UNIT-2

Electronic Space Division Switching

INTRODUCTION:

Efforts to improve the speed of control and signaling

- Late 1940s and early 1950s. Use of vacuum tubes, transistors, gas diodes, magnetic drums and cathode ray tubes.
- Arrival of modern electronic digital computers.
- The registers and translators of common control systems can be replaced by a single digital computer.

2.1 Stored Program Control

Stored Program Control (SPC)

- A program or a set of instructions to the computer is stored in its memory and the instructions are executed automatically one by one by the processor.
- Carrying out the exchange control functions through programs stored in the memory of a computer.

Consequence

- ✓ Full-scale automation of exchange functions
- ✓ Introduction of a variety of new services to users.

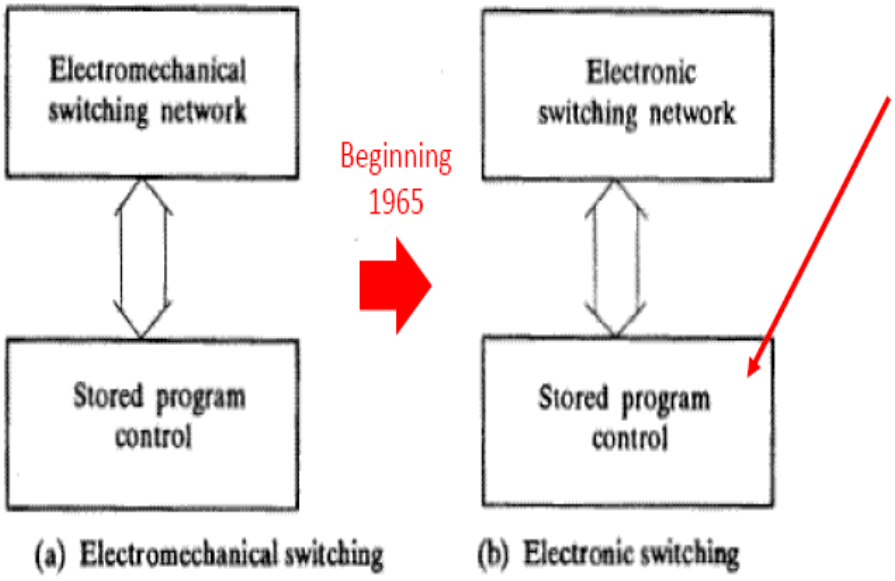
New features possible for SPC

- ✓ Common Channel Signaling (CCS)
- ✓ Centralized maintenance
- ✓ Automatic fault diagnosis
- ✓ Interactive human-machine interface

Special Requirements of SPC

- ✓ Operating without interruption
- ✓ Fault tolerant hardware and software

- ✓ Introducing a computer to carry out the control functions of a telephone exchange is not as simple as using a computer for scientific or commercial data processing.
- ✓ A telephone exchange must operate without interruption, 24 hours a day, 365 days a year and for say, 30-40 years. This means that the computer controlling the exchange must be highly tolerant to faults.
- ✓ Fault tolerant features were unknown to early commercial computers and the switching engineers were faced with the task of developing fault tolerant hardware and software systems.
- ✓ In fact, major contributions to fault tolerant computing have come from the field of telecommunication switching.
- ✓ Two types of Space division electronic switching systems
  - ✓ Electromechanical Switching
    - ✓ SPC + Electromechanical switching network
  - ✓ Electronic Switching
    - ✓ SPC + Electronic switching network



Stored Program Control

Basically a computer used to:

1) Monitor the status of the subscribers,
2) Receive dialled digits,
3) Close the correct contacts to establish a connection between the calling line and the called subscriber
4) Monitor the call when established,
5) Disconnect/tear down the call
6) Bill

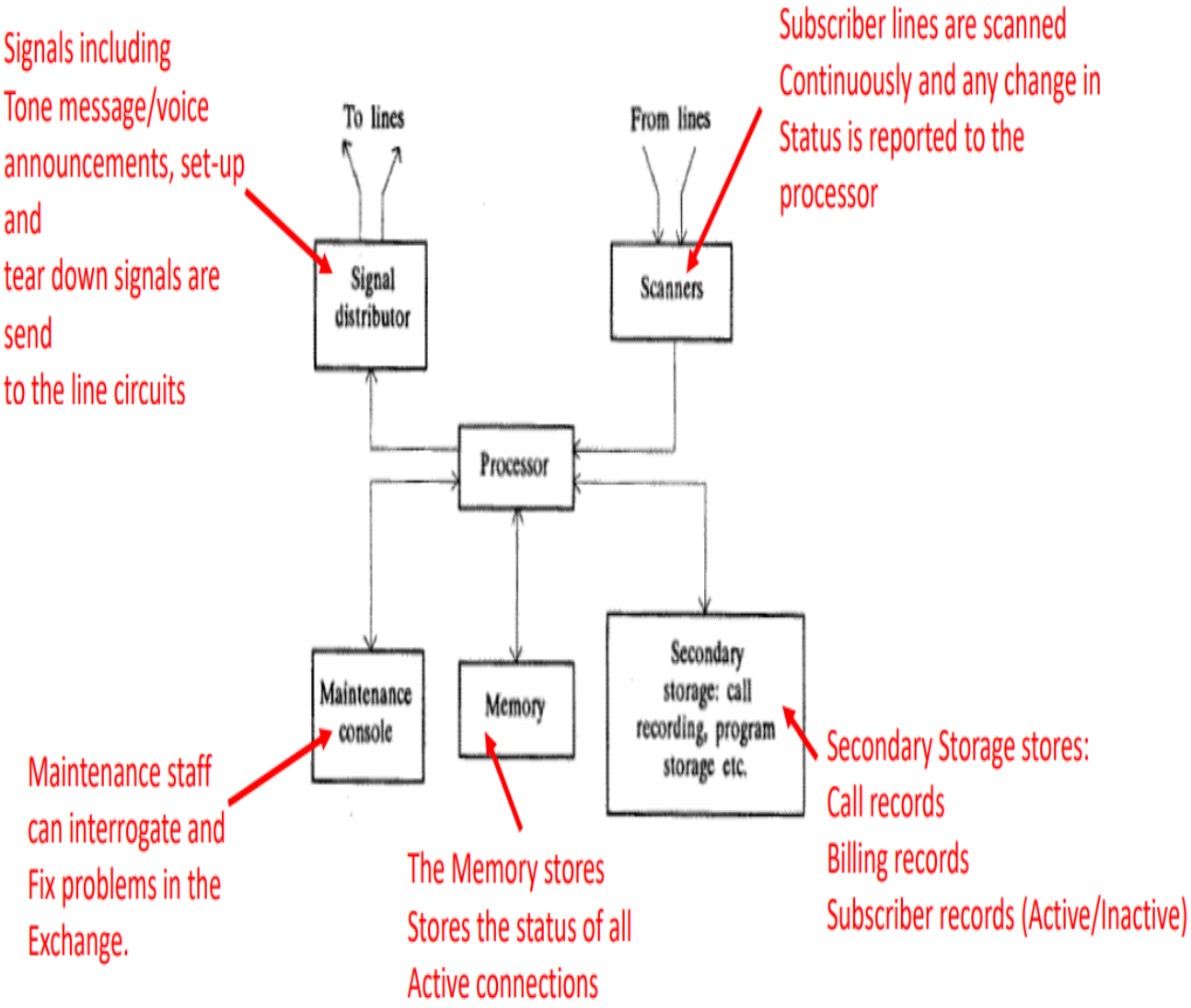
- ➢ Organization of SPC
  - ➢ Centralized SPC
    - ✓ Broadly used in early SPC switching systems.

- Distributed SPC
  - ✓ Gaining popularity in modern switching systems.

- Although many present day exchange designs continue to use centralized SPC, the advent of low cost powerful microprocessors and very large scale integration (VILSI) chips has made distributed SPC more popular.

2.2 Centralized SPC

- All the control equipment is replaced by a single powerful processor.
- The processor must be capable of processing 10 to 100 calls per second, depending on the load on the system, and simultaneously performing many other ancillary tasks.
- A typical control configuration of an ESS using centralized SPC is shown in Figure.



- A centralized SPC configuration may use more than one processor for redundancy purposes.
- Each processor has access to all the exchange resources like scanners and distribution points and is capable of executing all the control functions.
- A redundant centralized structure is shown in Figure
- Redundancy may also be provided at the level of exchange resources and function programs.
- In actual implementation, the exchange resources and the memory modules containing the programs for carrying out the various control functions may be shared by processors, or each processor may have its own dedicated access paths to exchange resources and its own copy of programs and data in dedicated memory modules.

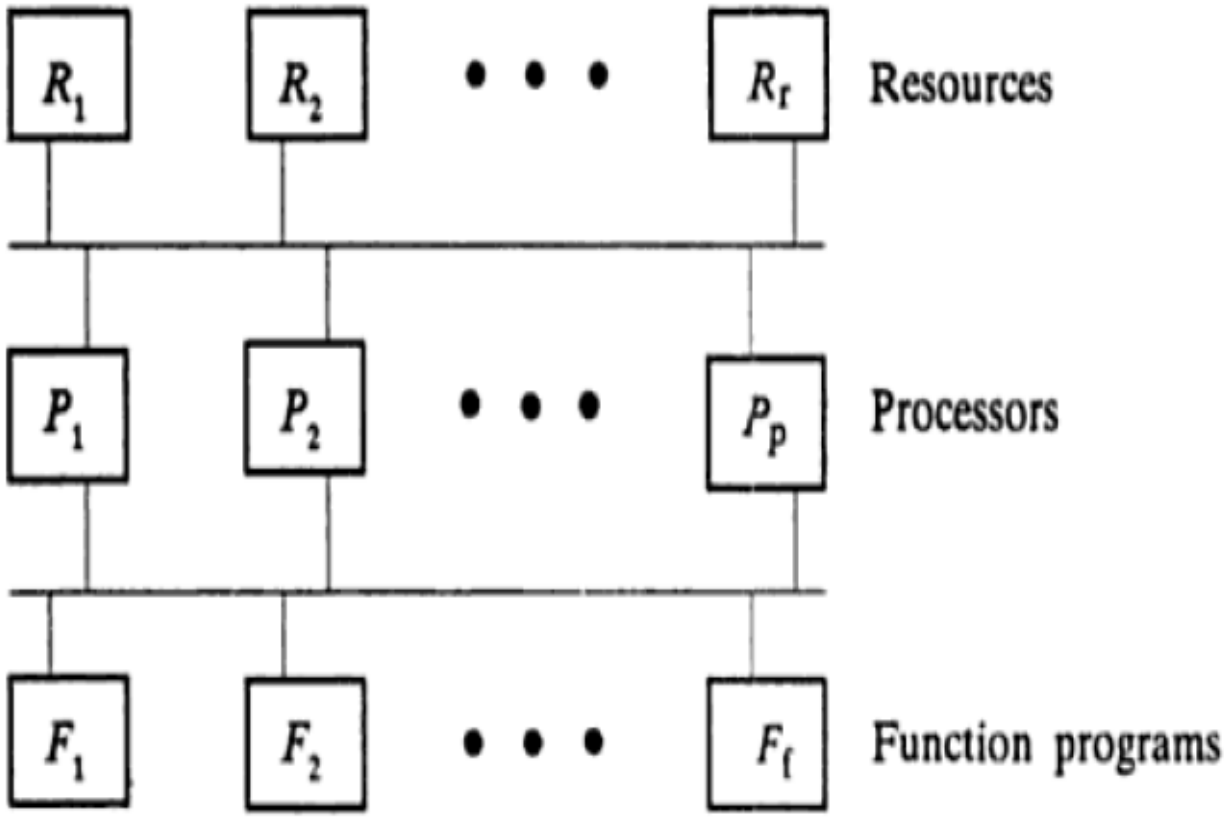


Fig. 4.3 A redundant centralised control structure.

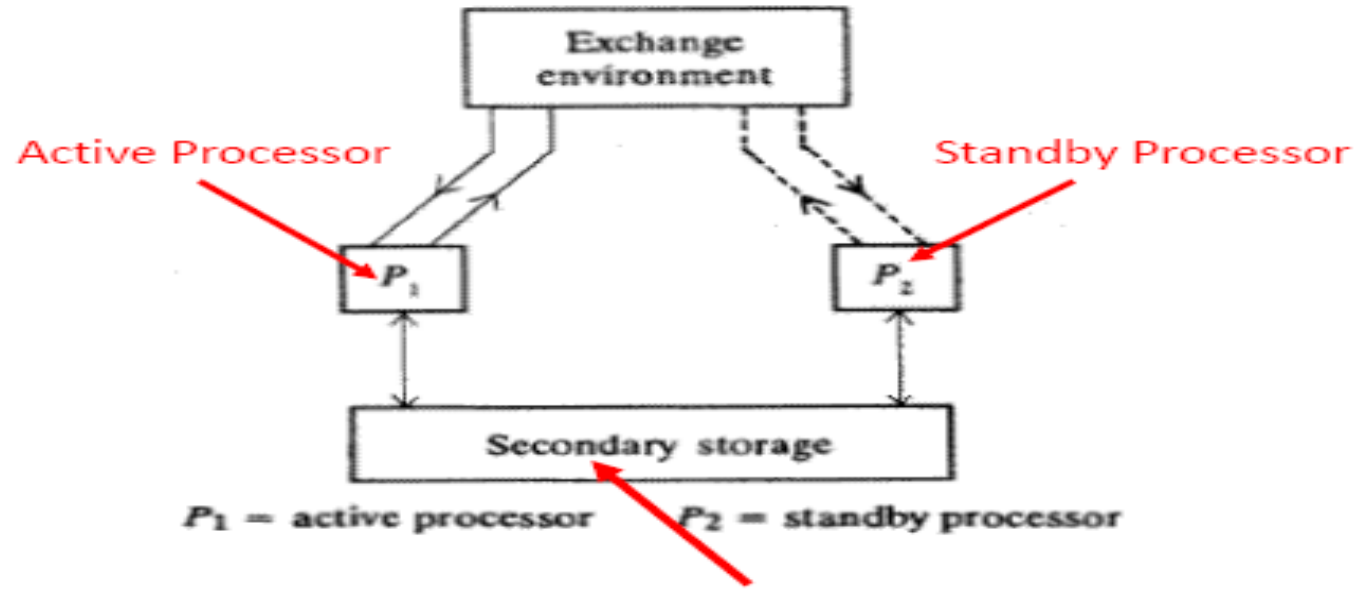
- Most electronic switching systems, using centralized control, use only a two-processor configuration.

- Dual processor architecture may be configured to operate in one of three modes:

    1. Standby mode
    2. Synchronous duplex mode
    3. Load sharing mode.

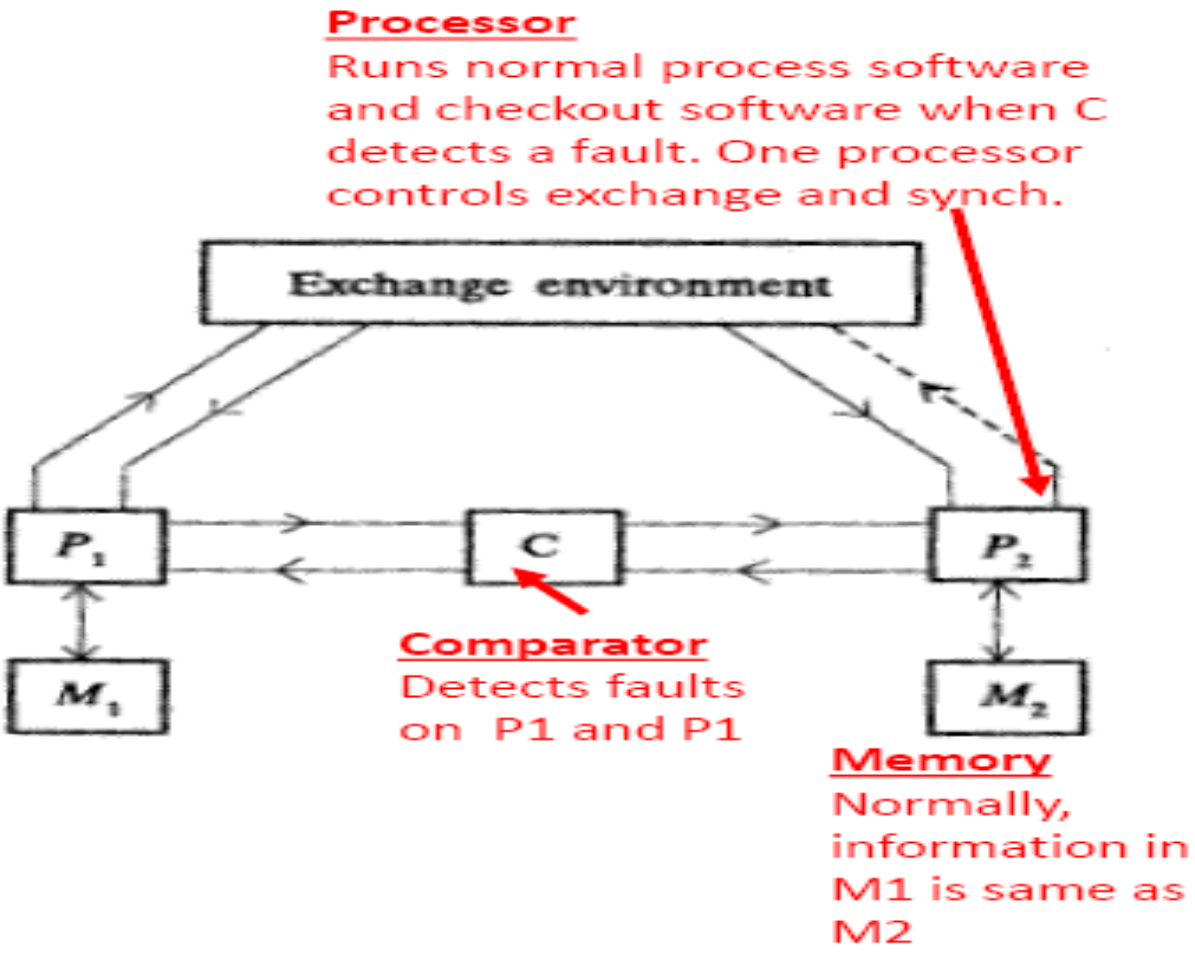
Stand-by mode

- In stand-by mode, one processor is active and the other is on standby, both hardware and software wise.
- The standby processor is brought online only when the active processor fails.
- The active processor copies the status of the system periodically into a secondary storage.
- When a switch over occurs, the standby processor loads the most recent update of the system status from the secondary storage and continues the operation.
- As a result, only the calls which changed status between the last update and the failure of the active processor are lost/disturbed.



Secondary Storage contains the connection status, e.g. subscribers and trunks are busy or free, which of the paths are connected through the switching network etc.

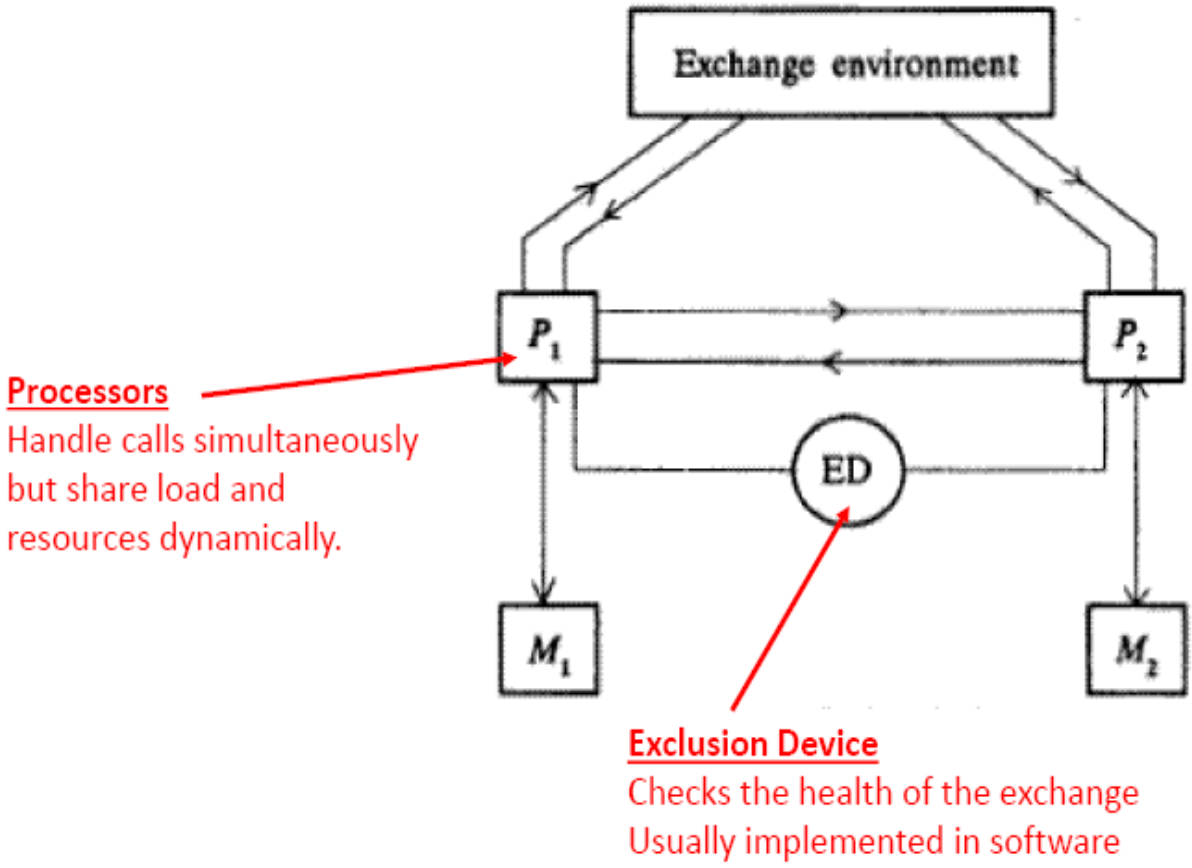
Synchronous Duplex Mode:



- In synchronous duplex mode of operation, hardware coupling is provided between the two processors which execute the same set of instructions and compare the results continuously.
- If a mismatch occurs, the faulty processor is identified and taken out of service within a few milliseconds.
- When the system is operating normally, the two processors have the same data in their memories at all times and simultaneously receive all information from the exchange environment.
- If a fault is detected by the comparator, the two processors P1 and P2 are decoupled and a check-out program is run independently on each of the machines to determine which one is faulty.

- The check-out program runs without disturbing the call processing which is suspended temporarily.
- When a processor is taken out of service on account of a failure or for maintenance, the other processor operates independently.
- When a faulty processor is repaired and brought into service, the memory contents of the active processor are copied into its memory before it is synchronized with the active processor and then the comparator is enabled.

Load Sharing Mode:



- Both two processors have access to entire exchange environment. Each of them has

independent memories for redundancy purpose.

- Both two processors are active simultaneously and share the load and the resources dynamically.

- An incoming call is assigned randomly or in a predefined order to one of the processors which then handles the call right through completion.
- Inter-processor links are configured for processors to exchange information needed for mutual coordination and verifying the 'state of health' of the other.
- If a processor fails, the other processor takes over the entire load including the calls already set up by the failing processor.
- Sharing of resources calls for an exclusion mechanism so that both the processors do not seek the same resource at the same time. The mechanism may be implemented in software or hardware or both.
- Load sharing increases the effective traffic capacity by 30 percent compared with synchronous duplex.

Availability of SPC Systems:

AVAILABILITY OF SINGLE TELEPHONE EXCHANGE

1. One of the main purposes of redundant configuration is to increase the overall availability of the system.
2. A telephone exchange must show more or less a continuous availability over a period of perhaps 30 or **40** years.
3. The availability, A, of a single processor system is given by:

$$A = \frac{MTBF}{MTBF + MTTR}$$

Where

MTBF = Mean Time Before Failure

MTTR = Mean Time to Repair

Unavailability, U, is given by:

$$U = 1 - A$$

$$= 1 - \frac{MTBF}{MTBF+MTTR}$$

$$= \frac{MTTR}{MTBF\ MTTR}$$





If MTBF >> MTTR then

$$U = \frac{MTTR}{MTBF}$$

AVAILABILITY OF DOUBLE PROCESSOR TELEPHONE EXCHANGE(1)

- A dual processor system is said to have failed when the second processor fails when the 1st one is undergoing repair, i.e fails during the MTTR for single processor.
- The meantime before failure is given by:

$$MTBF_D = \frac{(MTBF)^2}{2MTTR}$$

- The availability A_D is therefore

$$A_D = \frac{MTBF_D}{MTBF_D + MTTR} = \frac{(MTBF)^2/(2MTTR)}{[(MTBF)^2/(2MTTR)] + MTTR}$$

$$= \frac{(MTBF)^2}{MTBF^2 + 2MTTR^2}$$

Unavailability, U_D is therefore

$$U_D = 1 - A_D$$

$$= 1 - \frac{(MTBF)^2}{MTBF^2 + 2MTTR^2}$$

$$= \frac{2MTTR^2}{MTBF^2 + 2MTTR^2}$$

If $MTBF \gg MTTR$, then

$$U_D = \frac{2MTTR^2}{MTBF^2}$$

WORKED EXAMPLE

Given MTBF of 2,000 hours and MTTR of 4 hours, calculate the un-availability in 30 years for

(a) a single

(b) dual processor systems.

SOLUTION

(a) Single Processor, Unavailability, $U = \frac{MTTR}{MTBF} = \frac{4}{2{,}000} = 0.002$

or 525 hours in 30 years.

(b) Double processor, Unavailability, $U_D = \frac{2MTTR^2}{MTBF^2} = \frac{2\times16}{4\times10^6} = 8 \times 10^{-6}$

or 2.1 hours in 30 years.

Control in Centralized SPC:

- In Exchange, all the functions are classified into following categories:
  - Event Monitoring and Distribution
  - Call Processing
  - Operation, Maintenance & Call Charging
- In exchange, the processor will process all the functions according to "Interrupt Processing"
- "Interrupt Processing" is done using the priority levels of the programs are being executed by the processor
- The following will interpret the concept of levels of processing or priority of the processing
- From the below diagram it is understood that
- Level 3 Process : Event Monitoring and Distribution
- Level 2 Process : Call Processing
- Level 1 Process : Operation, Maintenance & Call Charging
- The priority of Level 3 > Level 2 > Level 1

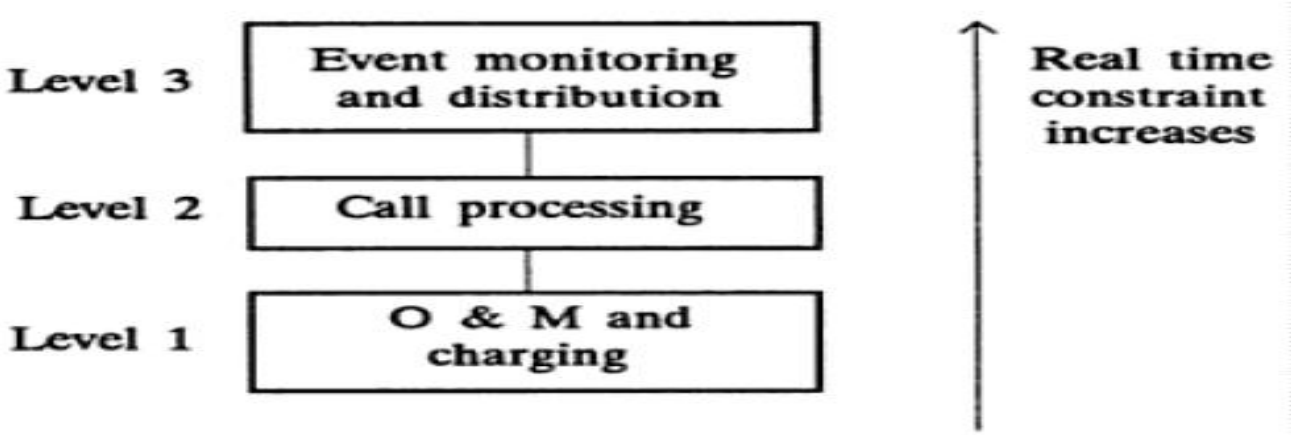


Fig. 4.7 Levels of control functions.

- Let a processor is currently executing a Level 1 Process like "Bill generation" of a consumer, meanwhile if exchange is assigned a new level 2 Process like "Call Connecting" then Processor will currently pause the Level 1 Process and will continue level 2 Process. After completing level 2 Process it will resume level 1 Process this depicts the "Interrupt Processing" as shown below:

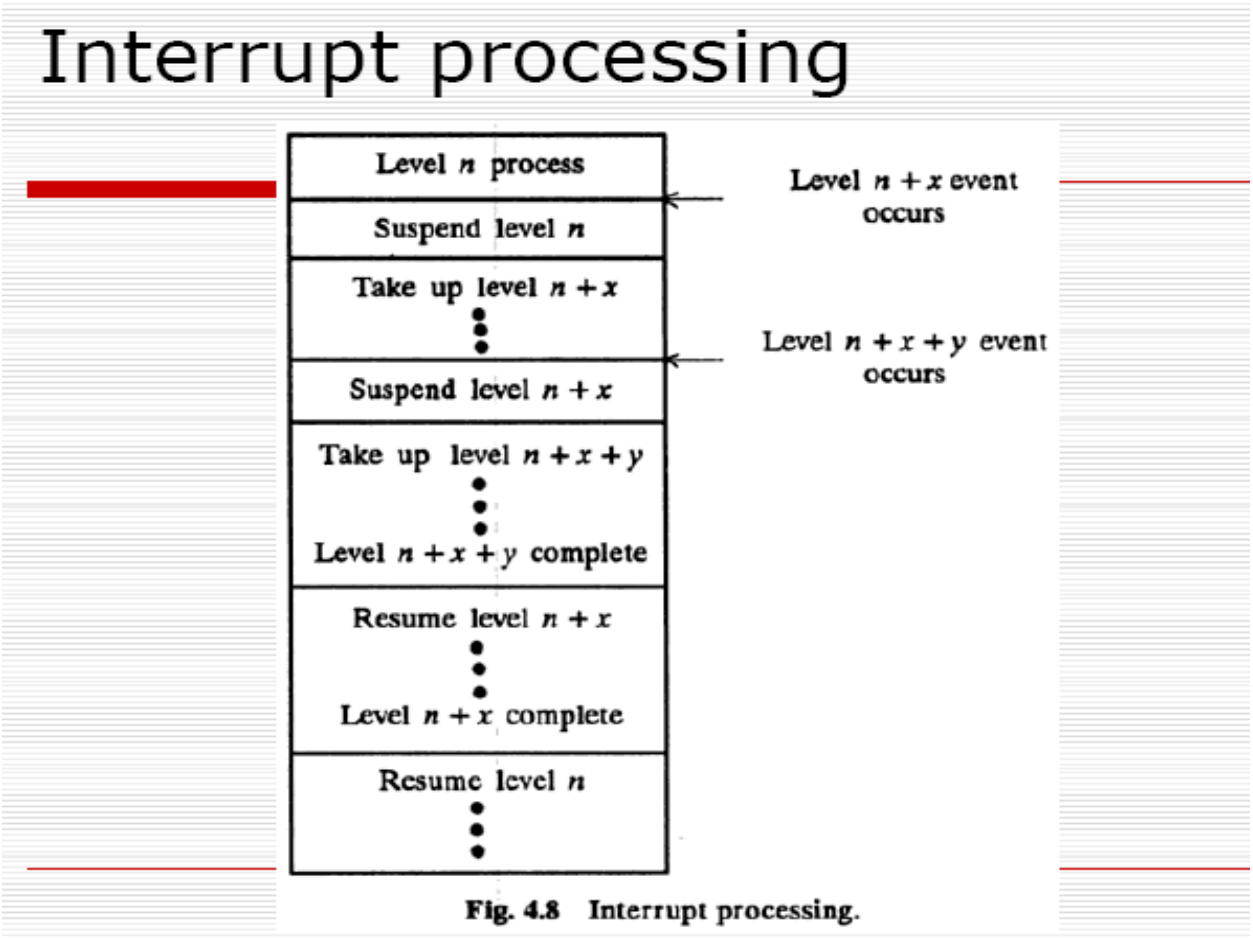


Fig. 4.8 Interrupt processing.

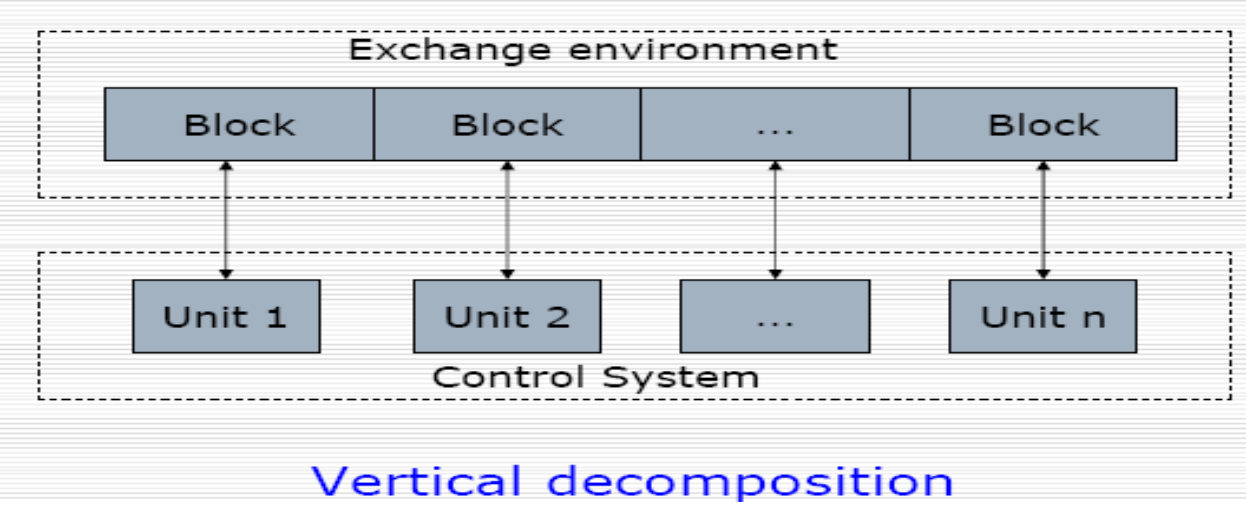
- Interrupts are basically in following types:
- **Maskable Interrupt :** process instructions with different Priorities
- **Non Maskable Interrupt:** The Highest Priority Interrupts like Power Failure, Reset Instruction
- In interrupt Processing when an interrupt occurs program execution is shifted to an appropriate service routine address in the memory through branch operation, this accomplishes with two methods:
- **Vectored Interrupt:** In this method, the set of branch addresses are supplied to the processor with different interrupting sources
- **Non Vectored Interrupt:** In this method, the set of branch addresses are supplied to the processor from fixed source
- In case of Centralized SPC, only one processor is used to process all the exchange functions where as in case of "Distributed SPC" three different processors are used for different levels of operations

2.3 Distributed SPC

- The control functions are shared by many processors within the exchanges.
- This type of structure owes its existence to the Low cost processors
- **Advantages:** Better Availability , Better Reliability
- Exchange Control Functions may be Decomposed either vertically or horizontally for distributed processing.

Vertical decomposition

- The exchange environment is divided into several blocks.
- Each block is assigned to a processor.
- A processor performs all control functions related to the corresponding block.
- The processor in each block may be duplicated for redundancy purposes.
- Obviously, the control system consists of a number of control units.
- The modular structure is flexible for system expanding.



Horizontal decomposition

- The control functions are divided into groups, e.g. event monitoring, call processing, and O&M functions.
- Each processor performs only one or some of the exchange control functions.
- A chain of processors are used to perform the entire control of the exchange.
- The entire chain may be duplicated to provide redundancy.

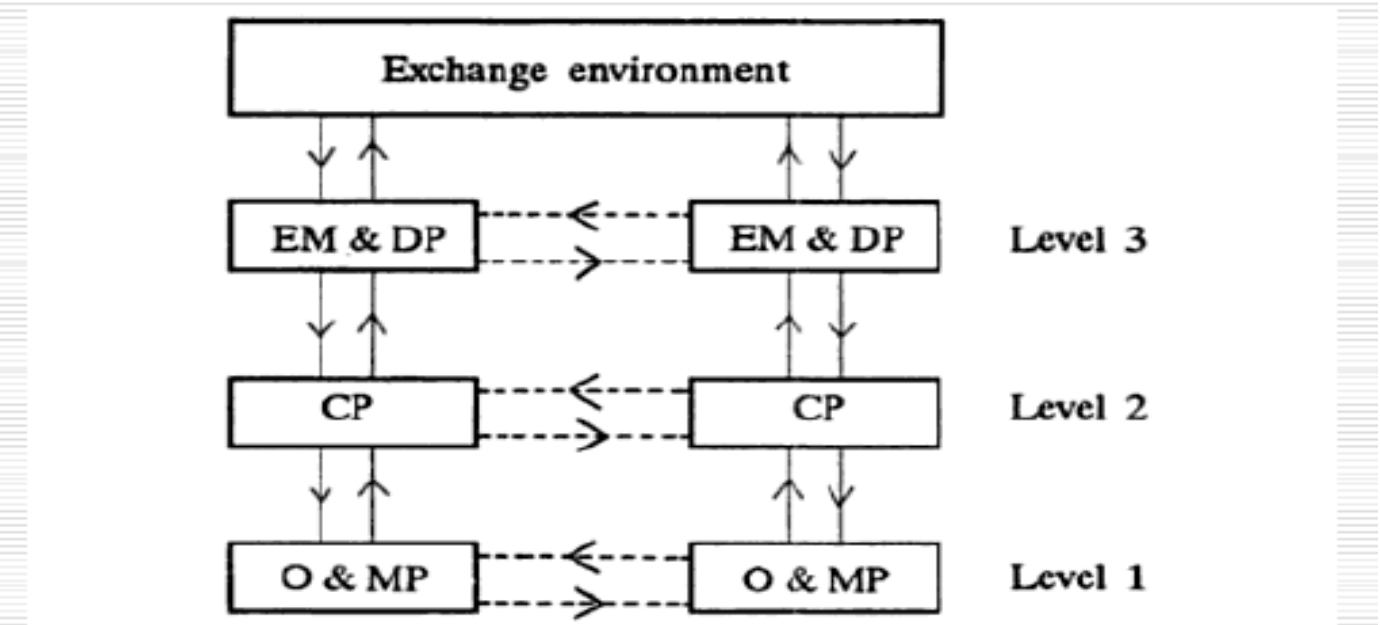


Fig. 4.9 Dual chain distributed control.

- In case of Centralized SPC, only one processor is used to process all the exchange functions where as in case of "Distributed SPC" three different processors are used for different levels of operations.
- From above figure, it is understood that, at each level of processing there are two set of processors are available one set is for active processing and another set is for standby

Level 3 Processing

- Level 3 Processing will include the functions like:
  - Scanning : Subscriber lines/Trunks
  - Distribution : Subscriber lines/Trunks
  - Marking : Registers
  - Controlling all incoming & Outgoing local calls, STD Calls, ISD Calls, Fax &Data services
  - Control of all functions are carried by specially designed Processors with "Micro-programmed Control"

Control schemes

- Hard-wired control unit
  - Designed as a collection of logic circuits using logic elements
- Microprogrammed control unit
  - Using microprocessors to implement all control logic

Table 4.1 Characteristics of Electronic Control Schemes

Microprogrammed control	Hard-wired control
Flexible	Not flexible
Slower	Faster
More expensive for moderate processing functions	Less expensive for moderate simple and fixed processing
Easier to implement complex processing functions	Difficult to implement complex functions
Introducing new services is easy	Not easily possible
Easier to maintain	Difficult to maintain

Level 2 Processing

- Level 2 Processing or Processor is also called Switching Processing or Switching Processor
- The concept of "system availability" it is understood that, the availability of a telephone exchange for a user is completely depending upon the availability of Switching devices at the exchange to connect any two phones are computers. So switching unit play a major role in telephone exchange
- The architecture of switching processors is designed to for 99.9% availability and fault tolerance and security operations
- **Switching Occupancy:** The traffic handling capacity of the control equipment is usually limited by the capacity of the switching processor.
- The load on the switching processor is measured by its occupancy "t", estimated by the simple formula:

$$t=a + bN$$

Where,

- t = Switching Processor capacity
- a = fixed overhead o
- b = average time to process a call o
- N = Number of calls per unit time

Level 1 Processing:

- The Level 1 control handles operations and maintenance (O&M) functions. Which involves the following steps:
    - Administer the exchange hardware and software.
    - Add, modify or delete information in translation tables.
    - Change subscriber class of services.
    - Put a new line or trunk into operation.
    - Monitor traffic.
    - Detect and locate faults and errors.

- Run diagnostic and test programs.
- Man-machine interaction.

- This kind of operations is not required in a huge demand like Level 3 & Level 2 Operations .Because of this reason, a central telephone exchange will provide service of Level 1 Processing.
- Meaning, all the nearby exchanges of a central exchange contain their own level 3 & Level 2 Processing units but Level 1Procesing unit is available at a central telephone exchange. In this way expenses of small exchanges are reduced
- The below diagram will depict the concept of a central Operation and Maintenance and Call Charging Unit of some nearby exchange.

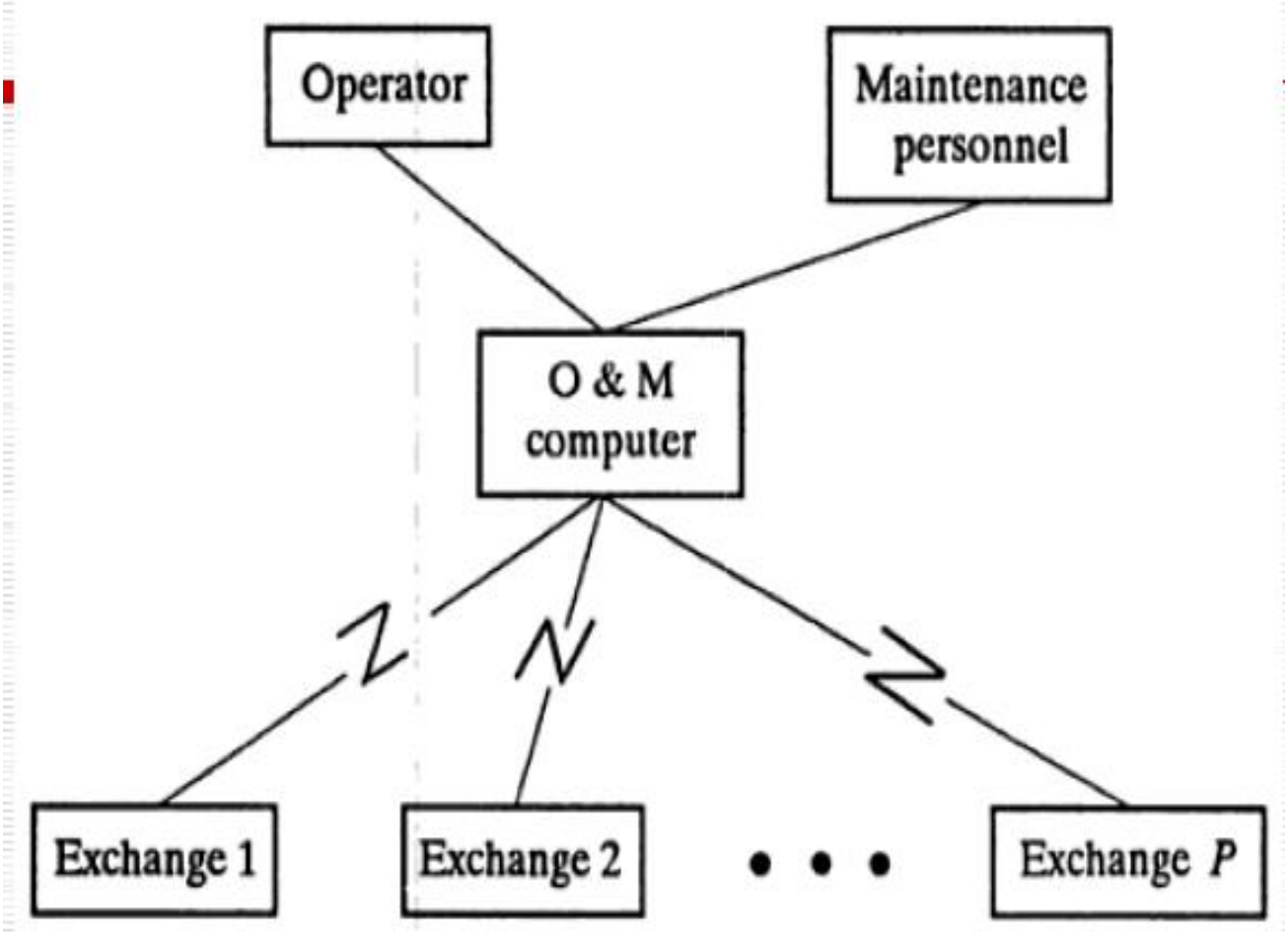


Fig. 4.10 Remote operation and maintenance.

2.4 Software Architecture

- The Software of the SPC systems may be placed under two broad categories:

i. System Software (Operating System)

ii. Application Software (Software based on Operating System)

- We focus on the call processing software systems.

Multiprogramming Feature

- Call processing is event oriented processing function.
- Call setup involves a series of separated processing actions, each action is triggered by an event occurring at a subscriber line or trunk.
- There are many calls being processed simultaneously, each handled by a separate process.
- **Process:** a program or an instruction executed by the processor is commonly called as a "Process"

States of a process

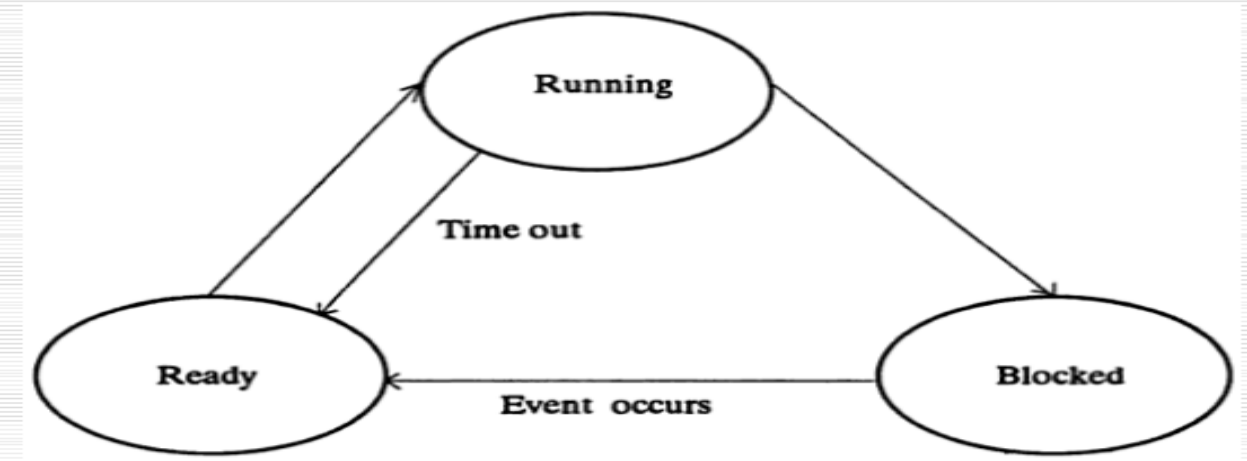


Fig. 4.11 Process states and transitions.

- **Running state:** currently possessing the CPU resources.
  - A CPU can be allocated to only one process at any instant of time.
- **Ready state:** waiting for availability of the CPU.
  - All processes in ready state are ordered according to some priority.

- The first process in the ordered queue is the next which will receive the CPU.
- A timer is employed to prevent any process from monopolising the CPU.

- **Blocked state:** waiting for some event to occur.

Process Control Block (PCB)

- Each process is represented in the operating system by a process control block(PCB) which is a data structure containing the following information about the process:
  - ✓ Current state of the process
  - ✓ Process priority and CPU scheduling parameters
  - ✓ Register save area to save the contents of the CPU registers when an interrupt occurs
  - ✓ Memory allocated to the process
  - ✓ Process account like the CPU time limits and usage, process number etc.
  - ✓ Status of events and I/O resources associated with the process.
- The CPU registers include a program status word (PSW) which contains the address of the next instruction to be executed, the types of interrupts enabled or disabled currently etc.
- Process switching is also known as context switching. Process switching occurs in following cases:
  - ✓ The current running process becomes blocked;
  - ✓ An event or interrupt triggers a high priority process.
- Process switching implies PCB saving and loading, occurs very often in a switching processor.

The act of switching CPU between processes is shown in below figure.

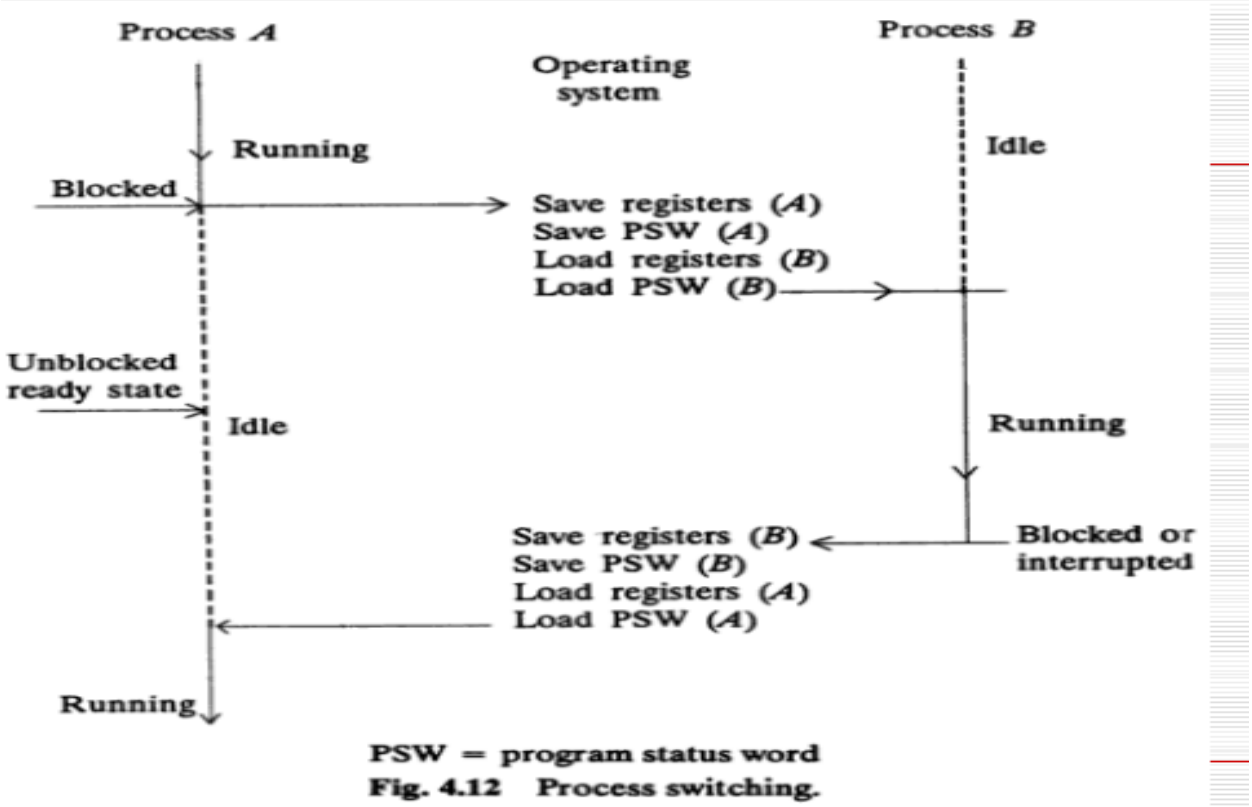


Fig. 4.12 Process switching.

Data sharing in switching system

- Processes share common variables, update common tables, write into common files, and so on.
- If a process A scans a particular subscriber line and finds it free, then the process establishes a call with that subscriber.
- However, if another process B claims the priority and establishes a call with the same subscriber at the same time, then both the processes need to make a call to the same subscriber at the same time, which is not suggestible. A similar problem might occur with other shared tables and files also.
- **Mutual exclusion:** When one process accesses a shared table, all other processes want to access the same table are kept waiting.
- When a process is accessing shared data in any time of its execution, then the process is said to be in **"Critical Region".**
- Mutual exclusion implies that only one process can be in critical region at any instant for a given shared data.

- **Semaphore:** In order to avoid the problem of accessing any two or more processes are in critical state and to avoid "Deadlock" a variable "Semaphore" used

Software production:

- **Basic factors associated with switching software**
  - Complexity and size of the software
  - Long working life required
  - Real time operation
  - Stringent reliability and availability
  - Software portability
- The study of problems encountered in the production and maintenance of large scale software for complex systems has led to the emergence of a special branch of engineering known as software engineering.
- The practice of software engineering technique calls for Four stages in the production of the software systems
  - Functional specification
  - Formal description and detailed specification
  - Coding and verification
  - Testing and debugging
- The subject of software for SPC systems was entrusted to the CCITT (Consultative Committee for International Telephone and Telegraph) study group on "Telephone Switching", SG XI, by the 1968 CCITT Plenary Assembly.
- **CCITT standards on language**
  - Z.100 - specification description language (SDL)
  - Z.200 - CCITT high level language (CHILL)

Z.3xx- Man-machine language (MML)

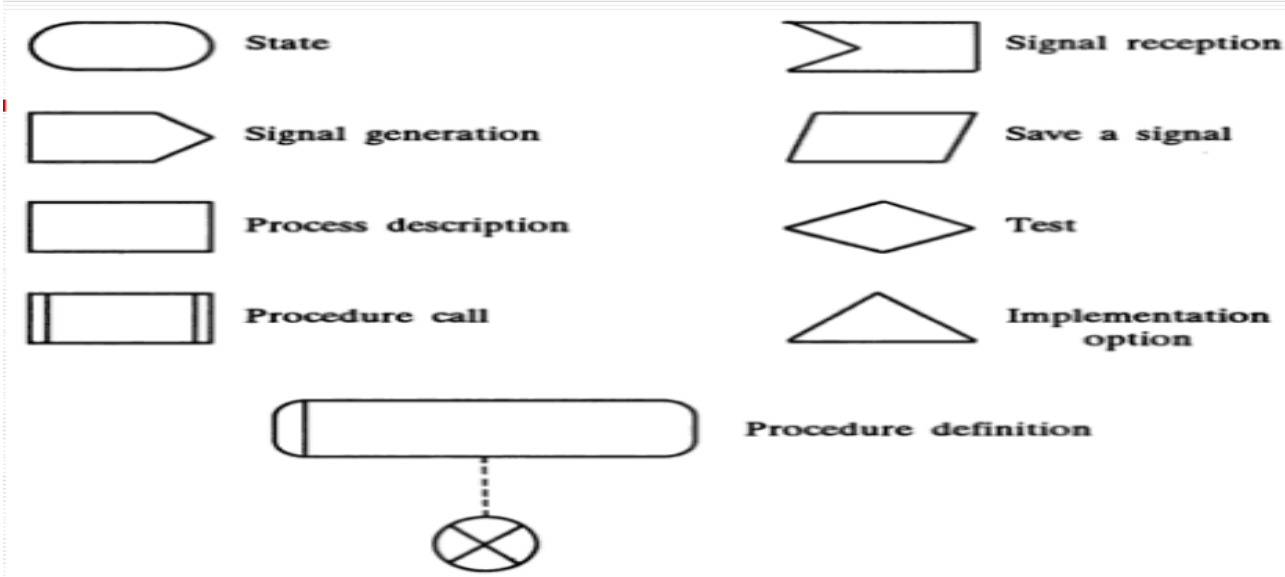


Fig. 4.13 Standard symbols in SDL.

- Switching systems basically belong to the class of finite state machines (FSM) which are asynchronous in nature and follow a sequential logic for their operation.
- FSM can be modeled by using a combinational part and a memory part as shown in below figure

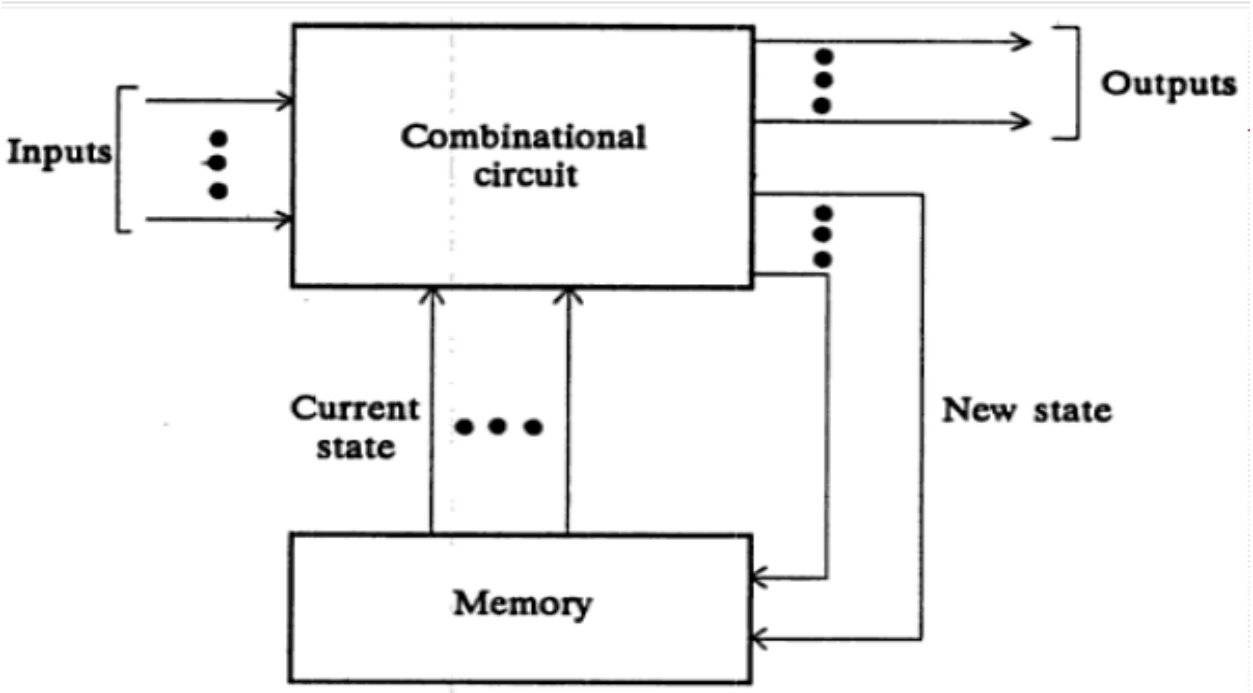


Fig. 4.14 Finite state machine model.

- Asynchronous sequential operation gives rise to many problems due to transient variations that may occur in the logic circuits and memory elements.
- Clocked synchronous operation shown in below figure overcomes such problems

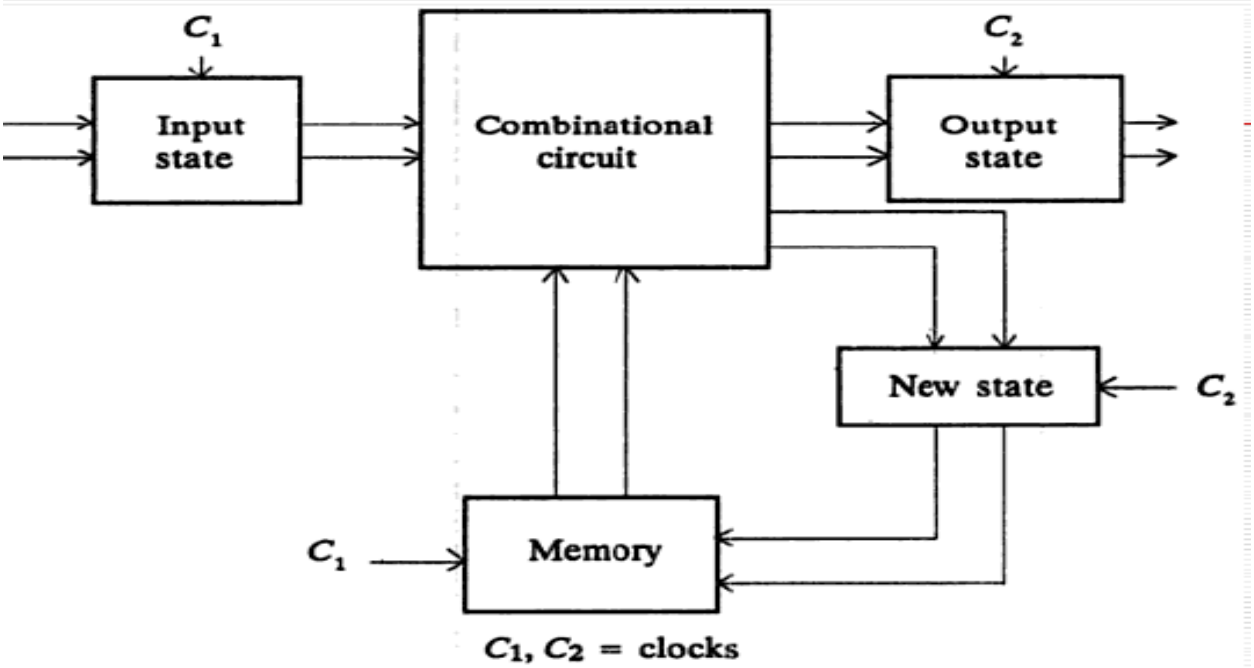


Fig. 4.15 Synchronous FSM.

2.5 Application Software

- The application software of a switching system may be divided into three main Classes. They are
  - Call processing software
  - Administrative software
  - Maintenance software
- A software package is described by its organization, the data structures it uses and the processing functions it performs.
- Application software packages of a switching system use a modular organization.
- Modular organization
  - The software package is divided into program modules.
  - Each module deals with a specific task.

- The size of each module varies depending on the task.
- Modules exchange data through interfaces or data table.
- Modules are grouped together to constitute independent functional units.
- A functional unit runs as a separate process.

The modules of a process are strung together through special programs or chaining tables. Module chaining through tables is illustrated in below figure.

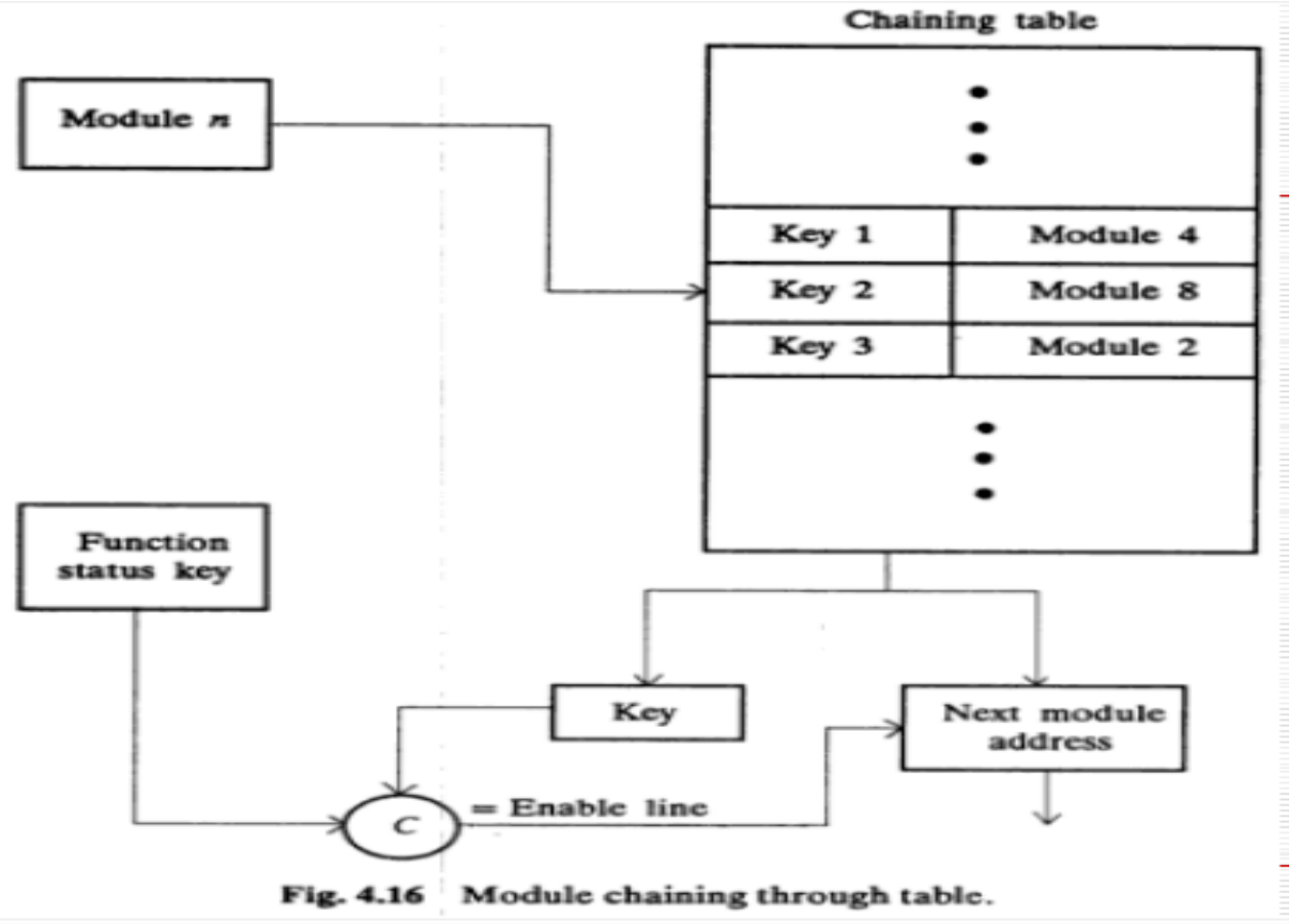


Fig. 4.16 Module chaining through table.

- **Chaining Table**
  - Each entry consists of a key and a module number
  - When a module completes execution, entries in the chaining table are scanned and the keys are compared with a function status key.
  - The matched module is executed next.

- Flexibility for modifying a functional unit: adding or removing modules.

- Switching system software almost always uses a parameterized design the parameters may be divided into system parameters and office parameters.

- **System parameters**
  - Afford flexibility at the overall system level, such as signaling time delays, fault thresholds, etc.

- **Office parameters**
  - Define program execution limits at specific exchanges, such as the number of subscribers, the maximum number of simultaneous calls etc.

- Parametric data are stored in the form of tables or files in the system.

- The nature of the parametric data may be classified as either **semipermanent** or **temporary.**

- **Semipermanent data:**
  - e.g. hardware parameters
  - Updated rather infrequently
  - Stored as files

- **Temporary data**
  - e.g. information specific to a process
  - Have a lifetime equal to the process they pertain to
  - Stored as tables

- Semipermanent contains the following Hardware description files
  - 1.Terminal circuit connection file
  - 2. Switching network configuration file

- Terminal circuit connection file has four fields in each record
  - Associated distributor address
  - Associated scanner address
  - Switching network address

- Physical location address

- Switching network configuration file contains information about the interblock connections
  - Connected subscriber lines
  - Trunks towards other exchanges
  - Rules for digit translation and routing
- Subscriber line information files
  - Correspondence between line equipment number and directory number
  - In-service or out-service status
  - Type of telephone instrument
  - Nominal transmission parameters
  - Call restrictions
  - Subscriber's entitlement
  - Subscriber instructions
- Temporary data are created and modified during call processing . They define the dynamic state of resources and links.
- They constitute the call related data stored in the working area of a process. The main state description tables are:
  - Subscriber line state table
  - Terminal circuit state table
  - Switching network link state table
  - Working area of a process

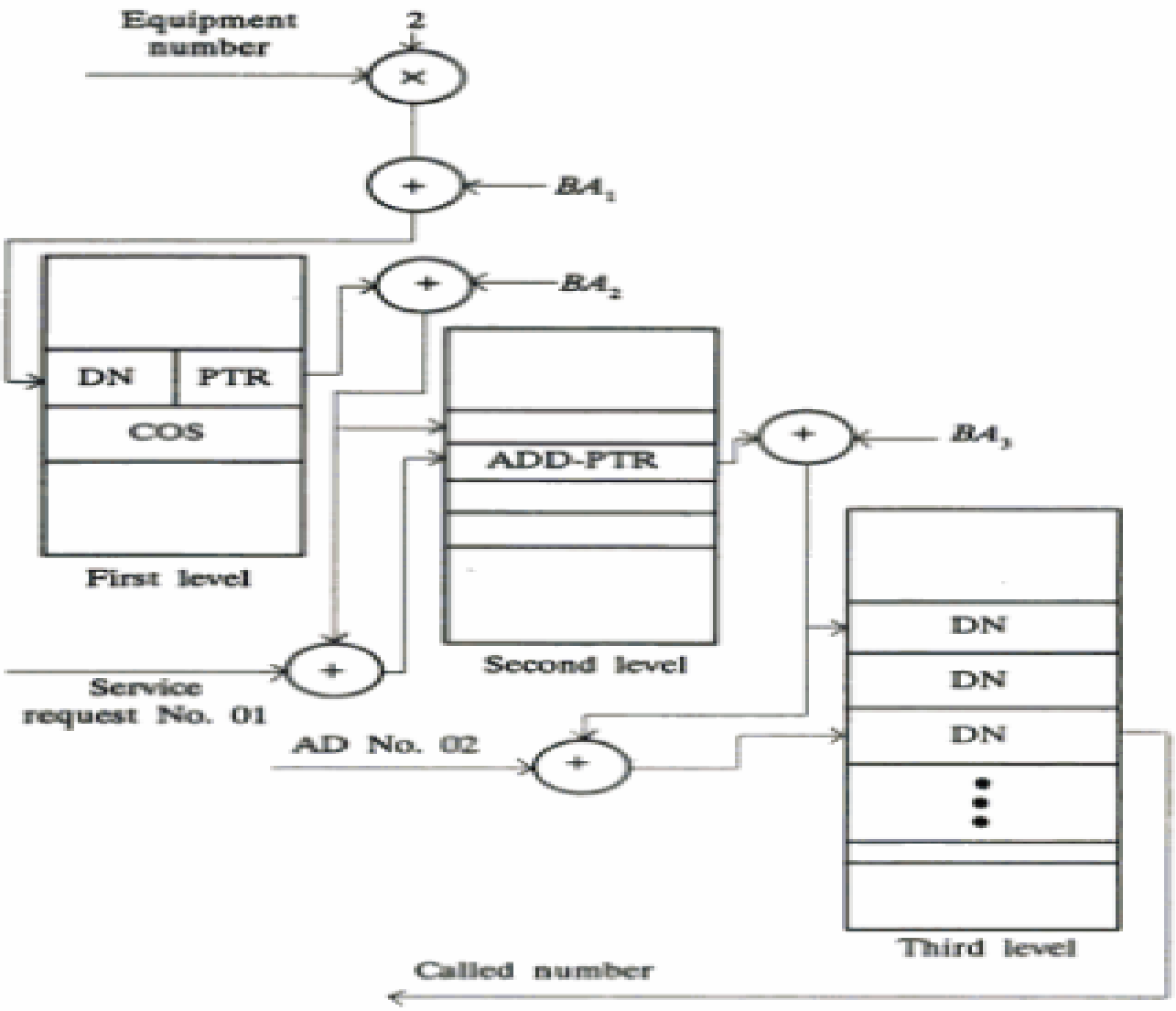


Fig. 4.17 Access to calling line data.

- Typical table entry structures for calling line data are shown in below figure. Which also illustrates the access mechanism for abbreviated dialing.
- Line data tables may be loaded anywhere in the processor memory, depending upon the space availability and allocation.
- At the first level in figure, the equipment number when multiplied by two provides the offset value.
- There are two words per entry in this table and hence the need to double the equipment number.

- The first word contains two parts. The first part is the directory number of the calling subscriber which is needed for transmitting the calling party identification to downstream exchanges or to the called party and for billing purposes.
- The second part contains a pointer to the optional services table if the subscriber has availed any of the optional services. Otherwise, it has a null value.
- The second word contains class of service information which includes the type of instrument, the type of line (individual telephone or public coin box).
- At the second level, each entry takes as many words as the number of optional services offered by the system if we assume that each word in this entry stores information regarding one optional service.
- The value at the first level is suitably adjusted taking this into account.
- When the pointer value is added to the base address 2, the starting address of the entry corresponding to the calling subscriber is obtained.
- The user request for a service is converted to an offset which is added to the starting address of the entry to obtain the word corresponding to that service.
- Example in figure, the calling subscriber request abbreviated dialing facility which is given the service request number 01.
- The word 1 of the entry corresponding to the abbreviated dialing service contains a pointer, ADD-PTR, to a third level table which is the abbreviated dialing directory for the subscribers.
- An access mechanism similar to the one in the second level gives out the directory number of the called subscriber corresponding to the abbreviated dialing number two.

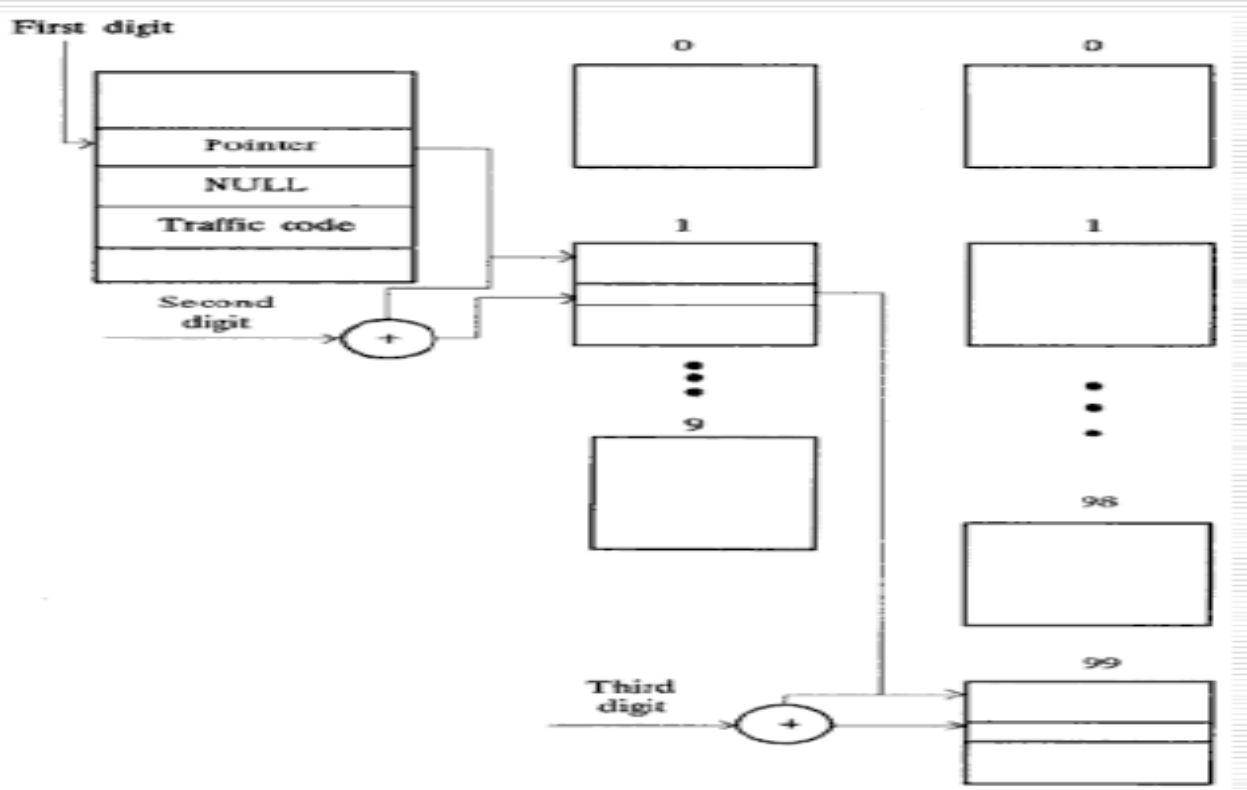


Fig. 4.18 Pyramidal structure for office code translation.

- In telephone environment, the number of address digits to be translated is rarely fixed.
- Exchange codes are either two are three digits. An address that starts with digit zero implies an intercity or international call requiring translation action immediately after the first digit is received.
- In view of this variable number of digits, pyramidal table structures are preferred in electronic exchanges.
- Here, the digits are decoded one by one as they arrive. At each decoding level, the received digit indexes a table and the entry in the table determines the next step.
- The scheme is illustrated in below figure.
- All tables in this scheme have 10 entries each. There is one table in the first level, a maximum of 10 tables in the second level and 100 tables in the third level.
- If certain digits are not used, the corresponding tables in the next level do not exist.
- An entry in the table may contain a traffic code or a pointer to the beginning of a block in the next level or a null value
- The null value means that the particular digit combination is not in use.

- The traffic code supplies the outgoing trunk group number and the associated signaling characteristics

2.6 Enhanced Services

- Categories of enhanced services
    - 1. Services associated with the calling subscriber and designed to reduce the time spent on dialing and the number of dialing errors.
    - 2. Services associated with the called subscriber and designed to increase the call completion rate.
    - 3. Services involving more than two parties.
    - 4. Miscellaneous services.
- These new services are known as supplementary services and some of the prominent ones are as follows:
- **Category 1**
    - Abbreviated dialing
    - Recorded number calls or no dialing calls.
    - Call back when free
- **Category 2**
    - Call forwarding
    - Operator answer
- **Category 3**
    - Calling number record
    - Call waiting
    - Consultation hold
    - Conference calls
- **Category 4**
    - Automatic alarm

- STD barring
- Malicious call tracing

- A subscriber issues commands to an exchange to activate or deactivate a service, record or clear data in the subscriber line data area or solicit an acknowledgement from the exchange.
- As an example, a user may enable or disable STD facility on his line by using a command. A command may or may not have data associated with it.
- The number of digits in the data, when present, may vary depending upon the command. As a result, subscriber commands are designed to be of variable length necessitating the use of an end of command symbol.

The general command syntax is shown in below figure.

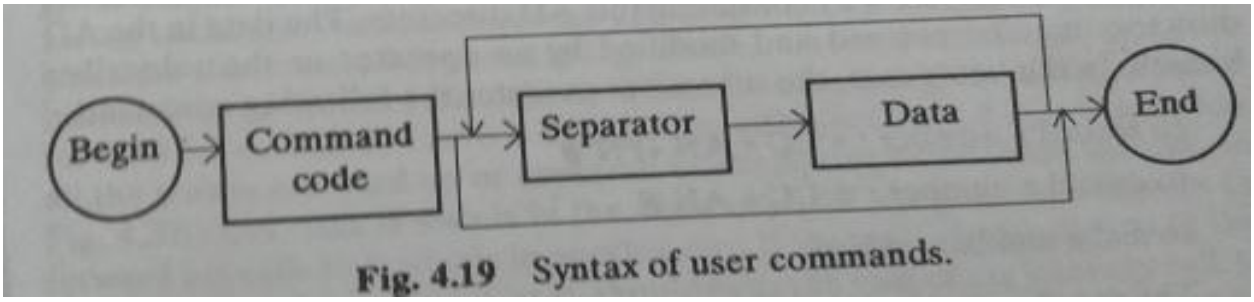


Fig. 4.19 Syntax of user commands.

Abbreviated Dialling (AD): This facility allows an entitled subscriber to call any of a predefined list of other subscribers by dialling just one or two digits. Memory area called abbreviated dial directory is resreved for each user availing AD facility, which contains the abbreviated number (AN) and the corresponding full number (FN) of the subscriber to be called

Recorded Number calls: This facility permits a subscriber to call a predetermined number by simply lifting the handset without dialling any digit whatsoever. Unlike a hot line facility where a dedicated line between the calling and called subscribers exists and no other calls are permitted using this line and instrument, recorded number call service is programmable one. Here the subscriber may use his telephone in the normal way and at the same time have recorded number facility.

Call back when free: This feature permits the calling subscriber to instruct the exchange , when the called party is busy, to monitor the called line and ring him back when it becomes free.

Call Forwarding : It enables a subscriber to instruct the exchange to forward all his calls to another number. It is relatively straight forward to implement this facility in a PABX or local exchange.

Operator answer service: This facility diverts all the calls of a subscriber to an operator, who answers the calls, take down messages which are communicated to the subscribers whenever he calls the operator.

Calling number record feature: This feature keeps a record of the number calling the subscriber when he is unable to attend to the calls for same reason of the other. The number of calling numbers recorded is usually limited to a few, say up to five most recently dialled numbers:

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Call waiting feature: Provides an indication to a busy subscriber that another party is trying to reach him. This indication is given through a short audible tone , lasting typically about three seconds.

Consultation hold: is a facility that enables a subscriber in conversation to place the other subscriber on hold and contact a third subscriber for consultation.

Conference call facility: is an extension of the consultation hold feature. After the third party is brought in, a conference connection is set up among all the three. Each of the parties then receives the speech signals of the others and can proceed with the conversation in a conference mode.

Automatic alarm call : This facility allows a user to record the time at which the alarm call is to be given. The SPC processor rings back the subscriber at the appropriate time. Usually a separate synchronous process that runs periodically , say every five minutes , scans a table that holds the alarm times and the corresponding subscriber numbers. When the alarm time matches the time of the day , a ringing tone is sent to the subscriber's instrument , usually for one minute or until he answers, whichever is earlier.

STD barring : Many a time, particularly in office premises , telephones with STD/ISD facility are misused . Preventing this by using a manual lock places restrictions on even local calls being made:

Malicious call tracing: is easily done in an electronic exchange and is usually activated by the network operator on request from subscriber.

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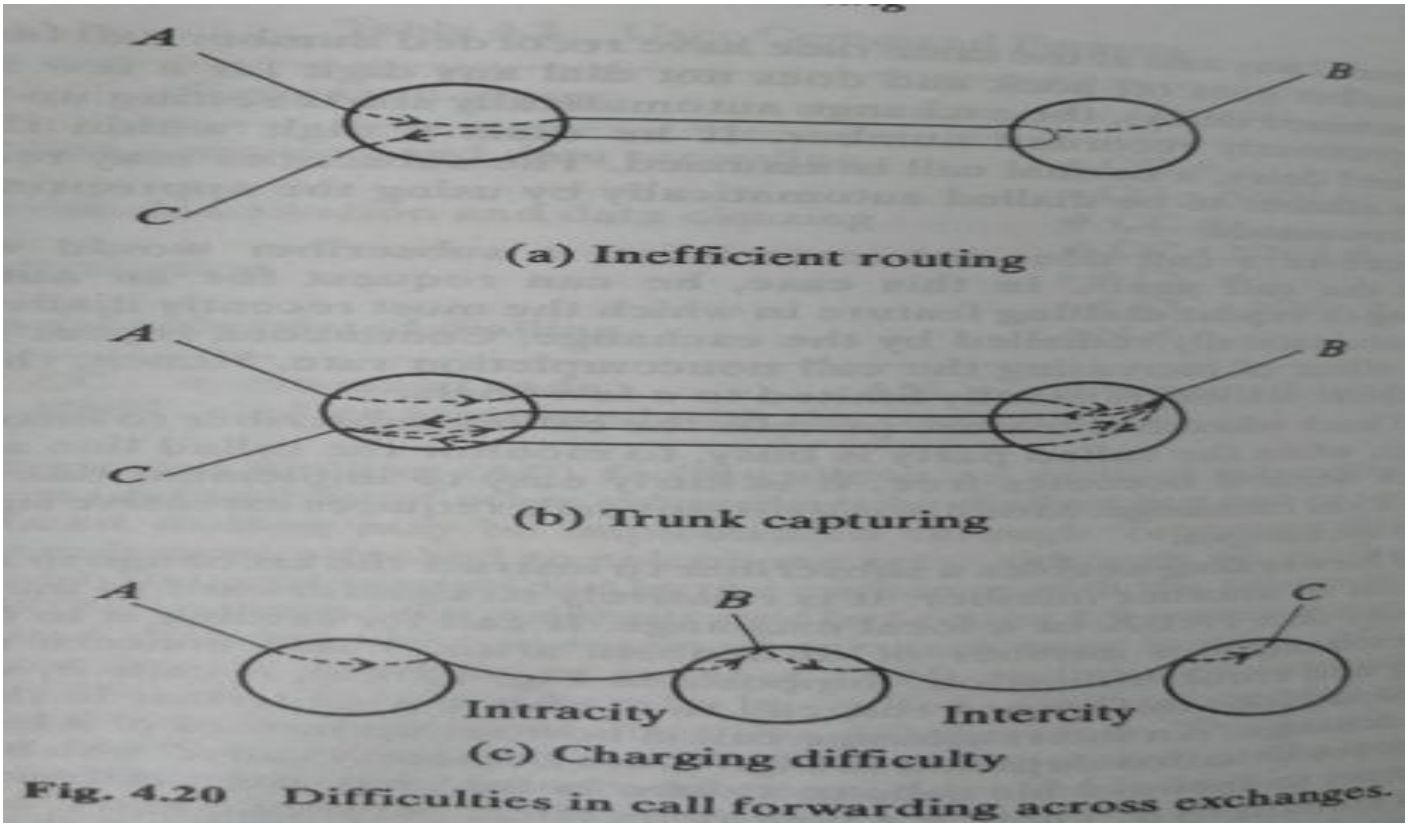


Fig. 4.20 Difficulties in call forwarding across exchanges.

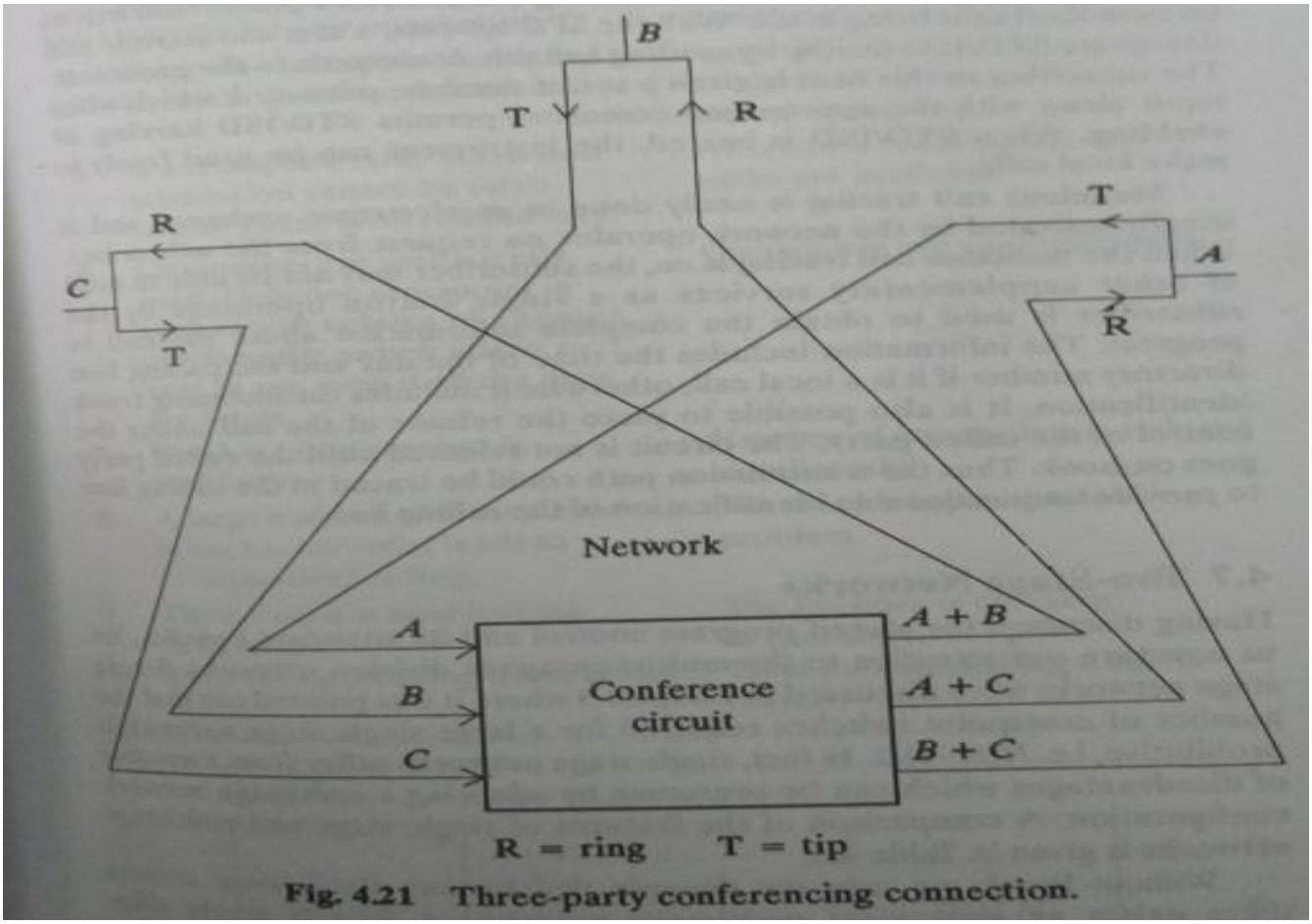


Fig. 4.21 Three-party conferencing connection.

2.7 Two-Stage Networks

- For any single stage network, there exists an equivalent multistage network.
- **Simple Two-stage N x N network**
  - A N x N single stage network with a switching capacity of K connections can be realized by a two stage network of N x K and K x N.
- **First Stage:** Any of the N inlets can be connected to any of the K outputs. NK switching elements.
- **Second Stage:** Any of the K inputs can be connected to any of the N outlets. NK switching elements.
- There are K alternative paths for any inlet/outlet pair connection.

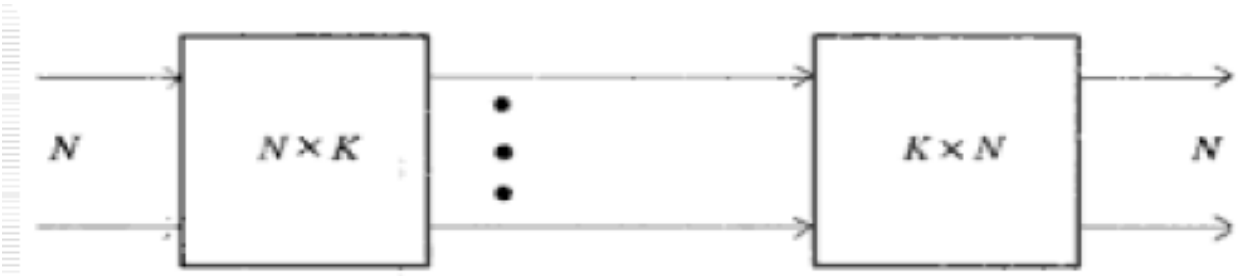
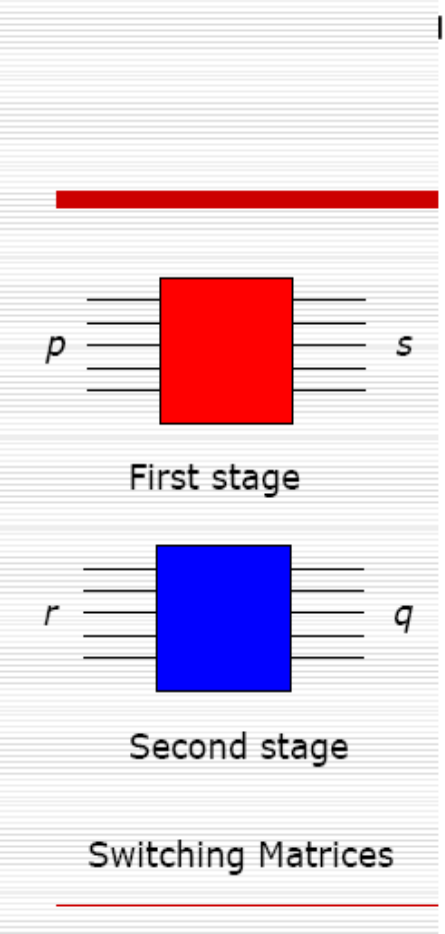


Fig. 4.22 A two-stage representation of an $N \times N$ network.

- **Full connectivity/full availability**
  - Any of the N inlets can be connected to any of the N outlets.
- **Example:**
- Assume 10% of the subscribers to be active on average. Set K to be N/16. The number of switching elements is S=N2/8.
- For N=1024, we have K=64, S=131072.

Architecture of General two-stage networks

- Multiple small size matrices are used in each stage.
- Easy to be realized in practice.
- Flexible in system design.
- **M x N two-stage network design**
  - M inlets are divided into r blocks of p inlets each such that M = p x r,.
  - N outlets are divided into s blocks of q outlets each such that N = q x s
  - Full availability: There must be at least one out let from each block in the first stage terminating as inlet on every block of the second stage.
  - The block sizes as p x s and r x q for the first and second stages respectively.



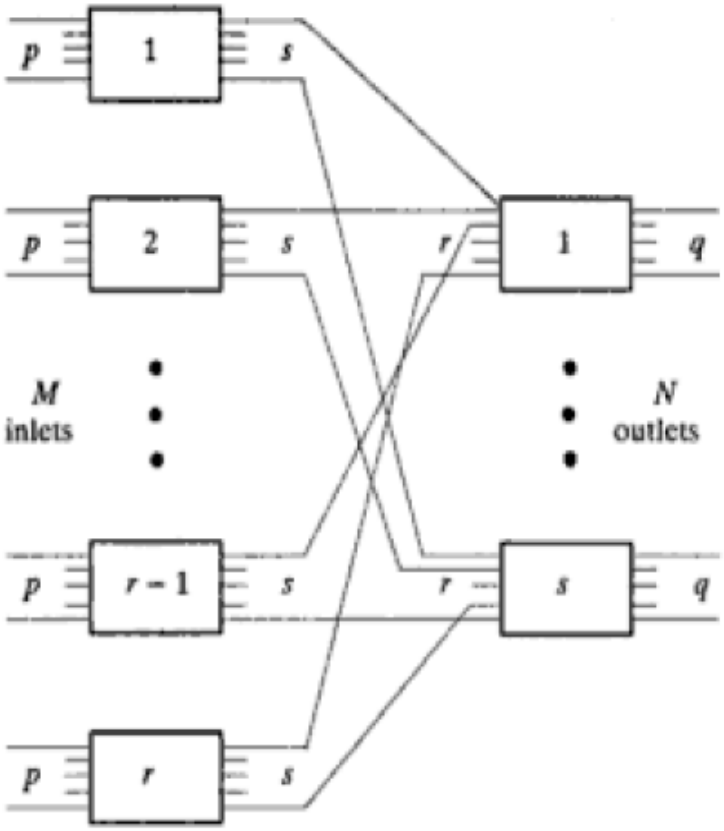


Fig. 4.23 Two-stage network with multiple switching matrices in each stage.

- **Parameters**
  - Number of switching elements (S)

$$S=psr+qrs=Ms+Nr$$

- The number of simultaneous calls that can be supported by the network,

i.e Switching Capacity (SC) is equal to the number of links between the first and the second stage.

$$SC= sr$$

- **Parameters**
  - **Blocking probability**
    - Blocking condition 1
      - There are r x s calls in progress, and the (rs+1)-th call arrives;

- The blocking probability PB is dependent on the traffic statistics.

- Blocking condition 2
  - There is a call in progress from I-th block in the first stage to the J-th block in the second stage, and another call originating in the I-th block destined to the J-th block.

Blocking probability:

$$P_B = \frac{M\alpha(s-1)((M/r)-1)\alpha}{rs(s-1)}$$

- Let α be the probability that a given inlet is active. Then, the probability that an outlet at the I-th block is active is

$$\beta=(p\alpha)/s$$

- The probability that another inlet becomes active and seeks an outlet other than the one which is already active is given by

$$(p-1)\,\alpha\,/\,(s-1)$$

- The probability that the already active outlet is sought is therefore,

$$P_B = \frac{p\alpha}{s}\left[1 - \frac{(p-1)\alpha}{s-1}\right]$$

Substituting $p = M/r$, we have

$$P_B = \frac{M\alpha(s-1) - ((M/r)-1)\alpha}{rs(s-1)}$$

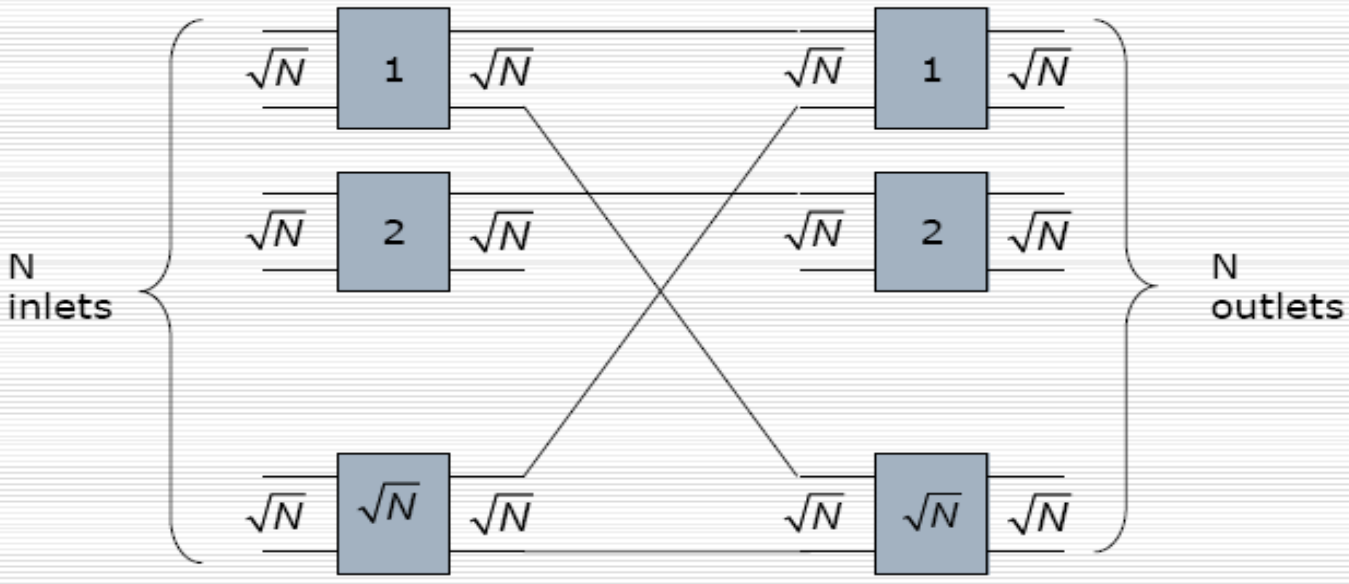
- Both S and SC are proportional to r & s.
- Blocking probability PB is reversely proportional to r & s.
- Strategy: Tradeoffs should be made between cost and quality of service.
  - The values of r & s should be as small as possible but give sufficient links to provide a reasonable grade of service to subscribers.

- **Terminology**
  - The network is Expanding the traffic: M<N
  - The network is Concentrating the traffic: M>N
  - Square network: M=N

Square two-stage networks

- Baseline networks
  - Square switching matrices are used as building blocks.
  - $p=r=s=q=N^{1/2}$
  - There are $N^{1/2}$ blocks, each block is a switching matrix of $N^{1/2} \times N^{1/2}$ inlets and outlets.
  - Switching elements: $S=2N \times N^{1/2}$
  - Switching capacity: $SC=N$
  - Support N simultaneous calls only if the traffic is uniformly distributed.

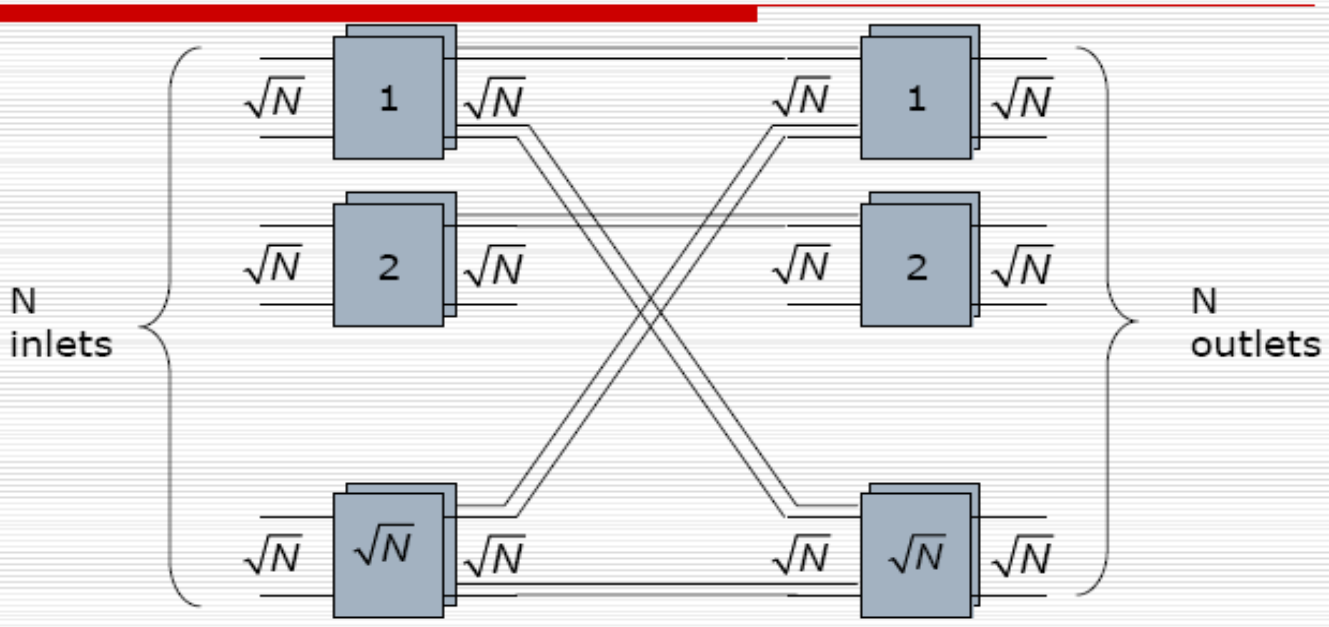
Baseline networks



Square two-stage networks

- Nonblocking networks
  - Why does blocking occur?
    - Only one link exists between a pair of first stage and second stage blocks.
  - How to reduce the probability of blocking?
    - Provide more links between the first stage and second stage blocks.
  - How many links should be provided?
    - A group of $k=N^{1/2}$ links should be provided for each pair of first stage and second stage blocks. $S=2N^2$.
    - In comparison with single stage network, the number of switching elements is doubled.

Nonblocking networks



$S=kx2NxN^{1/2}=2N^2$

2.8 Three Stage Network

- The blocking probability and the number of switching elements can be reduced significantly by adopting a three stage structure in place of two stage network.
- The general structure of an N x N three stage blocking network is shown in below figure.

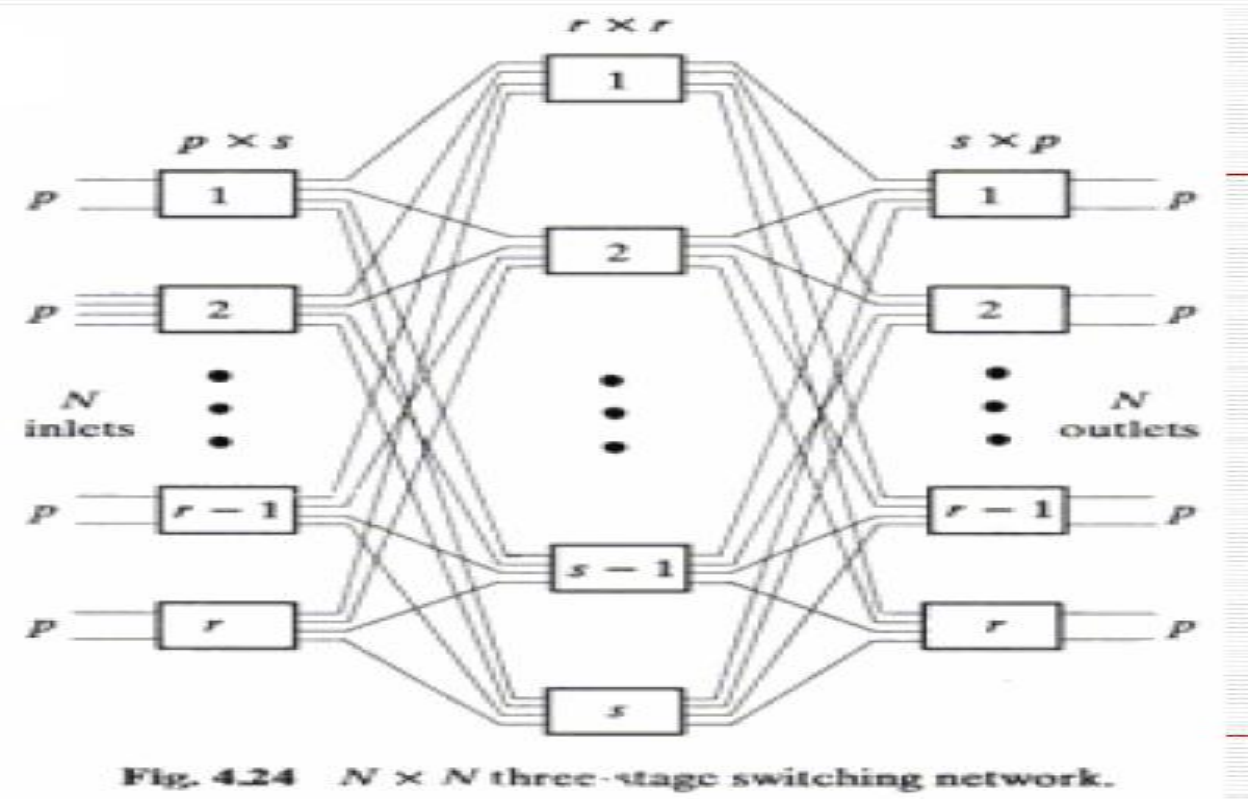


Fig. 4.24 $N \times N$ three-stage switching network.

- The N inlets and N outlets are divided into r blocks of p inlets and p outlets each respectively.
- The network realised by using
  - Stage 1: p x s switching matrices
  - Stage 2: r x r switching matrices
  - Stage 3: s x p switching matrices
- N=p x r, s is changeable
- Compared with a two-stage network, there are s alternative paths between a pair of inlet and outlet.

Number of switching elements

- $S=rps+sr^2+spr=2Ns+sr^2=s(2N+r^2)$
- If square matrices are used in both the first and third stages, then p=s=N/r and
  $S=2N^2/r+Nr$
- For a given value of N, there exists an optimal value of r which minimizes the value of S. To obtain this value of r, we differentiate above equation and equal to zero
  $dS/dr= -2N^2/r^2 +N=0$
- The optimal value of r is $r=(2N)^{1/2}$ and the corresponding minimum of S is
  $Smin=2N\ (2N)^{1/2}$

  $p=N/r=(2N)^{1/2}$

Blocking probability analysis

- A probability graph of a three stage network is shown in below figure.
- In the graph, the small circles represent the switching stages and the lines represent the interstage links.
- The network graph shows all possible paths between a given inlet and an outlet.
- Blocking probabilities in the network may be estimated by breaking down a graph into serial and parallel paths.

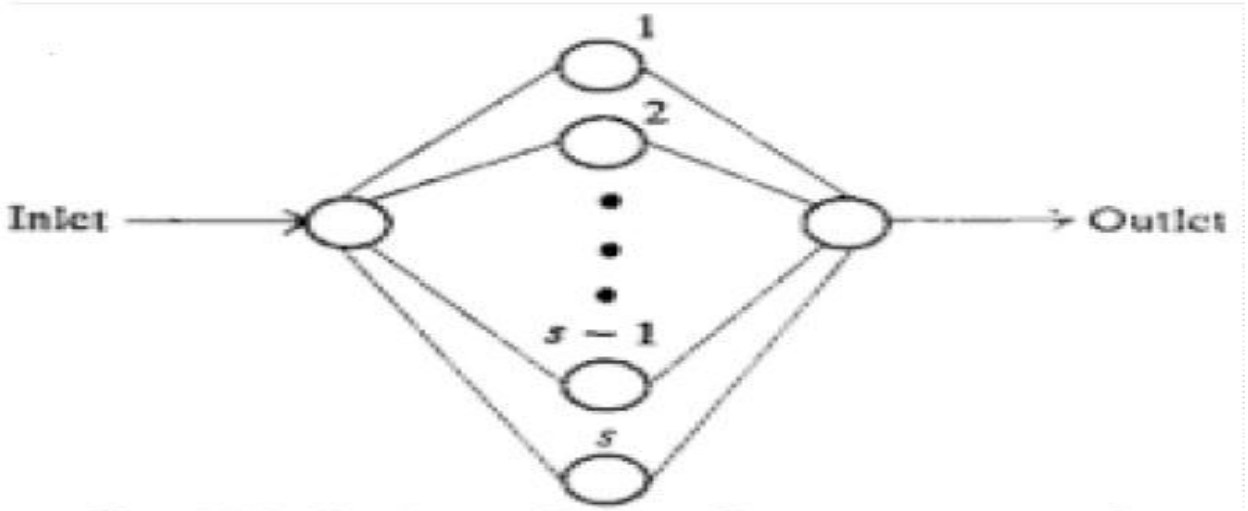
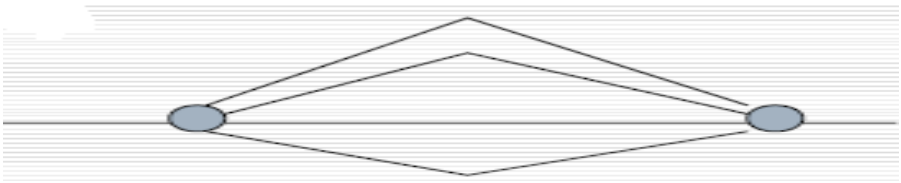


Fig. 4.25 Lee's graph for a three-stage network.

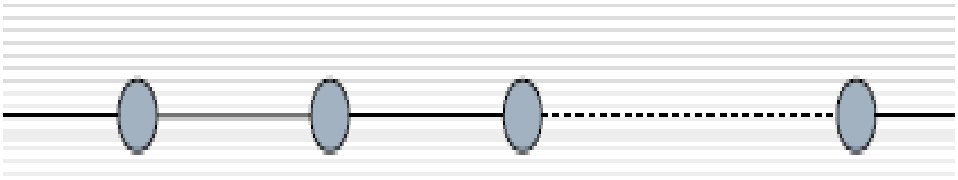
- Let, β: probability that a link is busy.
- β'=1-β: probability that a link is free.

- If there are s parallel links, the blocking probability is the probability that all the links are busy.



$$P_B = \beta^s \qquad Q_B = 1 - P_B = 1 - \beta^s$$

- When a series of s links are needed to complete a connection, the blocking probability is easily determined as one minus the probability that they are available.



$$P_B = 1 - (\beta')^s = 1 - (1 - \beta)^s$$

- For three stage network, there are two links in series for every path and there are s parallel paths. Therefore

$$P_B = [1 - (\beta')^2]^s = [1 - (1 - \beta)^2]^s$$

- If α is the probability that an inlet at the first stage is busy, then

$$\beta = p\alpha/s = \alpha/k$$

$$P_B = [1 - (1 - \alpha/k)^2]^s$$

Remarks on P_B of three-stage

- The notation k=s/p represents either space expansion (k>1) or concentration (k<1).
- Low P_B requests small α/ k
    - In case of small α, e.g. end offices and PBX, k can be small. It means concentration can be used in first stage.
    - In case of large α, e.g. transit exchanges, k should be large. It implies that expansion should be used in first stage

Nonblocking 3-Stage Switches

- **C. Clos:** pioneer researcher of multistage nonblocking networks.
- Clos showed that it is possible to construct multistage nonblocking networks that have less number of switching elements than the corresponding single stage networks.
- Multistage nonblocking and fully available networks are known as Clos networks after his name.
- A three stage switching network can be made nonblocking by providing adequate number of blocks in the second stage, i.e by increasing the value of s.
- **Worst situation for blocking**
    - 1.p-1 inlets in a block I in the first stage are busy;
    - 2.p-1 outlets in a block O in the third stage are busy;
    - 3. The p-1 second-stage blocks, on which the p-1 outlets from block I are terminated on, are different from the p-1 second-stage blocks from which the links are established to the block O.
    - 4.The free inlet of block I needs to be terminated on the free outlet of block O.
- The number of blocks required in the second stage for nonblocking operation is s=2(p-1)+1= 2p-1.
- The number of switching elements in the nonblocking configuration is given by

$$S = p(2p-1)r + (2p-1)r^2 + p(2p-1)r$$
$$= 2N\left(\frac{2N}{r} - 1\right) + r^2\left(\frac{2N}{r} - 1\right)$$
$$= \frac{4N^2 - 2Nr}{r} + 2Nr - r^2$$

- There exists an optimal value of r for minimizing the value of S

$$\frac{dS}{dr} = -\frac{4N^2}{r^2} + 2N - 2r = 0$$

i.e. $-2N^2 + Nr^2 - r^3 = 0$, or

$$r^2(N - r) = 2N^2$$

For large values of N, we have $N - r = N$, and hence

$$r = \sqrt{2N}, \quad p = \sqrt{N/2}$$

Substituting the value of r in Eq. (4.22), we have

$$S_{min} = \frac{4N^2}{\sqrt{2N}} - 2N + 2N\sqrt{2N} - 2N$$
$$= 4N\sqrt{2N} - 4N = 4N(\sqrt{2N} - 1)$$
$$= 4N\sqrt{2N}$$

We may now define a factor called switching elements advantage ratio λ as

$$\lambda = \frac{\text{number of switching elements in a nonblocking single-stage network}}{\text{number of switching elements in a nonblocking three-stage network}}$$

shows the values of S and λ for some values of N.

Table 4.4 Switch Advantage Ratio in Three-Stage Networks

N	Number of switching elements, S		λ
	Single stage	Three stages	
128	16,384	8,192	2
2,048	4 million	0.5 million	8
8,192	64 million	4 million	16
32,768	1 billion	32 million	32

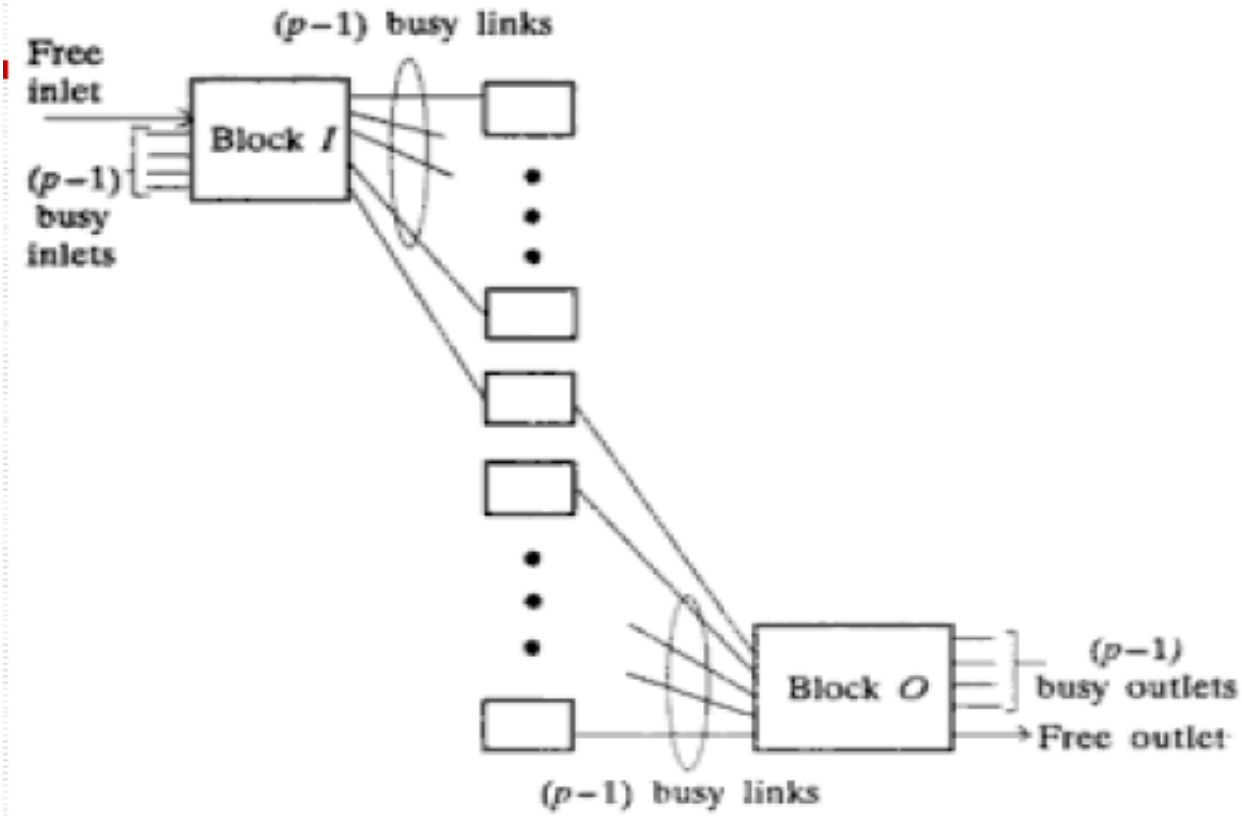


Fig. 4.26 Three-stage nonblocking configuration.

2.9 n-Stage networks

- Further reduction in the number of switching elements are possible by using even higher number of stages than three.
- Construction of multi-stage networks
    - By replacing the middle blocks with three-stage network blocks continually, any number of stages can be obtained.

Construction of five-stage switching network is shown below

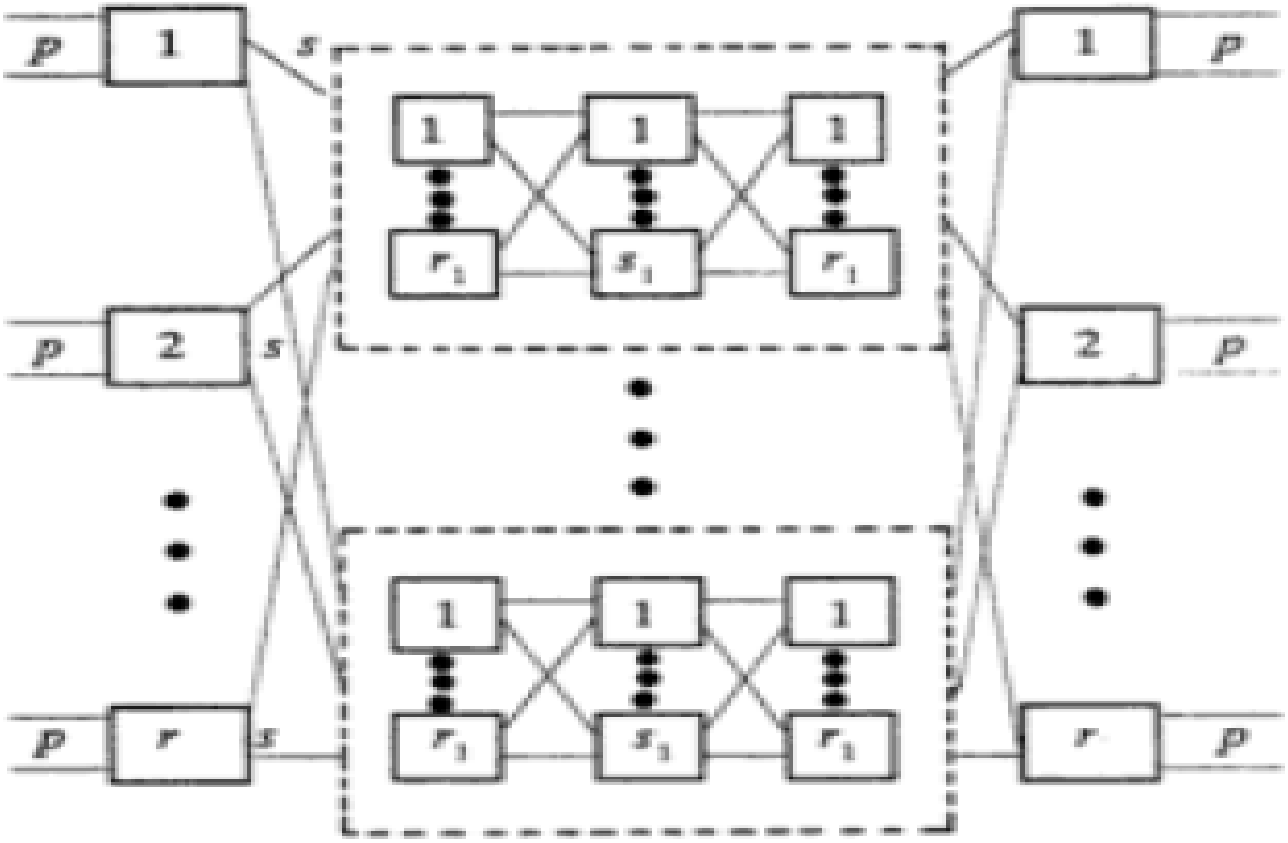


Fig. 4.27 Five-Stage switching network.

Single Stage Network	Multistage Network
1.Inlet to outlet connection is through a single cross-point	1.Inlet to outlet connection is through multiple cross-points
2.Use of a single crosspoint per connection results in better quality link	2.Use of multiple cross-points may degrade the quality of a connection.
3.Each individual crosspoint can be used for only one inlet/outlet pair connection	3.Same cross-point can be used to establish connection between number of inlet/outlet pairs.
4.A specific crosspoint is needed for each specific connection.	4. A specific connection may be established by using different sets of cross-points
5.If a crosspoint fails, associated connection cannot be established. There is no redundancy	5.Alternative cross-points and paths are available.
6.The network is nonblocking in character	6.The network is blocking in character
7.Time for establishing a call is less	7.Time for establishing a call is more
8.Number of crosspoints is probhibitive.	8.Number of cross-points is reduced significantly

UNIT – 2

* ELECTRONIC SPACE DIVISION SWITCHING *

→ Early crossbar systems were slow in call processing as they used electromechanical components for common control subsystems

→ when the modern electronic digital computers are come into picture, switching engineers soon realized that in principle the registers and the translations of the common control system could be replaced by a single digital computer.

⇒ stored program control (SPC)

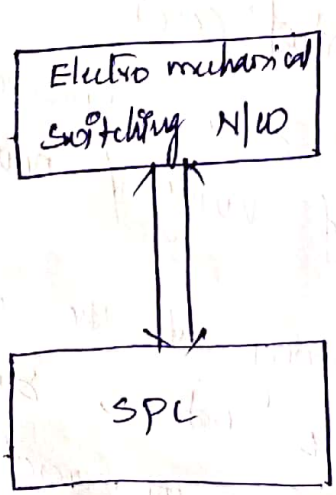
modern digital computer use the stored program concept, Here a program or a set of instructions to the computer is stored in its memory and the instructions are executed automatically one by one by the processor.

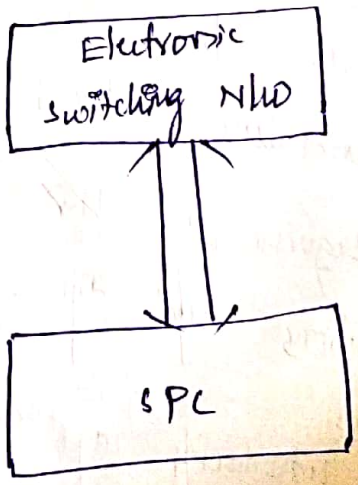
- carrying out the exchange control functions through program stored in the memory of computer led to the nomenclature "stored program control" (SPC)
- consequence to this SPC, full scale automation of Exchange functions and the introduction of variety of new service to users.
- Introducing a computer to carry out the control functions of a telephone exchange is not as simple as using a computer for scientific or commercial data processing

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- common channel signalling, centralized maintaince and automatic fault diagnosis and interactive human machine interface are the some of the features. are possible due to application of SPC telephone switching.
- Attempt to introduce electronics and computers in the control subsystems of exchange were encouraging enough to spur the development of full-fledged electronic switching systems.
- The world first electronic switching system known as No 1 ESS, was commissioned by AT&T Succeeding, Newjersey
- Today, SPC is a standard feature in all the electronic exchanges, replacement of space division - electromechanical switching matrices with semiconducts crosspoint matrices have not been greatly successful to engineers returns to electromechanical switching with complete electronic Environment.

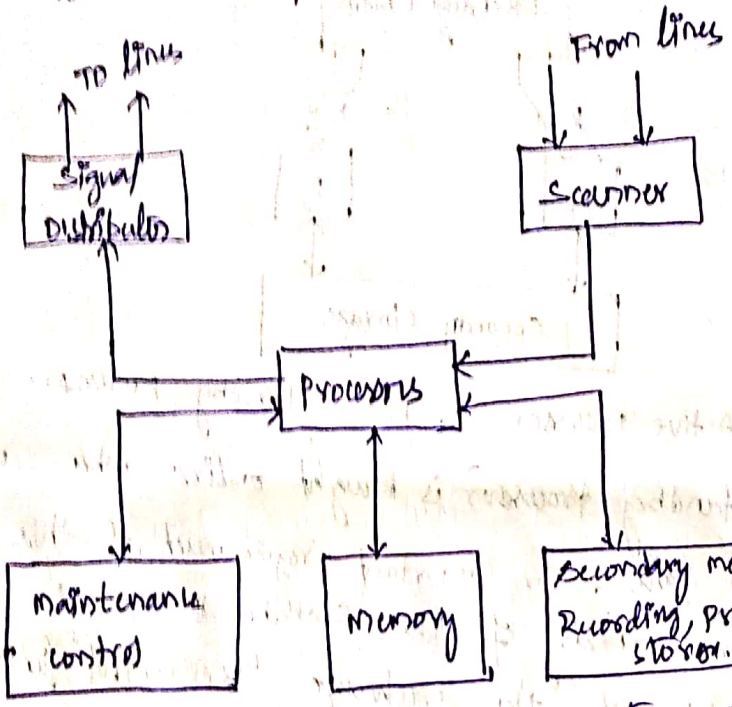




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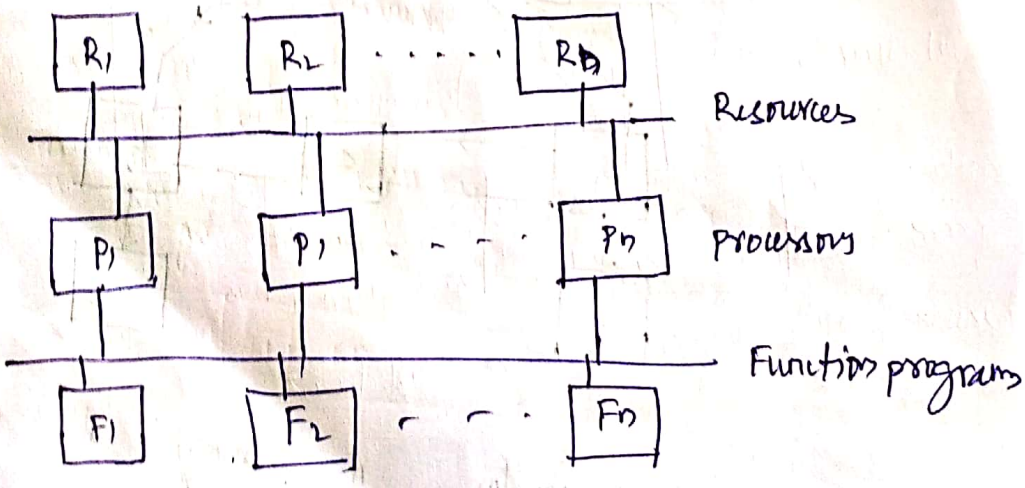
Centralized SPC:

→ In centralized spc all the control equipment is replaced by a single processor which might be quite powerful. It must be capable of processing 10 – 100 call / second.



Typical centralized SPC

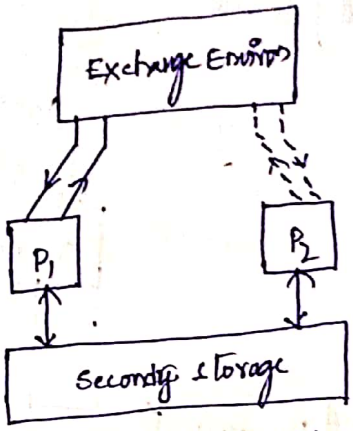
→ Depending on the load of the system, centralized SPC would simultaneously perform many other ancillary tasks.



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→ stand by mode
→ Synchronous duplex mode
→ load sharing mode.

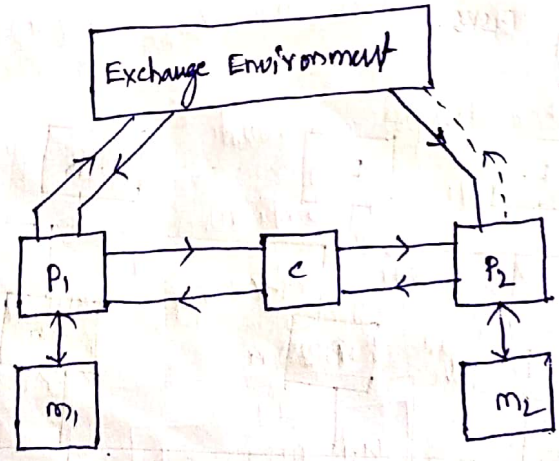
→ stand by mode configuration:



P_1 - Active processor , P_2 = standby processor.

→ The standby processor is brought online when only active processor fails. An important requirement of this configuration is the ability of the standby processor to reconstitute the state of the exchange to control functions.

→ Synchronous duplex configuration:



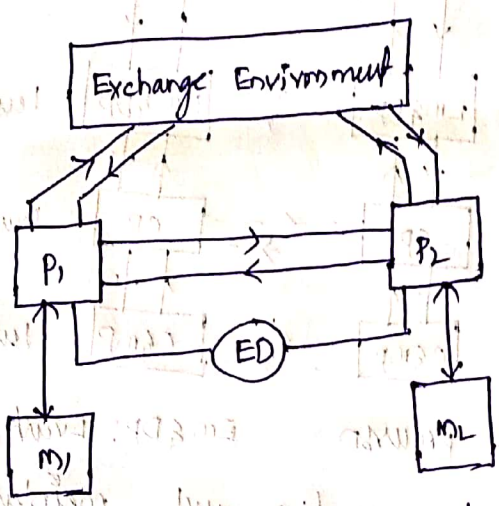
C = comparator m = memory

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→ In synchronous duplex mode of operation, hardware coupling is provided between two processors which executes the same set of instructions and compare the result continously.

→ If faulty any fault occurs one processor will continue the work.

⇒ Load sharing!



ED: Exclusive device

→ The total load of the exchange is shared by two processors they have temporary memories to save call data.

Note: The availability of single processor is given by

$$A = \frac{MTBF}{MTBF + MTTR}$$

MTBF: mean time between Failure

MTTR: mean time to repair

The unavailability = $U = 1 - A$

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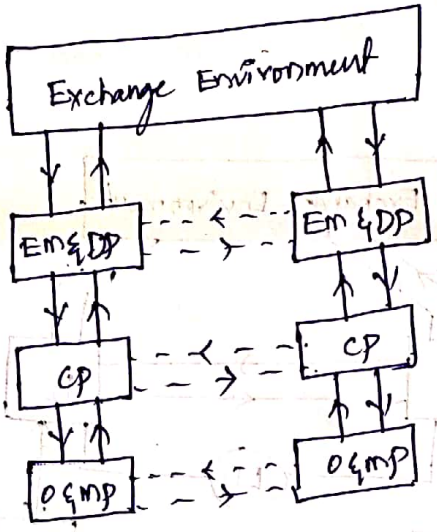
⇒ Distributed SPC:

In distributed, control functions are shared by many processors with the exchange itself. this structure offers better availability and reliability than centralised spc

→ Exchange control functions may be composed either horizontal, (or) vertically for distributed processing.

→ In vertical decomposition the exchange environment is divided into several blocks.

→ In horizontal decomposition each processor performs only one or some of the exchange control functions.



CP: call processor Em & DP: Event monitoring & Distribution

O & MP: operation and maintenance processor.

→ The traffic handling capacity of control equipment is usually limited by the capacity of the switching processor. The load on the switching processor is measured by it occupancy T:

$$T = a + bN$$

a = fixed overhead upon the Exchange

b = average time to process one call

N = No. of calls

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Software Architecture:

The software of the spc systems may be placed under two broad categories, system software & Application software

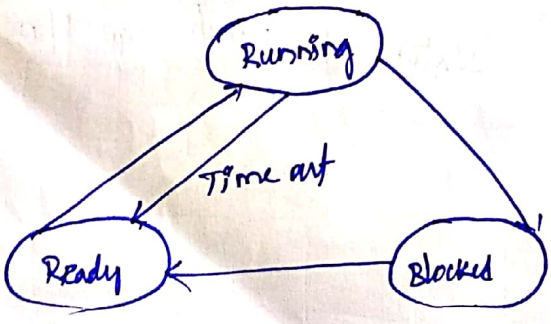
→ Software architecture deals with the system s/w Environment.

→ o&m functions are usually carried out by general purpose computer and the s/w architecture required for this purpose is similar to that of data processing systems.

→ call processing being specific to switching systems and demanding real time response.

→ call processing is an event oriented processing function, it is triggered by an int occuring at subscriber line (or) trunk.

→ A process is a program in execution, and A program by itself is not a process. program is a passive entity, whereas process is active entity.



process states and transitions

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→ An important characteristic of the system software of a switching processor is a powerful multiprogramming environment that is capable of supporting few thousands of process simultaneously.

→ A process is said to be running if it currently has the cpu allocated to it

→ A process said to be ready if it could be use a cpu if one were available

→ A process is said to be blocked if it is waiting for some event to occur before it can proceed.

Each process is represented in the operating system by process control block (PCB), which contains the following data

i) current state
ii) priority of process, scheduling
iii) Register to save when interrupt occurs
iv) memory allocated to the process
v) process account
vi) status of events of I/O resources.

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→ The PCB is repository of all the key information about the process required to restart the process when it next get the CPU.

→ The CPU register include PSW (program status word) which contains the address of the next instructions to be executed; Information regarding interrupts ... etc.

→ process switching is also known as context switching it may occur on account of the currently running process become blocked (or) on interrupt occurred (or) it highest priority.

→ Typical Exchange priorities in decreasing order

- Fault alarms
- interprocessor communications
- clock interrupt for periodic tasks
- Exchange peripherals
- real processing
- slow speed peripherals
- O & M tasks.

→ processes in a switching system cooperate in the same that they share common variables, update common tables.

→ when a process is accessing shared data, it is said to be in critical section or critical Regions

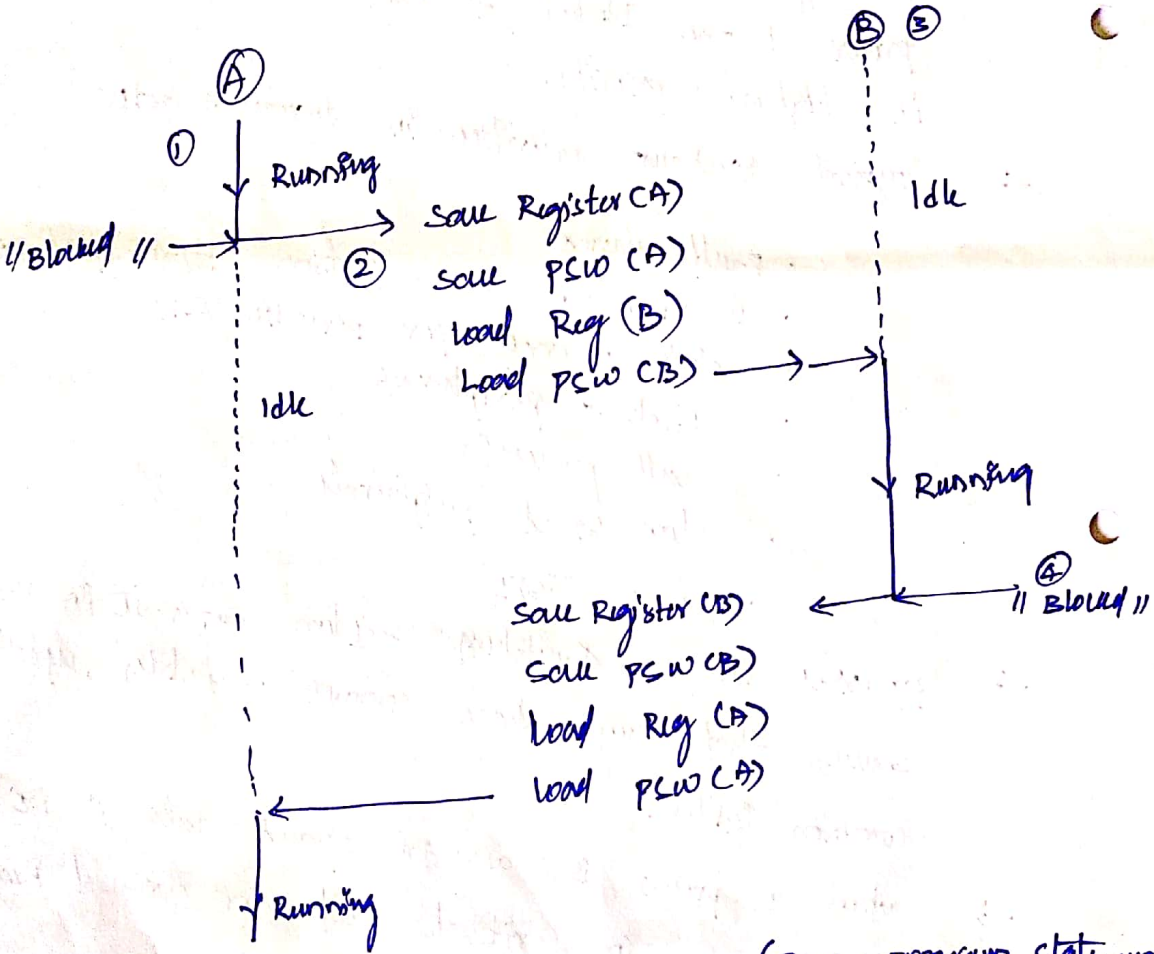
→ many H/w and S/w solutions have been devised to enforce mutual exclusion

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→ one of the more generalised sleep solution for mutual exclusion is "semaphore" is a synchronous tool.

→ Semphore is a protected variable that can assume non-negative integer values. one semaphore for each shared resource in the system.

(*) process switching



(PSW = program status word

→ In semaphore two standard operations test (P) and increment (V) are possible on semaphore.

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→ Each 'P' test 'S' to see if it nonzero, then decrement the value of S with 1, i.e reserving a resource from common pool

⇒ if 'S' is zero the process is blocked to be released by a 'V' operation, which increment the value of 'S' by one signifying the return of a resource to the pool.

→ where two or more processes are waiting indefinitely for a V operation, that can be caused by one of the blocked processes, this is called as 'Deadlock'

Eg:-

P0	P1
P(S0): S0 = S0-1	P(S1): S1 = S1-1
P(S1): blocked (S1)	P(S0): blocked (S0)

=

→ The s/w architecture associated with switching systems with five factors.

1) complexity and size of the s/w
2) long working life
3) Real Real time operation
4) s/w portability

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(4)(5)

→ The recommended approach to slw design is top-down i.e proceeding from the general to the particular with increasing level of complexity and abstractions.

→ The formal description and specification language, usually based on diagrams clearly shows all possible tasks.

→ In a translation process, converting the computer related part of the formal specification into programming language.

→ subject to software to the SPL, are resulted in three @ CCITT standards in 'Z' series.

- Z-100 – Specification Description Language (SDL)
- Z-200 – CCITT high level language (CHILL)
- Z-3xx – man–machine langs (mmi)

→ SDL → it is a formalised method of describing the functional specifications and the internal procedure. It is a slw development tool and high level documentation technique. It based mainly on state transitions diagrams

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→ SDL offers several advantages to both switching equipment and manufacturer.

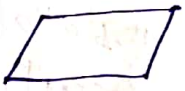
1) good top-down design technique
2) process interactions
3) many tools are available
4) SDL diagrams easily transformed to petri-nets which is an excellent mathematical tool for analysis.
5) Easy to learn, interpret and use.

Symbols in SDL are!


state

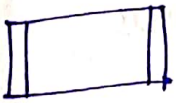

Signal Reception

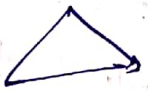

Signal Generation


Save a signal


process description


Test


procedure call


Implementation

CHILL!

⇒ The language is known as CCITT high level options language (CHILL) which has been specially designed to do following in SPL module

1) call handling
2) Test & maintaine.
3) OS

(A) ECITT: International consultative committee for Telephone & Telegraph

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4) on-line / off-line support
5) man-machine language translation
6) Acceptance testing

CHILL has 3 major features

1) Data structure
2) Action statement
3) program structure.

→ CHILL supports both simple and complex data objects.

MML:

⇒ The four main functions covered by MML are

1) operation
2) maintenance
3) installation
4) Acceptance testing.

⇒ Application software:

The Application s/w of a switching system may be divided into three main classes

→ call processing
→ Administrative
→ maintenance s/w.

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→ Application software packages of a switching system use a modular organisation. Each module dealing with the specific task. Size of the module is varied according with task.

→ Application software accounts for about 80% of the total volume of switching system. Administration and maintenance together will take 6% of total volume.

→ Depending on the Architectural support available from the switching processor, the OS may use overlay or virtual memory for this purpose.

→ switching system sho always use parameterised design the parameters are devided into system parameters and office parameters.

→ system parameters: Signalling time delay
Fault threshold ..etc

→ office parameters: no of Subscribers
Simultaneous calls ..etc

⟹ Enhanced Services

Day by Day subscriber want more no. of features in order to make ease of operations by flexible task completion. So improved services to be made available to the subscriber is main motto of Exchange

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→ Although there are a large number of services they may be grouped under 4 categories

1) Servie associated with the calling subscriber
   i) Abbreveated dialling
   ii) Reorded no. of dialling calls
   iii) call back when free
2) Servie associated with called subscribers
   i) call forwarding
   ii) operatin answer
3) Services involving more than 2 parties
   i) calling no. of reorded
   ii) call waiting
   iii) consultation hold
   iv) conference call
4) miscellaneous services
   i) Automatic Alarm
   ii) STD barring
   iii) malicious call tracking.

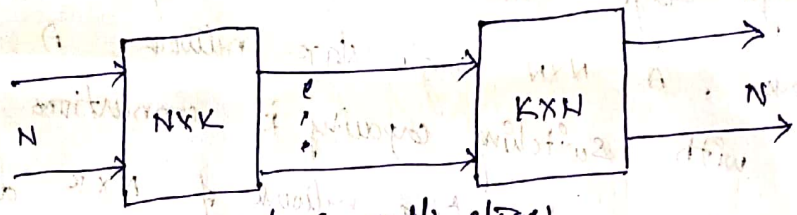
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Two Stage Network:

The switching operation will performed by the networks with inlets and outlets. one inlet is connected to one outline through single crosspoint

→ no of crosspoint switches required for a large single stage network is prohibitive $N(N-1)/2$.

→ single stage N/W facing no of disadvantages which can be overcome by adopting a multistage n/w



⇒ Differences b/w single & multi stage:

single stage	multistage
→ inlet and outlet connection is through a single crosspoint	→ Inlet and outlet connection is through multiple cross points
→ single crosspoint result better quality of link	→ multiple crosspoints may degrade the quality of connection
→ one crosspoint for only one inlet and outlet	→ same crosspoint can be used for number of inlets and outlets
→ If a crosspoint fails associated connection can't connect. No redundancy	→ Alternative crosspoints and paths available

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→ No of crosspoints are prohibitive

→ large number of crosspoints in each inlet/outlet leads to capacitive loading

→ N/w is non-blocking in character

→ less time to connect a call

→ Reduced significantly.

→ There is no capacitive loading.

→ N/w is blocking in character

→ more time to connect.

→ A single stage network exists an equivalent multistage network. A NXN single stage network: A NXN stage with switching capacity 'k' connections can be realised by a two stage network of NXK and KXN.

→ Any of the N inlets can be connected to any of the K outputs of first stage, similarly any of the K inputs of second stage can be connected to n outlets.

→ There are k' alternative paths for any inlet/outlet pair connection.

→ The any of n inlets to be connected to any of the n outlets is called "fully connectivity (or) fully available" network

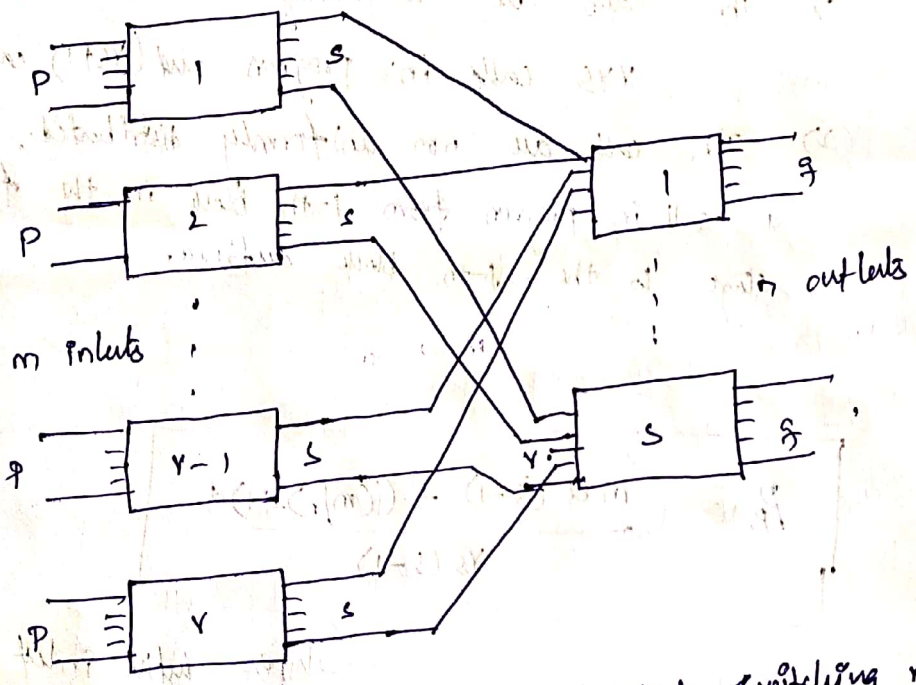
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→ for large number of inlets/outlets the switching matrix NXN may still difficult to realize practically.

→ It is necessary to consider architecture that uses smaller sized switching matrices.

→ consider the two stage network with smaller switching matrices.



Two stage n/w with multiple switching matrices.

→ m inlets are divided into r blocks of p inlets i.e $m = pr$.

→ N outlets are divided into s blocks of q outlets $N = qs$.

→ Block sizes as $p \times s$ and $r \times q$

$$S = psr + qrs \Rightarrow S = ms + Nr$$

(total no. of switching elements)

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The number of simultaneously calls that can be supported by the network i.e switching capacity 'Sc' is equal to the number of links between the first and second stage.

$$Sc = rs$$

→ The two stage network is blocking in nature and the blocking may occur under two conditions.

1) The calls are uniformly distributed as rxs calls in progress and (rs+1) call arrives.

2) The calls are non uniformly distributed, there is a call in progress from i-th block in the first stage to the j-th block destined.

$$P_B = \frac{m\alpha(s-1) - C(m/r)-1)\alpha}{rs(s-1)}$$

α = active inlet

p = m/r from

m = pr

→ 'N' simultaneous call can be supported on this network only if the traffic is uniformly distributed.

→ Networks that support 'N' simultaneous connections but under restricted traffic distribution condition known as baseline N/w.

→ To make two stage non-blocking, we must have $K = \sqrt{N}$, then

$$C = 2N^{\frac{3}{2}}$$ $SC = N$ ✓

→ for a non-blocking configuration, a two stage networks offers no distinct advantage over a single stage, except to provide 'N' alternative paths.

⇒ Three-stage Networks:

The blocking probability and the number of switching elements can be reduced significantly by adopting a three stage structure in place of two stage N/w

General NxN → r blocks of p inlets and p outlets

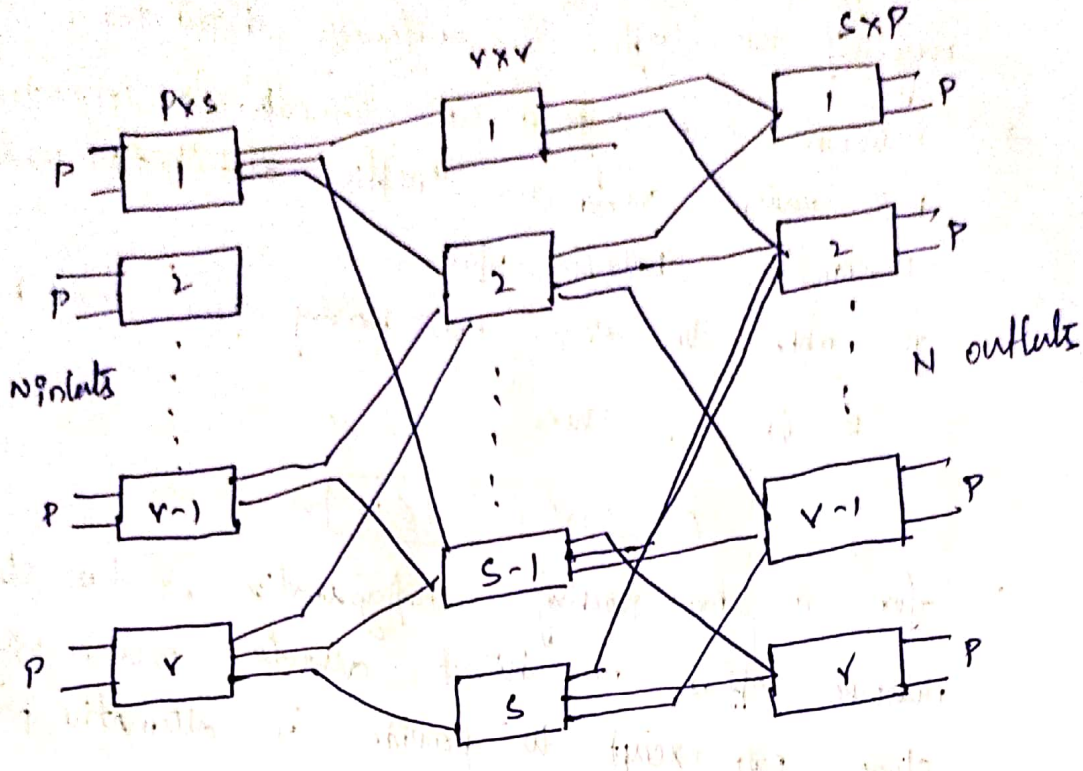
Switching matrices size of pxk – S_1

rxr – S_2

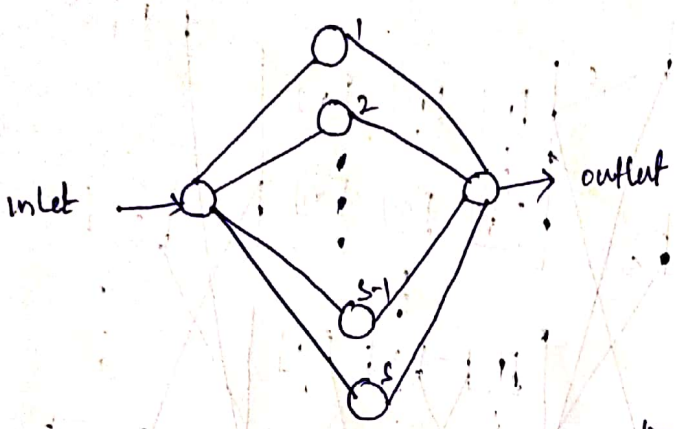
kxp – S_3

RIPLOX

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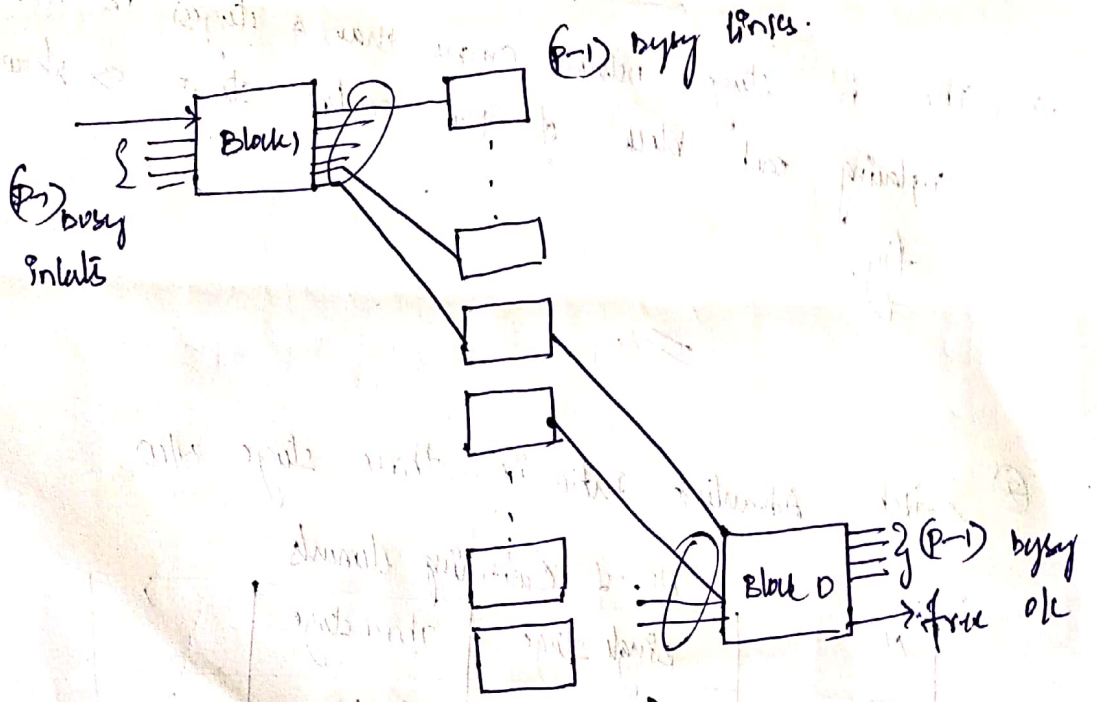

N inlets
N outlets
P
P
P

→ The network graph shows all possible paths between a given inlet and an outlet.



Lee graphs for three stage N/w.

Three stage non-blocking configuration:



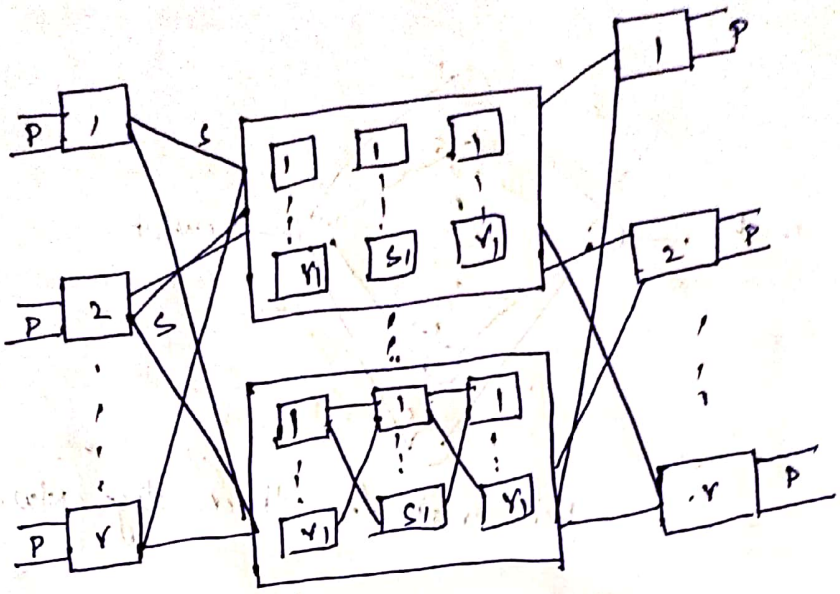
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switching elements advantage ratio:

$$x = \frac{\text{no. of switching elements in a non-blocking slage N/w}}{\text{no. of switching elements in a non-blocking three stage N/w.}}$$

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n- stage Network:



n- stage network.

→ The n' stage network consist than 4 stages is formed by replacing each block of the centre stage as shown in fig.

⊛ Switch Advantage Ratio in three stage N/W

N	No. of Switching elements: single stage	Three stage	λ
128	16,384	6,192	2
2,048	4 million	0.5 million	8
8,192	64 million	4 million	16
32,768	1 billion	32 million	32

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