



INTERNATIONAL ATOMIC ENERGY AGENCY  
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION  
**INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS**  
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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION



**INTERNATIONAL CENTRE FOR SCIENCE AND HIGH TECHNOLOGY**

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**SMR/474 - 20**

**COLLEGE ON  
"THE DESIGN OF REAL-TIME CONTROL SYSTEMS"  
1 - 26 October**

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**CASE STUDY FROM TELEPHONY**

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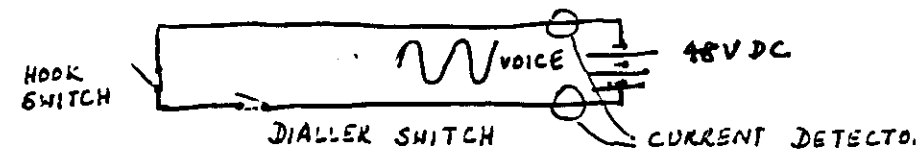
**These are preliminary lecture notes, intended only for distribution to participants.**

# CASE STUDY ON TELEPHONY

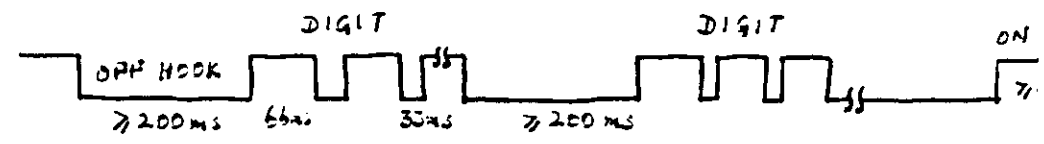
- BASICS OF TELEPHONY
- SMALL PBX 100 LINES  
NO REAL TIME O.S.
- LARGE EXCHANGE 16,000 LINES  
REAL TIME O.S.

# BASIC TELEPHONY

- TELEPHONE
- INFORMATION
  - VOICE
  - DATA (MODEM)
- SIGNALLING
  - OFF HOOK
  - ON HOOK
  - RINGING
  - DIGITS
    - DECADIC
    - DTMF



- OFF HOOK - CURRENT
- ON HOOK - NO CURRENT
- DIGITS - PULSES

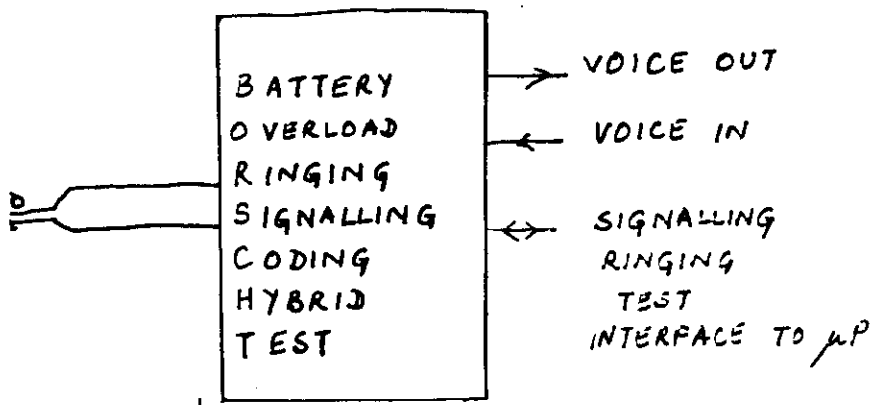


• VOICE

• DIGITIZATION

- 300 Hz - 3400 Hz BAND PASSED
- SAMPLING RATE 8 KHz.
- A/D 12 BIT
- 12 BIT LINEAR COMPANDED 8 BIT
  - $\mu$ -LAW N. AMERICA, JAPAN
  - A-LAW REST OF WORLD.

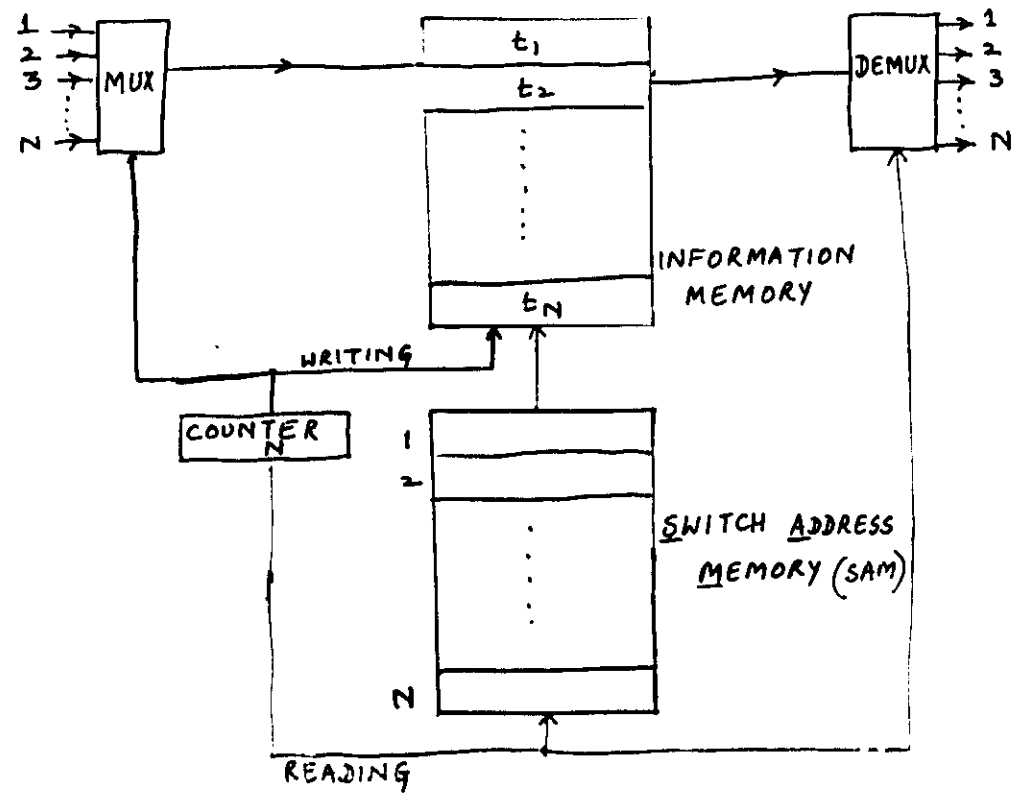
• CODEC



• TONES

- STORED DIGITALLY
- TREATED AS 6 LIKE TELEPHONES
- ONE TONE → ONE TELEPHONE
- NO NEED OF BORSCHT

TIME SWITCH



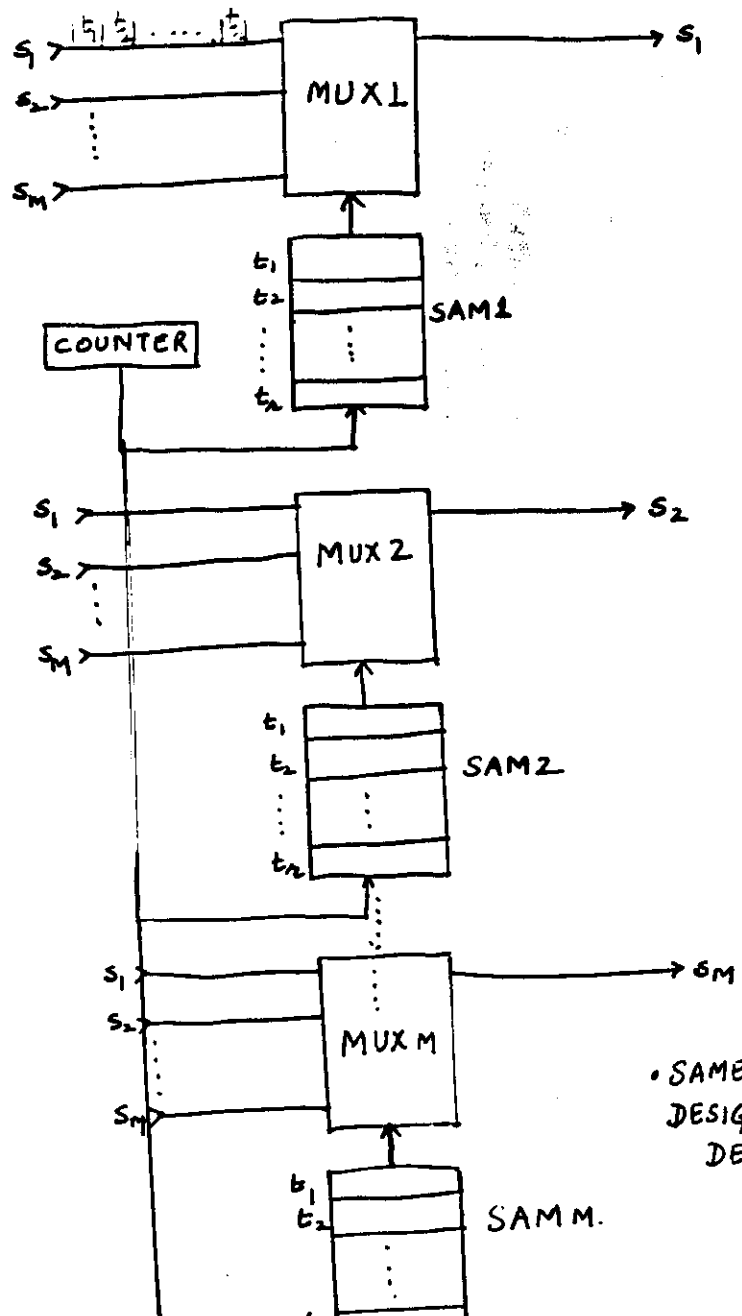
- SEQUENTIAL WRITE/RANDOM READ
- ONE CYCLE IN 125 μs.
- LIMITATION - SPEED OF RAM
- SIMPLE INTERFACE
- SAM MEMORY MAPPED TO μP

- DOUBLE BUFFER SCHEME
- CAN ALSO BE RANDOM WRITE/SEQ. READ
- BROADCAST & MULTICAST POSSIBLE

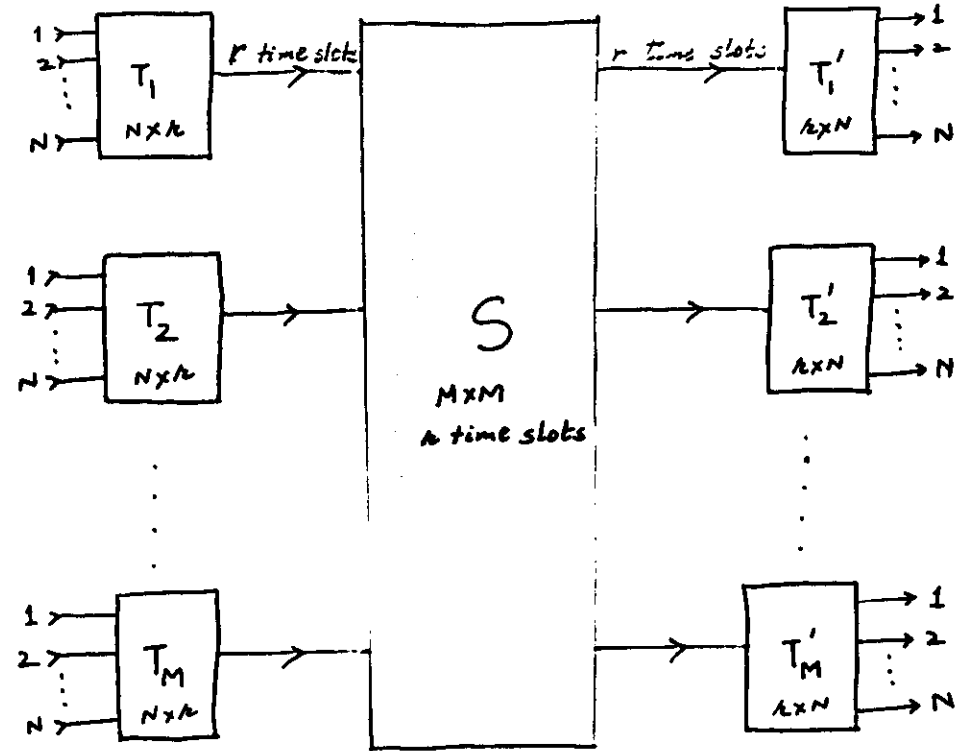
⑤

# T-S-T SWITCH

## SPACE SWITCH



• SAME CAN BE DESIGNED USING DEMUX



### • BLOCKING

- TWO SUBS. FREE BUT NO PATH
- $r = 2N - 1$  TOTALLY NON BLOCKING
- $r = 2N$  IN PRACTICE

• FOR 16000 L EXCHANGE

$N = 512$   
 $r = 1024$   
 $M = 32$

# TRAFFIC



ERLANG - FRACTION OF TIME LINE IS BUSY

$$\text{ERLANG} = \text{CALL RATE} \times \text{HOLDING TIME}$$

EXAMPLE:

OBSERVE 1 LINE

CALL 10 TIMES IN 1 HOUR

90 SECS. BUSY EACH TIME

$$\begin{aligned} \text{ERLANG} &= \frac{10}{3600} \times 90 \\ &= 0.25 \text{ E} \end{aligned}$$

EXCHANGE OF 100 LINES

$$\text{CALL RATE} = 10 \times 100 / \text{HOUR}$$

$$= \frac{1000}{3600} / \text{SEC}$$

$$\approx 1 \text{ CALL IN 3 SECS.}$$

# LOAD ON THE SYSTEM



CASE 1: USING ONLY SOFTWARE

- MAX. LOAD WHILE DIALLING
- MIN. PULSE WIDTH  $\approx 20 \text{ ms.}$   
THREE SAMPLES FOR MAJORITY LOGIC  
SAMPLING TIME 6 ms:
- DIALLING TIME 6 SEC.  
FOR 100 L EXCHANGE 0.25 E  
2 LINES TO BE MONITORED  
  
FOR 500 L EXCHANGE 0.25 E  
10 LINES TO BE MONITORED  
  
PER LINE PROCESSING TIME 600  $\mu\text{s.}$



REAL-TIME CRITICAL!!!

(9)

## CASE 2: USING HARDWARE

- RELEGATE THIS JOB TO HARDWARE
- MAX. LOAD WHILE DIALLING.
- EVENTS OCCUR ON THE AVG. EVERY 700ms.
- FOR 100L EXCHANGE 0.25E  
ONE EVENT IN 350ms.
- FOR 500L EXCHANGE 0.25E  
ONE EVENT IN 70ms !!



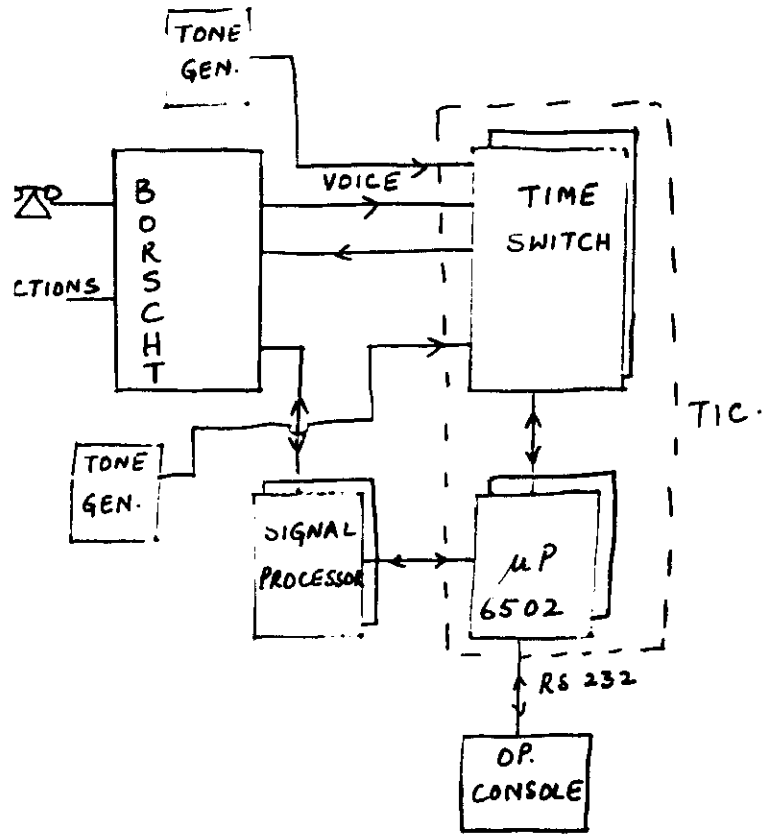
CAN USE INTERRUPT FOR R/W DATA  
REAL TIME CRITICALITY LESS SEVERE.

- FOR 15000L EXCHANGE 0.25E  
ONE EVENT IN  $\approx 2ms$  !!

## FAULT TOLERANCE

(1)

- CRITICAL MODULES TO BE MADE RESILIENT
- ERROR-CORRECTING CODES  
E.G. HAMMING CODE
- TRIPLE MODULAR REDUNDANCY
- PAIR OF PAIRS
- DUPLICATION
- CRITERIA FOR FAULT TOLERANCE
  - GRADE OF SERVICE  
(SYSTEM/SUB SYSTEM DOWN TIME)
  - MEAN TIME BETWEEN FAILURES (MTBF)
  - MEAN TIME TO REPAIR (MTTR).

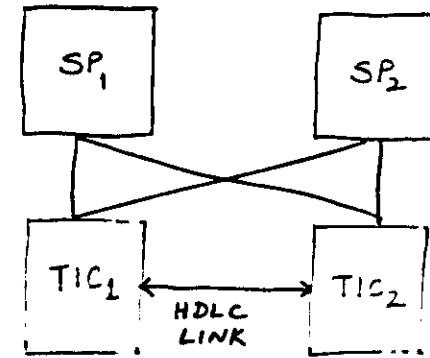


μP

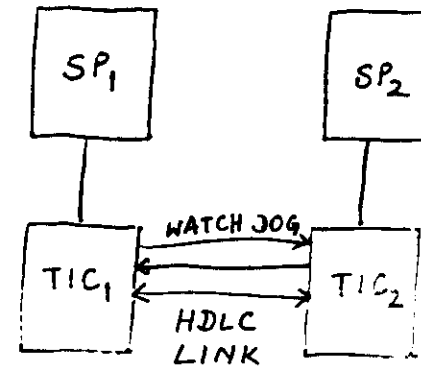
- 6502
- ROM, RAM
- RTC
- ACIA
- HDLC - .
- DIAGNOSTICS
- CONNECT TO COPY.
- EEPROM

• DUPLICATION  
ACTIVE & HOT STANDBY

SCHEME 1.



SCHEME 2.



## SOFTWARE

- CALL PROCESSING
- MAINTENANCE
  - ROUTINING
  - RECONFIGURATION
  - DIAGNOSTICS
  - RECOVERY
- ADMINISTRATION
  - BILLING
  - RECENT CHANGE

## SOFTWARE MODEL

INTER-EVENT TIME  $\approx$  500 ms.  
WHEREAS PROCESSING EACH EVENT  $\approx$  3-4 ms.

$\therefore$  NO TIME SLICING NEEDED.

### • PROCESS MANAGEMENT

- NO TIME SLICE
- EVENT DRIVEN SCHEDULING
- FOREVER LOOPS CANNOT BE TRAPPE

### • MEMORY MANAGEMENT

- WORST CASE STATIC ALDIMENT  
ONE PORT - 32 BYTES  
 $\therefore$  128 PORTS - 4K BYTES.

$\therefore$  NO MEMORY MANAGEMENT

### • TIME MANAGEMENT

- TIME-OUTS  $\approx$  SECS. 100MS RTC.
- $\therefore$  EVENT DRIVEN. & SCANNING.

### • SYNCHRONISATION

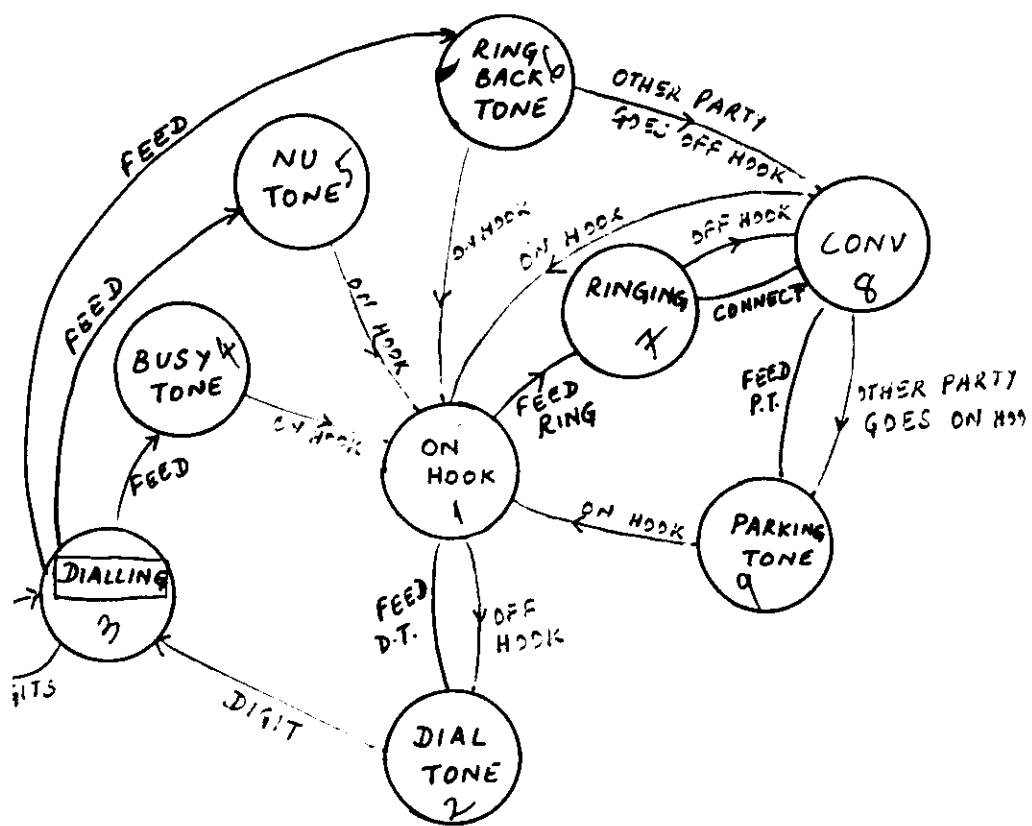
- NO TIME SLICING
- $\therefore$  NO SEMAPHORES BETWEEN PROCESSE
- SYNC BETWEEN HIGH LEVEL & INT. ROUTI
- $\therefore$  MASK INTERRUPTS.

## SHARED MEMORY MODEL

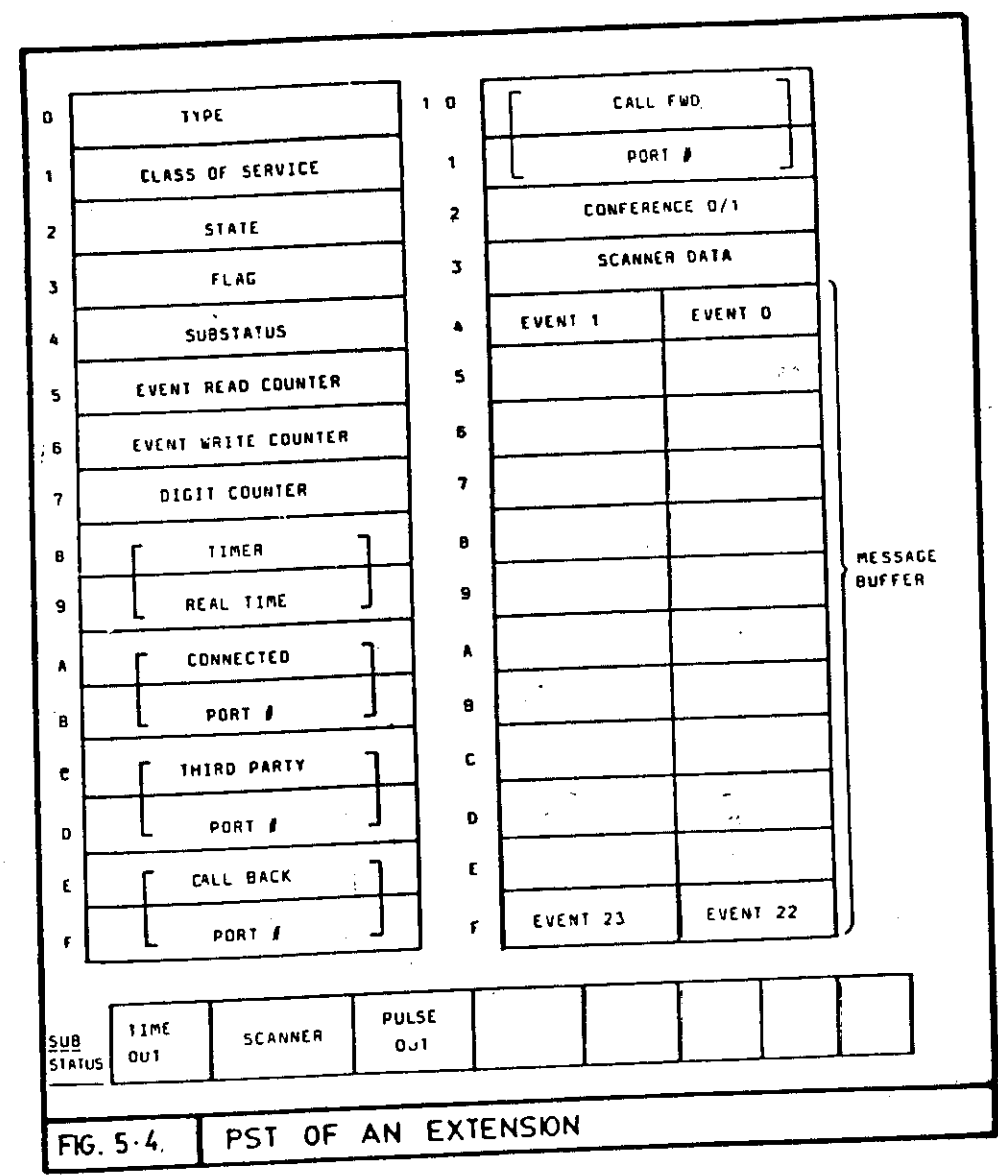


# FINITE STATE MODEL OF TELEPHONE (15)

(SIMPLIFIED)



— OUTPUT FROM TELEPHONE  
 — INPUT TO TELEPHONE



# FAULTS

(17)

## • PERMANENT FAULTS

- PERMANENT ERROR
- TRANSIENT ERROR
- NO ERROR

## • TRANSIENT FAULTS

- PERMANENT ERROR
- TRANSIENT ERROR
- NO ERROR

# TESTS

(18)

## • RESULT

- CORRECT
- WRONG
- NO OUTPUT

## INFRENCING

## • DECISION TABLES

TEST 1	TEST 2	INFERENCE
C	C	SYSTEM OK
C	W	MODULE 1 BAD
C	N	⋮
W	C	⋮
N	N	DO TEST 5
⋮	⋮	

# THE SCHEDULER

- CALL PROCESSING
- OPERATOR SERVICE
- DIAGNOSTICS
- CALL PROCESSING - EVENT DRIVEN
- TIME OUT HANDLER
- PULSE OUT HANDLER
- SP SCANNER
- OPERATOR SERVICE
- CALL PROCESSING
- ADMN. COMMANDS

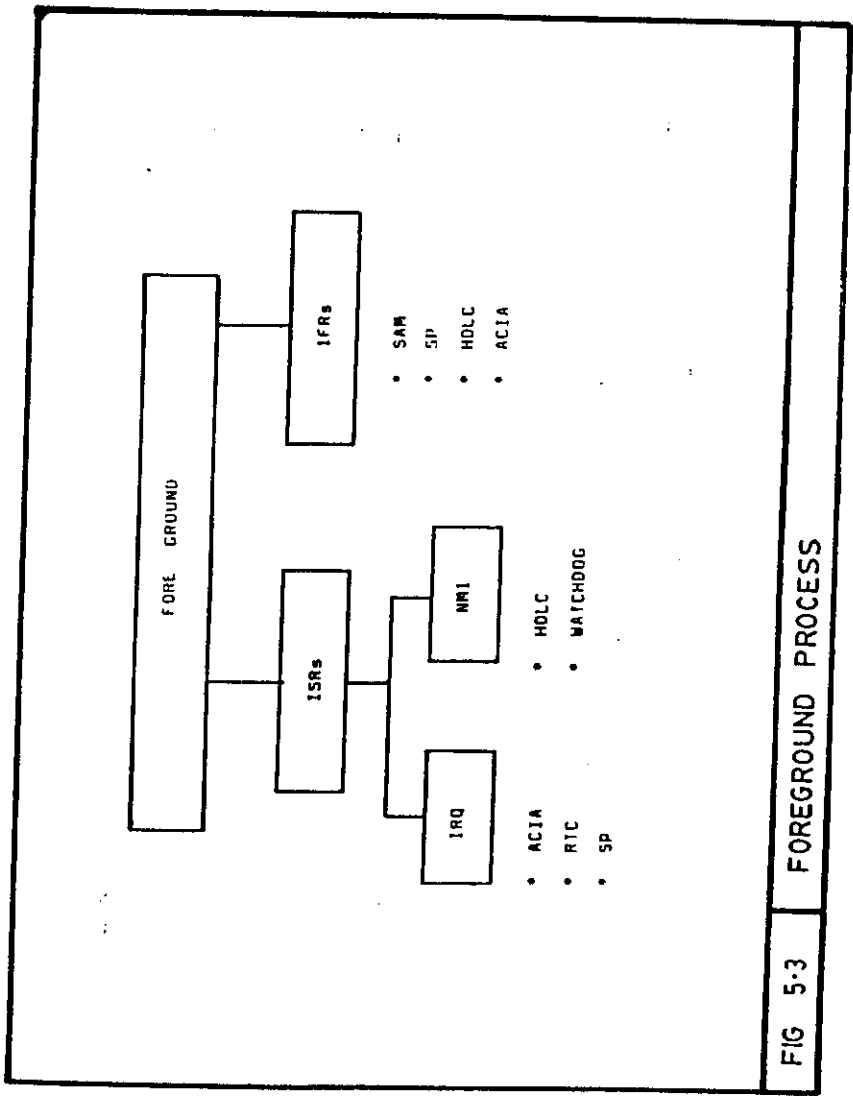


FIG 5-3 FOREGROUND PROCESS

### TRAFFIC.

• FOR 16000 L EXCHANGE 0.25E

ONE EVENT IN 2 ms.

SOLUTION:

DISTRIBUTED PROCESSING!!

• ONE PROCESSOR FOR 500L. (B.P.)  
ONE EVENT IN 70 ms.

CASE 1:

TOTAL DISTRIBUTION.

- REPLICATION OF DATA BASE
  - MORE MEMORY/PROCESSOR
  - CONSISTENCY ACROSS 32 PROCESSORS
  - TRUNKS CANNOT BE HANDLED EFFICIENTLY.

CASE 2:

- DATA BASE CENTRALISED
- TRUNKS ALLOCATION & TRANSLATION. (A.P.)

~~ONE EVENT IN 6 SECS/LINE~~

- 10 CALLS/LINE/HOUR
- 16000 L EXCHANGE  $\frac{160000}{3600} \approx 44$  CALLS/SEC

- ONE EVENT/CALL
- ONE EVENT IN  $\approx 20$  ms. A.P.

### SYSTEM ARCHITECTURE

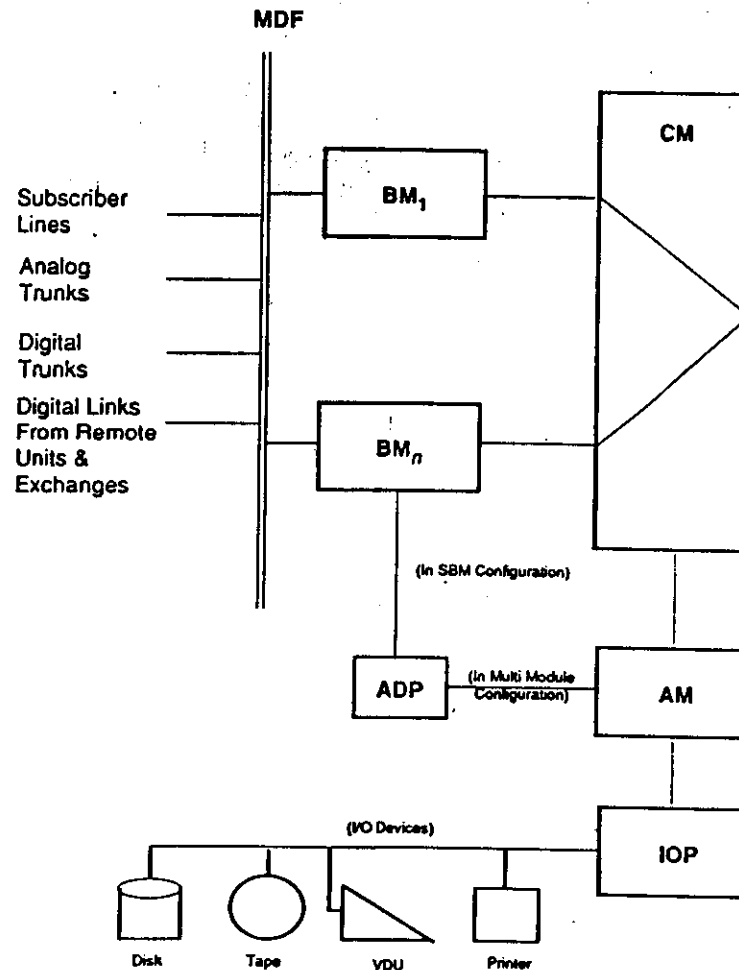
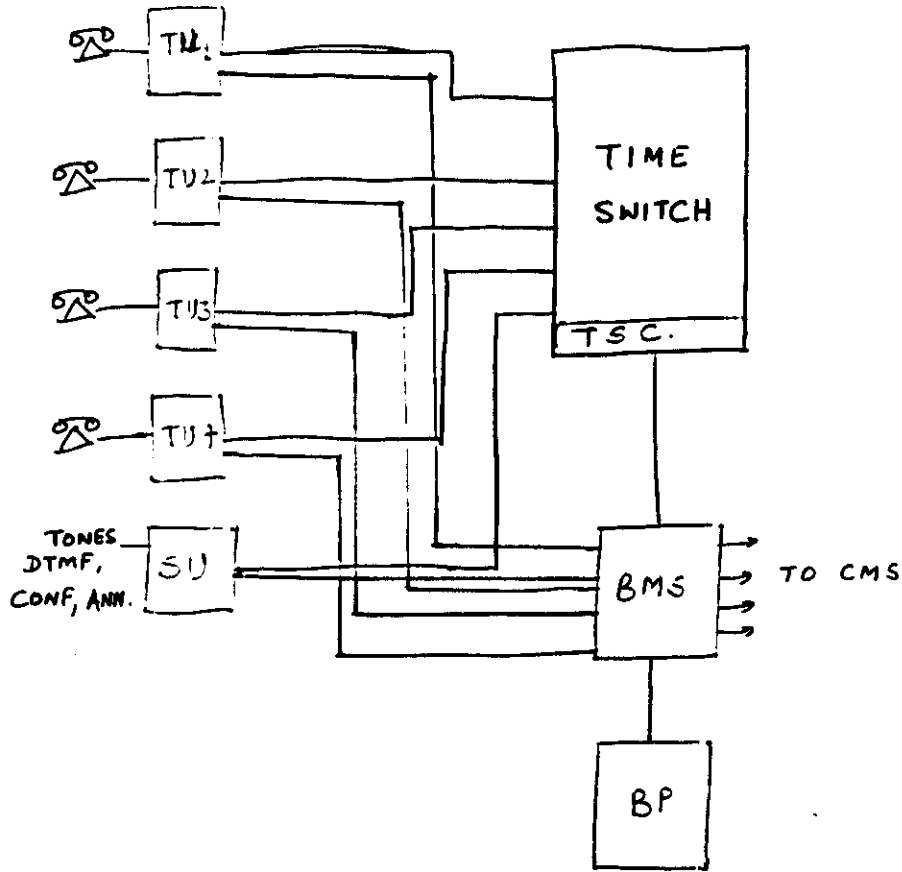


Figure 2.1  
CDOT DSS MAX Basic Architecture

# BASE MODULE



- VOICE PATH

- MESSAGE LINKS. (PHYSICALLY THROUGH VOICE PATH)

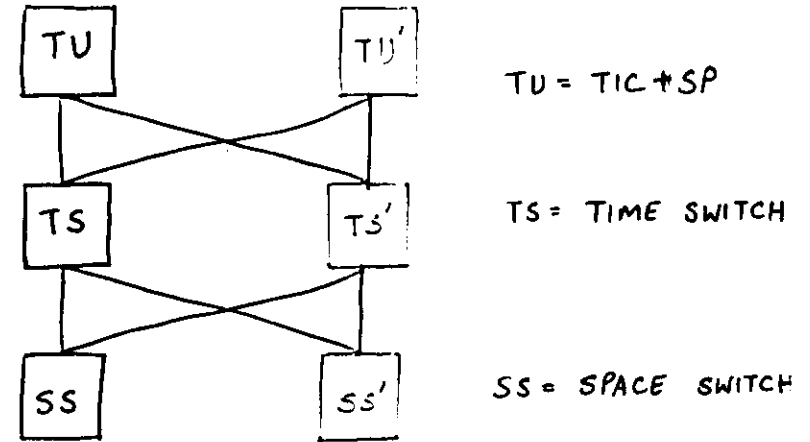
• DEFINE PROTOCOL

• RECALCULATE LOAD USING

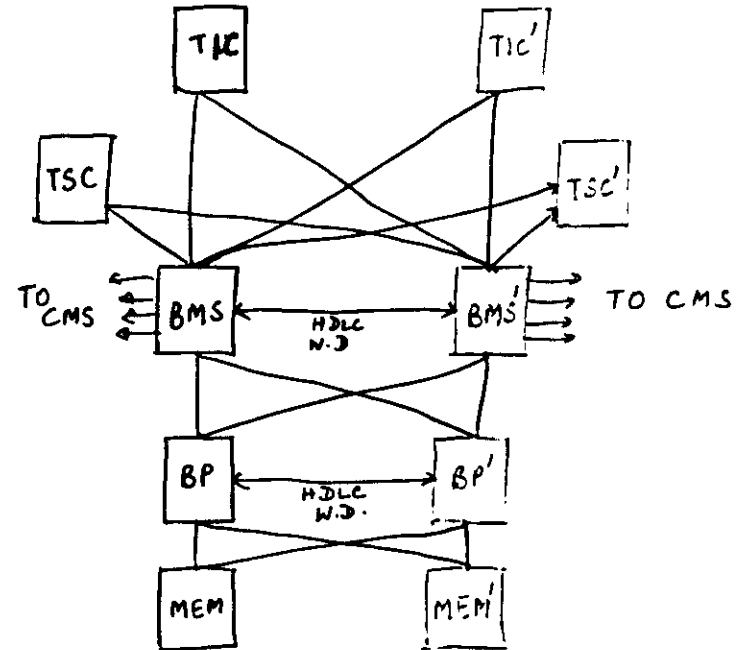
## QUEUEING THEORY I

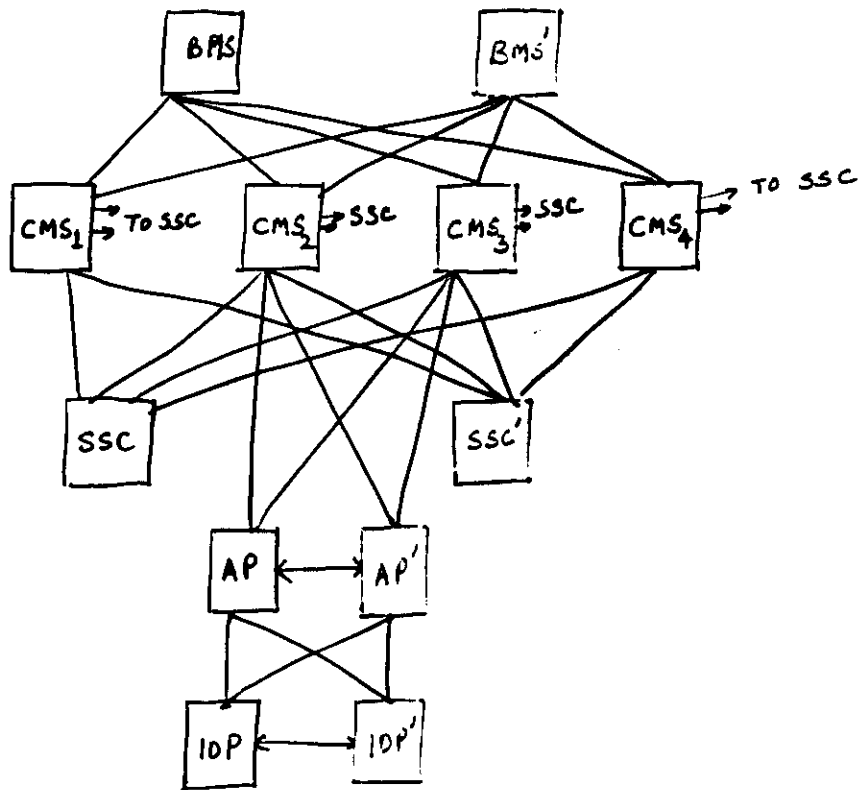
# REDUNDANCY SCHEME

VOICE



CONTROL





• ALL DUPLICATION IN HOT-STANDBY MODE  
EXCEPT CMS IN LOAD SHARING MODE.

# A TYPICAL SCENE

- UNLOCKS STD
  - CHECK FOR AUTHORIZATION
    - ⇒ DATA BASE
- DIALS DIGITS
  - CHECK FOR OK. DIGITS
    - NOT OK ⇒ DIAGNOSTICS
  - TRANSLATION, FEEDING TONES
  - ESTABLISH CALL
    - ⇒ CALL PROCESSING
- ROUTINE CHECKING
  - SAM BAD
    - ⇒ SWITCH OVER TO DUPLICATE
- OPERATOR QUERIES TRAFFIC DATA
- OPENS NEW LINE
  - ⇒ ADMN SOFTWARE
- ALL THE ABOVE OCCUR CONCURRENTLY
  - ⇒ COORDINATING SOFTWARE
- INTER-PROCESSOR COMMUNICATION
  - ⇒ PROTOCOL

# SOFTWARE MODEL

• NEED FOR REAL-TIME O.S.

• INTERFACE TO OUTSIDE WORLD IS THROUGH MESSAGES

MESSAGE PASSING MODEL.

INTER PROCESS COMM. THROUGH MESSAGES

CALL PROCESSING.

• TERMINAL PROCESS

- ONE TYPE FOR ONE TYPE OF TERMINATION
- HANDLES TELEPHONY PROTOCOL

• CALL MANAGER

- HIGHER LEVEL
- ABSTRACT MODEL OF TELEPHONE

ASSUME EACH PROCESS 1K BYTES OF DATA+STACK

UNDER HEAVY LOAD 7 1M BYTE OF DATA+STACK

⇒ DYNAMIC CREATION & KILLING OF PROCESSES

⇒ MEMORY MANAGEMENT.

## SOFTWARE ARCHITECTURE

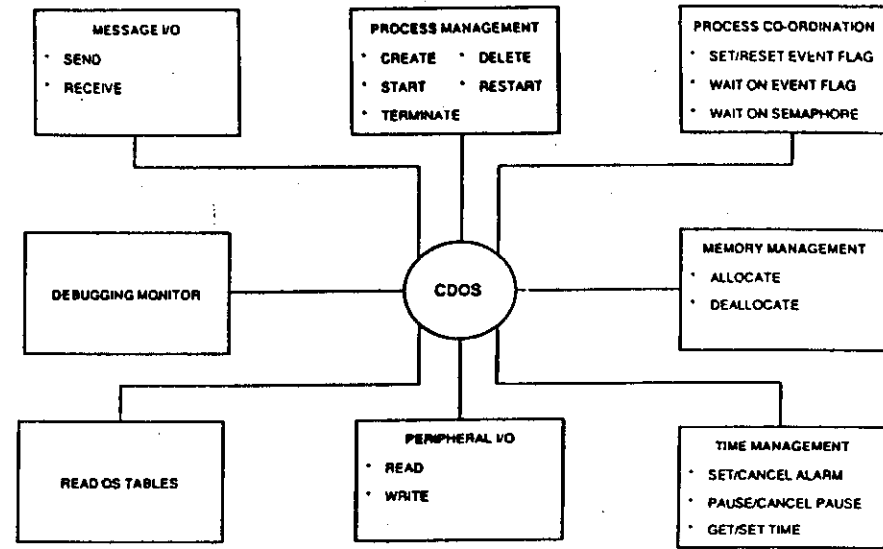


Figure 5.2 OS Services in CDOT DSS MAX

11/03/87 Rev. 0.01

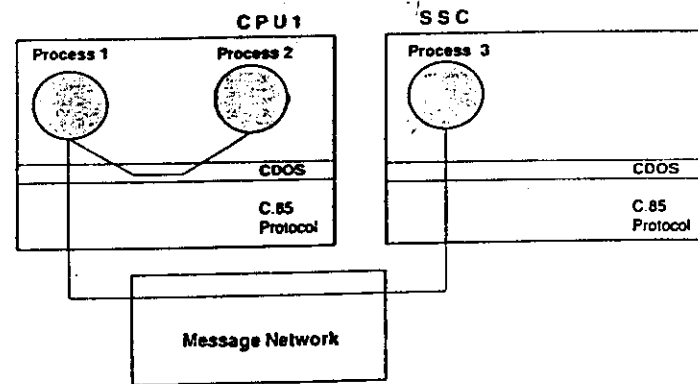


Figure 5.3 Inter-Process Communication Through CDOS

11/03/87 Rev. 0.01

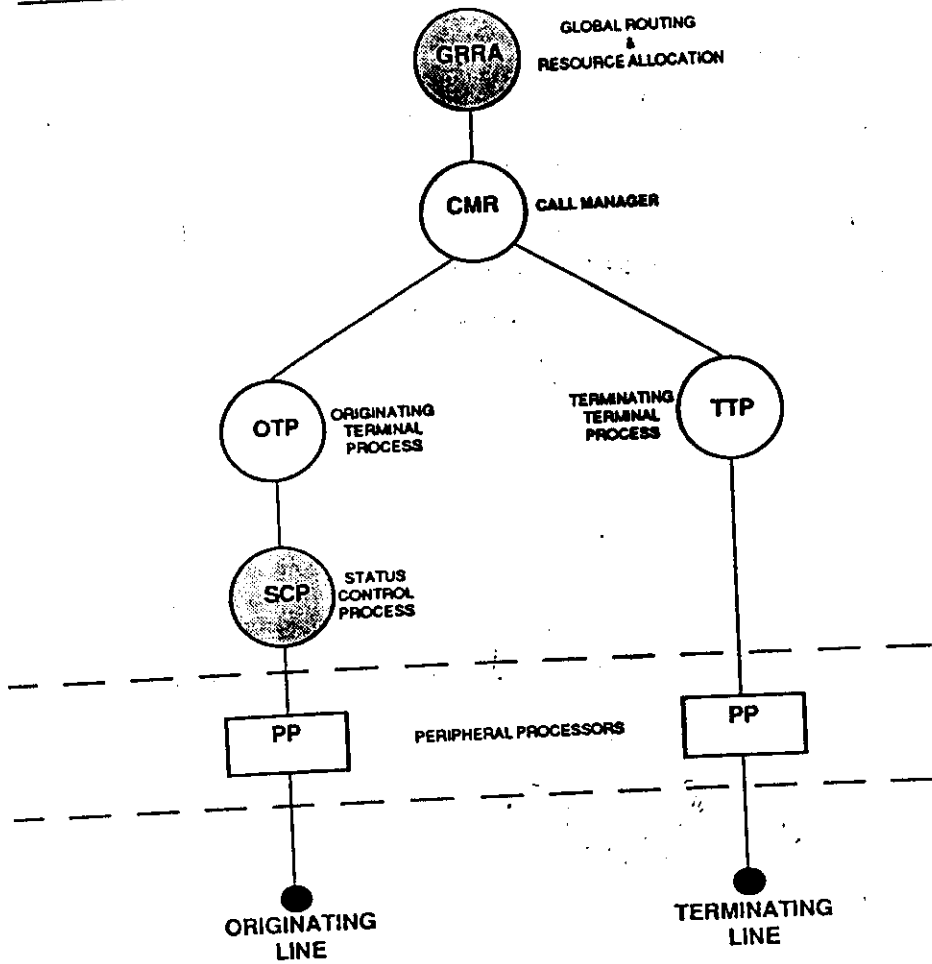


Figure 5.4  
Processes in Call Processing Subsystem

MICALPRC.CHP  
CDOT DSS MAX

BM SOFTWARE

- CALL PROCESSING
  - TRANSLATION
  - FEEDING TONES
  - SWITCHING
- DATA BASE
  - DIRECTORY
  - FACILITIES
  - FEATURES
- ADMN
  - MMI
  - BILLING
  - TRAFFIC
- MAINTENANCE
  - DIAGNOSTICS
  - CONFIGURATION
  - RECOVERY
  - ROUTINING • AUDITS
  - INITIALIZATION
- O.S.
  - PROCESSOR MANAGEMENT
  - MEMORY MANAGEMENT
  - TIMER SERVICES
  - COMMUNICATION
    - INTRA PROCESSOR
    - INTER PROCESSOR



## • PROTOCOL

- NEED
  - ERRORS
  - TIME OUTS
  - OUT OF SEQUENCE
  - RESOURCE CRUNCH
  
- LINK LEVEL ACK EXPLICIT
- END TO END ACK EXPLICIT / PIGGY BACK
  
- WINDOW SIZE = 1.

## MAINTENANCE SOFTWARE

- CONFIGURATION
- INITIALIZATION
- ROUTINING
- RECOVERY
- AUDITS
- DIAGNOSTICS
- PERFORMANCE
- OVERLOAD CONTROL
- SWITCH MAINTENANCE
- TERMINAL MAINTENANCE
- SYSTEM INTEGRITY
- MMI

• CONFIGURATION

• STATES OF DUPLICATED UNITS

• INSERVICE

- ACTIVE
- FORCED
- STANDBY

• OUT OF SERVICE

- OPERATOR
- SUSPECT
- TEST
- SYSTEM

• UNEQUIPPED.

• ROUTINING

- CALENDER BASED
- PERIODIC
- IDLE TIME BASED
- ON DEMAND

• RECOVERY

- LOSS OF NO CALL
- LOSS OF TRANSIENT CALLS
- LOSS OF ALL CALLS
- SOFT START - PARTIAL BOOTING
- TOTAL BOOTING

• PROCESSES

- BMCM BASE MODULE CONF. MANAGER
- SMP SANITY MONITOR PROCESS
- SFH SWITCH FAULT HANDLER
- MR/PR MODULE/PATH ROUTINER
- DAP DIAGNOSTIC AID PROCESS
- TCA TERMINAL CKT. ADMINISTRATOR
- CFH CALL FAULT HANDLER
- TDP TERMINAL DIAGNOSTIC PROCESS
- MAP MODULE AUDIT PROCESS
- OCP OVERLOAD CONTROL PROCESS
- OSPM D.S. PERFORMANCE MONITOR
- ARM ALARM REPORT MANAGER
- MCI MAINT. COMMAND INTERPRETER