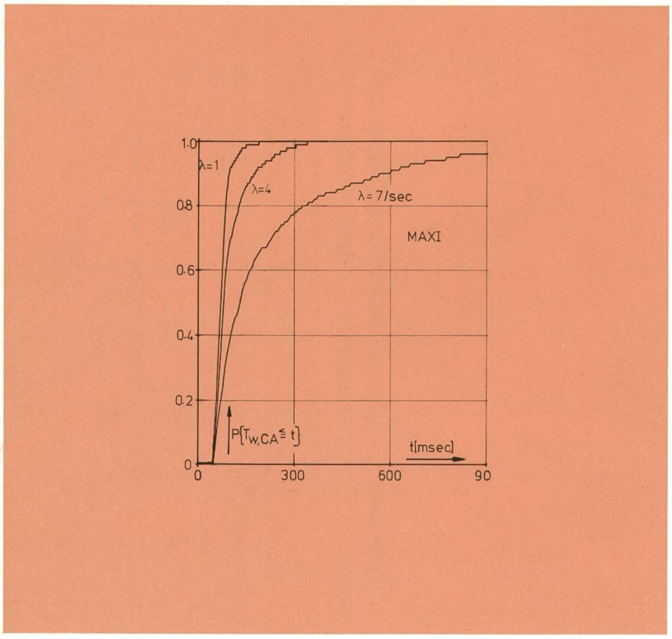

Fig. 12
Distribution Function of the Waiting Times for Call Requests
MAXI Maximal
$P\{T_{w,CA} \leqq t\}$ Probability that waiting is time less or equal to t

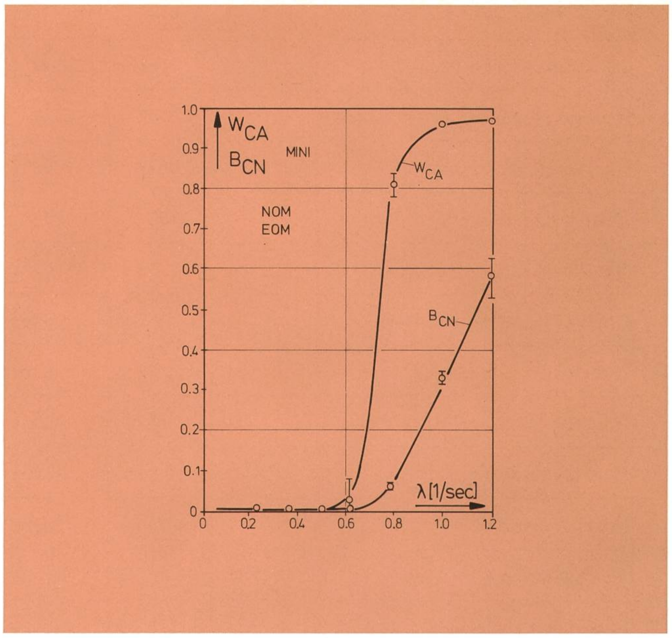

Fig. 13
Probability of Loss and Probability of Repeat for Connect and Call Requests

MINI	Minimal
NOM	Normal operation mode
EOM	Error operation mode
W_{CA}	Probability that the control has to perform another attempt to serve a call request
B_{CN}	Probability of loss for connect requests

the lowest, whereas the waiting times for call requests (CA) are the highest due to their lowest priority.

The difference between the waiting times for connect requests $t_{w,CN}$ in the normal operation mode (NOM) and the error operation mode (EOM) is due to the fact, that in the NOM each processor can only serve half of the connect requests (PR0 the requests from plane 1+2, PR1 from plane 3+4), whereas in the EOM each processor can serve each connect request.

Figure 12 shows the distribution function for waiting times for call requests $P\{T_{w,CA} \leqq t\}$ for the rates $\lambda = 1,4,7$ for the size MAXI.

In the case of the concentrator size MINI, the waiting times for connect and clear requests are decreasing with λ *(Fig. 10)*.

To explain this phenomena, *Figure 13* shows the probability of loss for connect requests (B_{CN}) and the probability that a call request is not served (W_{CA}) respectively for the size MINI.

For values of λ higher than 0.5 the probability of all trunks busy increases rapidly. Due to this fact, the mean duration of an active control phase decreases.

It should be mentioned however, that the engineered values for λ are 4 in case of MAXI and 0.5 in case of MINI.

Figure 14 shows the occupancy of the processor Y_{PR} as a function of λ for the sizes MAXI, MINI.

The occupancy of the processor is for $\lambda = 0$ according to the definition and the fact that only control phases of type NOP are performed

$$Y_{PR} = \frac{t_T + t_{SS} + t_{LS}}{t_T + t_{SS} + t_{LS} + t_O}$$

that is for the size MAXI 28/40 = 0.7 and for the size MINI 9/40 = 0.225.

As for the size MAXI and the considered values of λ, B_{CN} and W_{CA} are equal to 0, Y_{PR} is a linear function of λ.

In the case of size MINI, Y_{PR} also rises linearly as long as there are no losses or repetitions.

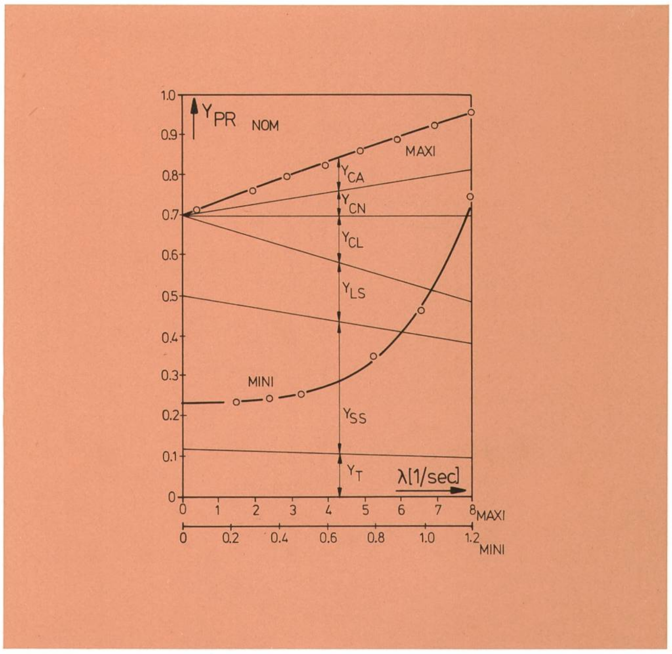

Fig. 14
Occupancy of the Control

Y_{PR}	Load of an active processor
NOM	Normal operation mode
MAXI	Maximal
Y_{CA}	Load of call requests
Y_{CN}	Load of connect requests
Y_{CL}	Load of clear requests
Y_{LS}	Load of line circuit scanning
MINI	Minimal
Y_{SS}	Load of subscriber circuit scanning
Y_T	Load of selftesting program

Furthermore, the total load Y_{PR} is split into the different parts due to the different tasks of the processor to be performed (chapter 33).

4 Investigation by Means of Calculation

41 Model 1

The first model to calculate interesting parameters is a single server queuing model *(Fig. 15)* with

- one class (type) of requests, served according to a FIFO strategy
- Poisson input, rate λ'
- infinite buffer
- clocked service with generally distributed clock periods, with mean τ and coefficient of variation v

To take into account the priorities of the requests in the real system (chapter 22), a constant factor p is introduced. p is identified with the probability, that in the considered clock period no request with higher priority has to be served. Therefore p is the probability that the first waiting request within the queue may begin service at the next clock instant.

If the service starts, it will be finished in any case before the next clock instant, having a constant service time t_s (Fig. 15).

The probability p has to be calculated for the three different types of requests in the system (CN,CL,CA) *(Tab. II)*.

The following parameters can be calculated

- probability, that the queue length Q just before a clock instant is greater than 0

$$p(Q>0)=\lambda'\tau/p$$

- mean queue length E(Q) just before the clock instant

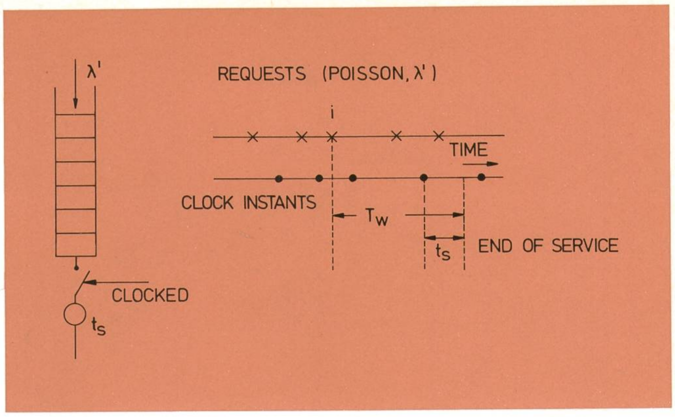

Fig. 15
Model 1 for Calculation

$$E(Q)=\frac{\lambda'\tau[2-\lambda'\tau(1-v^2)]}{2(p-\lambda'\tau)}$$

- mean waiting time t_w. (The waiting time of a request starts with inserting the request into the buffer and ends after the service of this request.)

$$t_w=\frac{\tau[2-p(1-v^2)]}{2(p-\lambda'\tau)}+t_s$$

To calculate the parameters for the concentrator control, the following relations are assumed for t_s (Fig. 7 and Tab. I)

- for CN-requests $t_{s,\,CN}=t_T+t_{SS}+t_{PS}$
- for CL-requests $t_{s,\,CL}=t_{LS}/2+t_C$
- for CA-requests $t_{s,\,CA}=t_{SS}+t_{LS}+t_{PS}+t_E$

The coefficient of variation is neglected in the following.

Table II shows the formulae to calculate the parameters for the three types of requests, CN,CL,CA.

Figures 16...18 show the calculated values (solid lines) together with the simulated values (circles) for the waiting times $t_{w,\,CN}, t_{w,\,CL}, t_{w,\,CA}$

Table II. Formulae for Characteristic Values (Size MAXI, times in ms)

Type of Request	Operation Mode	Parameter				Characteristic Values from Equation
		λ'	τ	t_s	p	
CN Connect Requests	NOM Normal Operation Mode	$\frac{\lambda}{4}$	$2t_{DC}$	28	1	$P(Q>0)=P_{CN}=\frac{\lambda t_{DC}}{2}$ $t_{w,CN}=\frac{t_{DC}}{1-\lambda t_{DC}/2}+t_s$
CN Connect Requests	EOM Error Operation Mode	$\frac{\lambda}{2}$	t_{DC}	28	1	$P(Q>0)=P_{CN}=\frac{\lambda t_{DC}}{2}$ $t_{w,CN}=\frac{t_{DC}}{2(1-\lambda t_{DC}/2)}+t_s$
CL Clear Requests	NOM Normal Operation Mode	λ	t_{DC}	30	$1-P_{CN}$	$P(Q>0)=P_{CL}=\frac{\lambda t_{DC}}{1-\lambda t_{DC}/2}$ $t_{w,CL}=\frac{t_{DC}(1+\lambda t_{DC}/2)}{2-3\lambda t_{DC}}+t_s$
CA Call Requests	NOM Normal Operation Mode	$\frac{\lambda}{2}$	t_{DC}	56	$(1-P_{CN})(1-P_{CL})$	$P(Q>0)=P_{CA}=\frac{\lambda t_{DC}}{2-3\lambda t_{DC}}$ $t_{w,CA}=\frac{t_{DC}(1+3\lambda t_{DC}/2)}{2(1-2\lambda t_{DC})}+t_s$

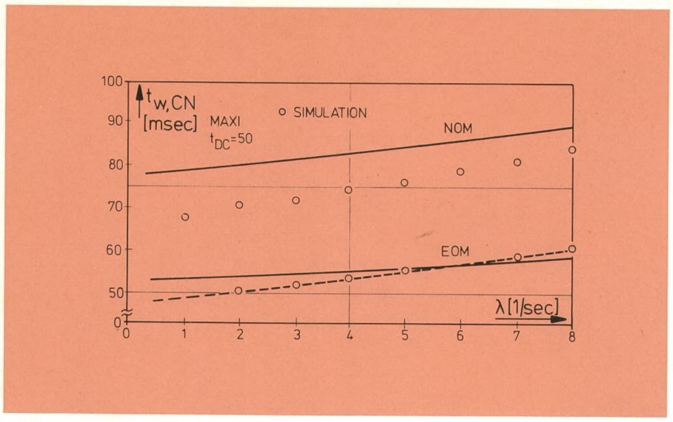

Fig. 16
Formulae for Characteristic Values (size MAXI times in ms)
$t_{w,CN}$ Mean waiting time of all connect requests
MAXI Maximal
NOM Normal operation mode
EOM Error operation mode
t_{DC} Mean duration of an active control phase

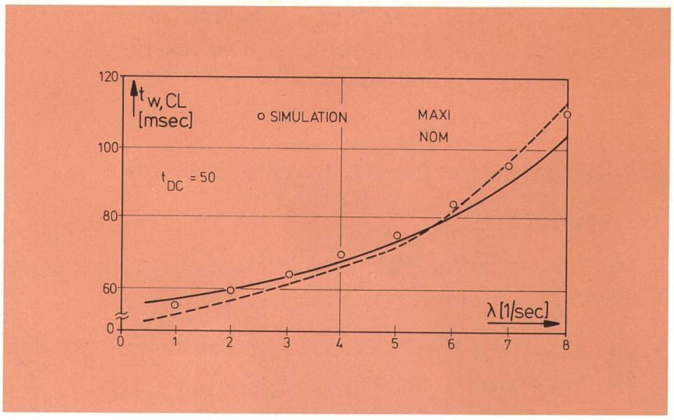

Fig. 17
Mean Waiting Time for Clear Request
$t_{w,CL}$ Mean waiting time of all clear requests
MAXI Maximal
NOM Normal operation mode
t_{DC} Mean duration of an active control phase

The chosen values for the mean duration of an active control phase (t_{DC}) are also shown. The diagrams show the good accordance between calculated and simulated values.

The dashed curves in Figures 16...18 have been calculated by a somewhat more refined model, which is discussed in the following.

42 Model 2

The second model for calculation *(Fig. 19)* is a standard priority model with four (non-preemptive) priority classes.

This model has in comparison to the comprehensive simulation model the following characteristics:

It takes fully into account the
- variable length of an active control phase
- priorities
- traffic dependent overhead phases

It approximates
- the variable (traffic dependent) time for LC-scanning
- different arrival processes for CN,CL,CA requests

It neglects the effects due to all lines busy in case of CN and CA requests.

Each of the four classes of the priority model has a poissonian input process with rate λ_i, mean service time h_i, a coefficient of variation c_{Hi}, and an offered traffic $A_i = \lambda_i \cdot h_i$, $i = 1...4$.

It holds (Fig. 19)

$$\lambda_1 = \lambda_{CN}$$
$$h_1 = t_T + t_{SS} + t_{PS} + t_E$$

$$\lambda_2 = \lambda_{CL}$$
$$h_2 = t_T + t_{SS} + k \cdot t_{LS} + t_c$$

$k \cdot t_{LS} (k \leq 1)$ represents the mean time for LC-scanning.

It is known that $k = 0.5$ for $\lambda \to 0$. Assuming that under normal conditions the probability that more than one request is waiting is low, k is chosen to 0.5 for the general case.

In case of an active control phase type CA, the time for scanning is t_{LS}, therefore

$$\lambda_3 = \lambda_{CA}$$
$$h_3 = t_T + t_{LS} + t_{PS} + t_E$$

The additional, fictive class 4 (NOP requests) models the phases with overhead. According to the mechanism described, λ_4 has to be choosen in such a way, that the processor is permanently occupied, therefore

$$A = \sum_{i=1}^{4} A_i = 1 \text{ or } A_4 = \lambda_4 h_4 = 1 - (A_1 + A_2 + A_3)$$

$$\text{Therefore } \lambda_4 = \lambda_{NOP}$$
$$h_4 = t_T + t_{SS} + t_{LS} + t_O$$

From these formulae, the maximum rate of successful call establishments, being processed by the concentrator control, for stationary operation can be calculated:

$$\lambda_4 = 0 \text{ or } A_1 + A_2 + A_3 \leqq 1$$

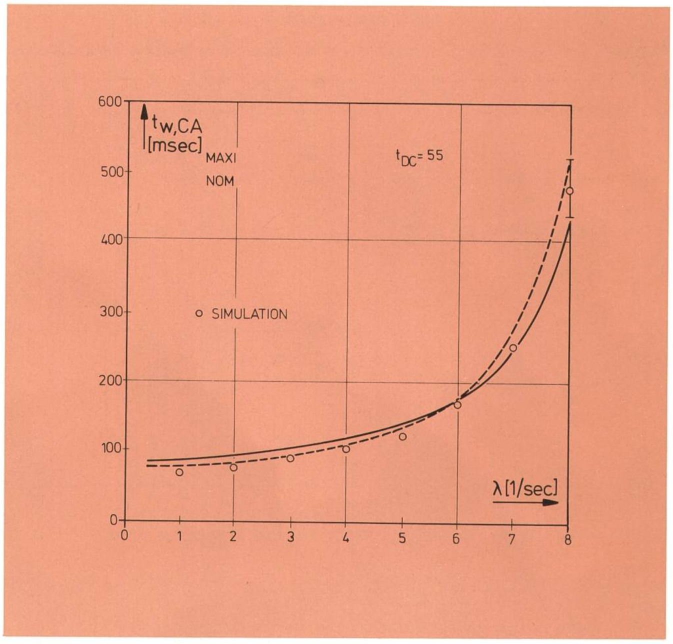

Fig. 18
Mean Waiting Time for Call Requests
$t_{w,CA}$ Mean waiting time of all call requests
MAXI Maximal
NOM Normal operation mode
t_{DC} Mean duration of an active control phase

As it is assumed that $B_{CN} = W_{CA} = 0$,

$$\lambda_{CL} = \lambda_{CN} + \lambda_{CA}.$$

Therefore

$$\lambda_{CN}(t_T + t_{SS} + t_{PS} + t_E) + (\lambda_{CA} + \lambda_{CN})(t_T + t_{SS} + t_{LS}/2 + t_C) + \lambda_{CA}(t_T + t_{SS} + t_{LS} + t_{PS} + t_E) = 1$$

For the size MAXI: $\lambda_{CN} \cdot 103$ ms $+ \lambda_{CA} \cdot 111$ ms $= 1$ or for $\lambda_{CN} = \lambda_{CA} = \lambda/2$

$\lambda_{MAX} =$ 9.35 call establishments per second.

Therefore 33660 BHC are possible in the stationary border line case.

According to Cobham [8] the mean waiting times (expectation values, without service times) are:

$$T_{W1} = \frac{\sum_{i=1}^{4} A_i (1 + c_{Hi}^2) h_i}{2 (1 - A_1)}$$

$$T_{W2} = \frac{T_{W1}}{1 - A_1 - A_2}$$

$$T_{W3} = \frac{1 - A_1}{1 - A_1 - A_2 - A_3} T_{W2}$$

As the service times are constant, it holds $c_{Hi} = 0$.

Furthermore B_{CN} and W_{CA} are assumed to be equal to 0 and $\lambda_{CN} = \lambda_{CA}$

Therefore $\lambda_{CN} = \lambda/2$, $\lambda_{CL} = \lambda$, $\lambda_{CA} = \lambda/2$

The determination of the characteristic traffic parameters from the waiting times of the model must reflect, for each type of request, up to which time within an active control phase, it can be served in reality.

- Mean waiting time $t_{w,\,CN}$ for CN-requests is according to the definition

$$t_{w,\,CN} = T_{W1} + t_T + t_{SS} + t_{PS}$$

- Mean waiting time $t_{w,\,CL}$ for CL-requests.

The request CL is detected in the real system during the LC-scanning.

$$t_{w,\,CL} = T_{W2} + t_{LS}/2 + t_C$$

- Mean waiting time $t_{w,\,CA}$ for CA-requests. Similarly it holds

$$t_{w,CA} = T_{W3} + t_{SS} + t_{LS} + t_{PS} + t_E$$

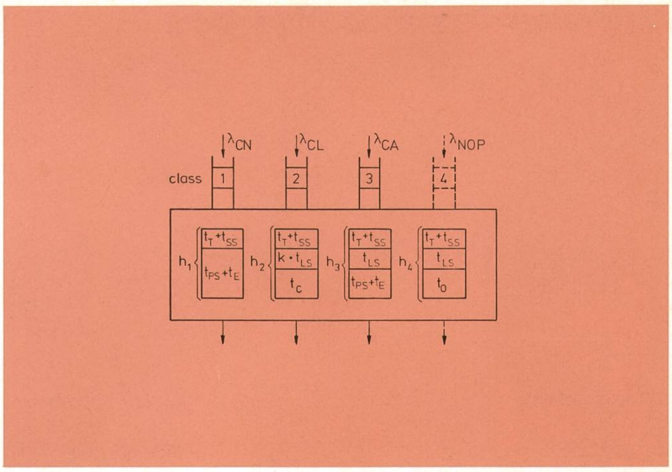

Fig. 19
Model 2 for Calculation

CN	Connect request
CL	Clear request
CA	Call request
NOP	No-operation
t_T	Selftesting time
t_{SS}	Subscriber circuit scanning time
t_{PS}	Path search time
t_E	Throughconnecting time
t_{LS}	Line circuit scanning time
t_C	Time for clear of a connection
t_O	Overhead time

The calculated values are printed in Figures 18...20 with dashed lines for the size MAXI.

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