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A.T.M SWITCH IN B-ISDN TECHNOLOGY

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in partial fulfilment of the requirements
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in
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53p + fig + Appendix

BY SUNIL KUMAR

JNU
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI

SCHOOL OF COMPUTER AND SYSTEMS SCIENCES
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI - 110067
INDIA

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CERTIFICATE

This is to certify that the dissertation entitled **A.T.M SWITCH IN B-ISDN TECHNOLOGY** being submitted by **SUNIL KUMAR** to School of computer and system sciences, Jawaharlal Nehru University, New Delhi, in partial fulfilment of the requirements for the award of the degree of Master of Technology in Computer Science, is a bonafide work carried by him under the guidance and supervision of **Dr. R.C. Phoha**. This work has not been submitted elsewhere for any other purpose.

Dean, SCSS

(Prof. G.V. Singh)
SC & SS, J.N.U.
New Delhi - 110067.

Supervisor

(Dr. R.C. Phoha)
SC & SS, J.N.U.
New Delhi - 110067.

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(Sunil Kumar)

CONTENTS

LIST OF FIGURES

LIST OF SYMBOLS

A.T.M	-	Asynchronous Transfer Mode
B-ISDN	-	Broadband Integrated Service Digital Network
η_i	-	Input Waiting Time
η_o	-	Output Waiting Time
T	-	Average Delay
E(w)	-	Mean Waiting Time
E(S)	-	Mean Service Time
VC	-	Virtual Channel
VP	-	Virtual Path
QOS	-	Quality of Services
VCH	-	Virtual Channel Handler
VPH	-	Virtual Path Handler
LT	-	Line transmission
VCC	-	Virtual Channel Concatenated
VPI	-	Virtual Path Identifier
VPC	-	Virtual Path Connection
ITU-T	-	International Telecommunications Union - Telecommunications Sector
AAL	-	A.T.M. Adaptation Layer
PM	-	Physical Media
TC	-	Transmission Convergence

VCI	-	Virtual Channel Identifier
NTI	-	Network Termination Type 1
NT2	-	Network Termination Type 2
OH	-	Overhead Information
VPH	-	Virtual Path Handler
VCH	-	Virtual Channel Handler
PC	-	Port Controller
NNI	-	Network Node Interface
C/G	-	Bits/Second
M	-	Switching Speed-up

CHAPTER I

INTRODUCTION

The A.T.M. is a transfer method for the broadband integrated services digital network. The B-ISDN protocal architecture includes 3 layers.

1) Physical layer
2) A.T.M layer
3) A.T.M adaptation layer

The task of the physical layer is to provide a transmission capability for the transfer of data units called cells.

The A.T.M layer includes the virtual channel identifier translation.

The purpose of the A.T.M adaptation layer is to add different sets of functionalities to the A.T.M layer, so as to differentiate the kind of services provided to the higher layers.

There are four service classes to be supported by the B-ISDN

i) Class 1 through class 3 support connection oriented service.

ii) Class 1 service used for constant bit rate sources.

iii) Class1 & class 2 are expected to provide a timing relationship between source and destination.

iv) class 4 is used for connectionless service.

Owing to the random traffic assumption, we can evaluate T as the average delay incurred by packets received at a specific port controller say Pc_i. We further assume that HOL packet in Pc_j in a specific slot is addressed to the output channel O_j. Let η_i and η_o denote the waiting time in the input and output queue respectively, time since the packet transmission time is 1 slot, We can write

$$T = E[\eta_i] + E[\eta_o] + 1 \qquad \text{---------------(1)}$$

The input queue can be modelled as a Geom/G/1 queue in which the server is represented by that portion of switch resources used to transport packets from Pc_i to the desired output queue. The waiting time Geom/G/1 queue is the mean no. of customers arriving during the mean waiting time and plus the mean service time.

i.e. $E(W) + E(S)$

Therefore $\eta_i = E(W) + E(S)$ ---------------(2)

From (1) & (2) we get,

$$T = \frac{\rho\, E\left[\theta_i (\theta_i - 1)\right]}{2\left[1 - \rho E(\theta_i)\right]} + E(\theta_i) + \frac{\rho}{2(1-\rho)} + 1 \qquad \text{----------} (3)$$

From the equation (3) we want to calculate optimal switch throughput ρ.

1.1 OBJECTIVE

The objective of this dissertation is to develop a model to compute the average packet delay T which is defined as the average no. of slots it takes for a packet received at a switch inlet to be transmitted to the required switch outlet. From the average packet delay T we want to calculate optimal throughput ρ.

1.2 ORGANIZATION OF THE DISSERTATION

The dissertation is divided into five chapters.

Chapter 1 is an introduction and focuses on the problem description aspect.

Chapter 2 is a review of B-ISDN over A.T.M network.

Chapter 3 address the B-ISDN architecture and its protocol.

Chapter 4 deals with A.T.M. switch in B-ISDN technology.

Chapter 5 contains results of the experiments and a conclusion.

CHAPTER II

Literature review

Asynchronous transfer mode is one of the promising proposals for implementing B-ISDN because of its ability to support a broad spectrum of traffic sources. Broadband ISDN has recently generated a lot of interest as it appears to be an effective way to integrate multimedia information such as Voice computer, data and images. Due to the large number of bursty traffic sources that an A.T.M. network is expected to support, controlling network traffic becomes essential in providing a desirable level of network perfomance and its users.

Many of the traffic sources that an A.T.M network supports are bursty. For instance interactive data and compressed video images are considered bursty. A bursty source may generate calls at a near - peak rate for a very short period of time.

The development of many incompatible data communication standards in the 1970_s led the International Standards Organisation and the International Consultative committee for Telephone and Telegraph to devise a plan known as Open Systems Interconnection. This plan defines an open system as a system that is able to communicate with other open system.

The related endeavors have advanced a good deal of literature in the field. A number of those reviewed have been presented in the following sections.

2.1 Interworking between B-ISDN and other Networks :-

In the case of interworking between B-ISDN and other networks, the connections in B-ISDN are no longer end to end. Instead, B-ISDN is considered a subnetwork, and the service provided by B-ISDN is a bearer connection between interworking units that connects the different networks.

Staalhegen [1] has made a detailed study on the A.T.M layer related to switching A.T.M cells internally in the B-ISDN. The functions of the A.T.M and physical layers are common to both types of bearer services. The functions at both sublayers of the B-ISDN physical layer are operating on a link by link basis. The physical and A.T.M layer are not partitioned, because the information flows related to signaling and uses information must be multiplexed at some point to be able to use the same transmission system for both types of information. Since the A.T.M cell is the basic unit of information at the lowest layer of the B-ISDN, where it can be determined to which connection the information belongs, it is logical to multiplex the signaling and user information at the A.T.M. layer.

Masa toshi Kawararaki [5] made a review for A.T.M - based B-ISDN architecture and protocol for high speed communications. The universal transport proceeding (multiplexing and routing) is performed by the A.T.M. which enables integrated transport of multirate traffic. A.T.M is expected to play an important role in expanding the network capabilities towards B-ISDN.

2.2 Discrete time single server Queue in A.T.M networks

An A.T.M switch is modelled as a discrete-time single server queuing system where a new call joins existing calls. Cell arrivals from a new calls are assumed to follow a general distribution. Since an A.T.M network is expected to support a large no. of bursty sources with different characteristics, a poisson process may no longer be suitable for describing network traffic.

Masayuki murata [6] proposed a model for an A.T.M switch and focus on one of the output ports of the switch and consider the case where a no. of calls are multiplexed onto the output port. It is assumed that the switch is fast enough so that queueing of cells occurs only on the outputs. As for the capacity of the buffering on the output, two cases are considered infinite and finite capacity cases. A finite buffer is assumed, and the cell loss probability and the distribution of queue length on an output are obtained. This model applies only for the finite buffer system.

M.L. Chaudhary [9] in a paper analyzes the Geom/G/1 queue and consider s a single server discrete-time queueing system with a finite buffer of size. It is assumed that the system has a clock such that time is slotted in intervals of equal length, separated by slot boundaries. The customers are served according to a first, come first served (FCFS) norm. Service can start only at slot boundaries and always takes an entire no. of slots. The customers leaves the system as soon as they have received the service. The recursive method developed in this paper has been tested for a variety of interarrival - time distributions with finite support. The method is reliable and workes even for a large buffer size as well as for various values of traffic intensity.

The survey of literature has shown that the A.T.M switch in B-ISDN technology has been the least attended topic, limited work has been done in this area and it needs further fully fledged research agenda.

CHAPTER 3

B-ISDN architecture and its protocol :-

3.1 Introduction :-

B-ISDN, which is considered as an evolution of ISDN, should include ;

i) Broadband and multimedia communication capability.

ii) Intelligent network capability to provide enhanced network services ; and

iii) Enhanced operation capability to achieve a highly reliable network performance even when there are failures and traffic fluctuations.

ISDN defines a universal network that is intended to handle a wide range of services, including both telephony and packet - switched data communication services. The first step towards this universal network was the narrowband integrated services digital network (N-ISDN). In N-ISDN, basic access provides the customer with two circuit switched B-channels of 64 kb/s and one D channel of 16 kb/s used for signaling and packet switched data communication. While N-ISDN is adequate for normal telephony and low speed data communication, it is unable to provide broadband services, such as video or high speed data transmission due to limited bitrates. This led the ITU-T to define the concept of the broadband ISDN (B-ISDN), which is designed to support a large range of services both interactive (e.g. traditional, telephony, Video library) and distributive (e.g. broadcast TV/radio), with bitrates for each connection from less that 1kb/s to more than 100Mb/s.

B-ISDN will use a synchronous transfer mode to transfer information between end systems. In A.T.M, the information is transferred in fixed size packets known as A.T.M cells through virtual connections (VC_s) fig. 1 shows the format of an A.T.M at the user network interface (UNI).

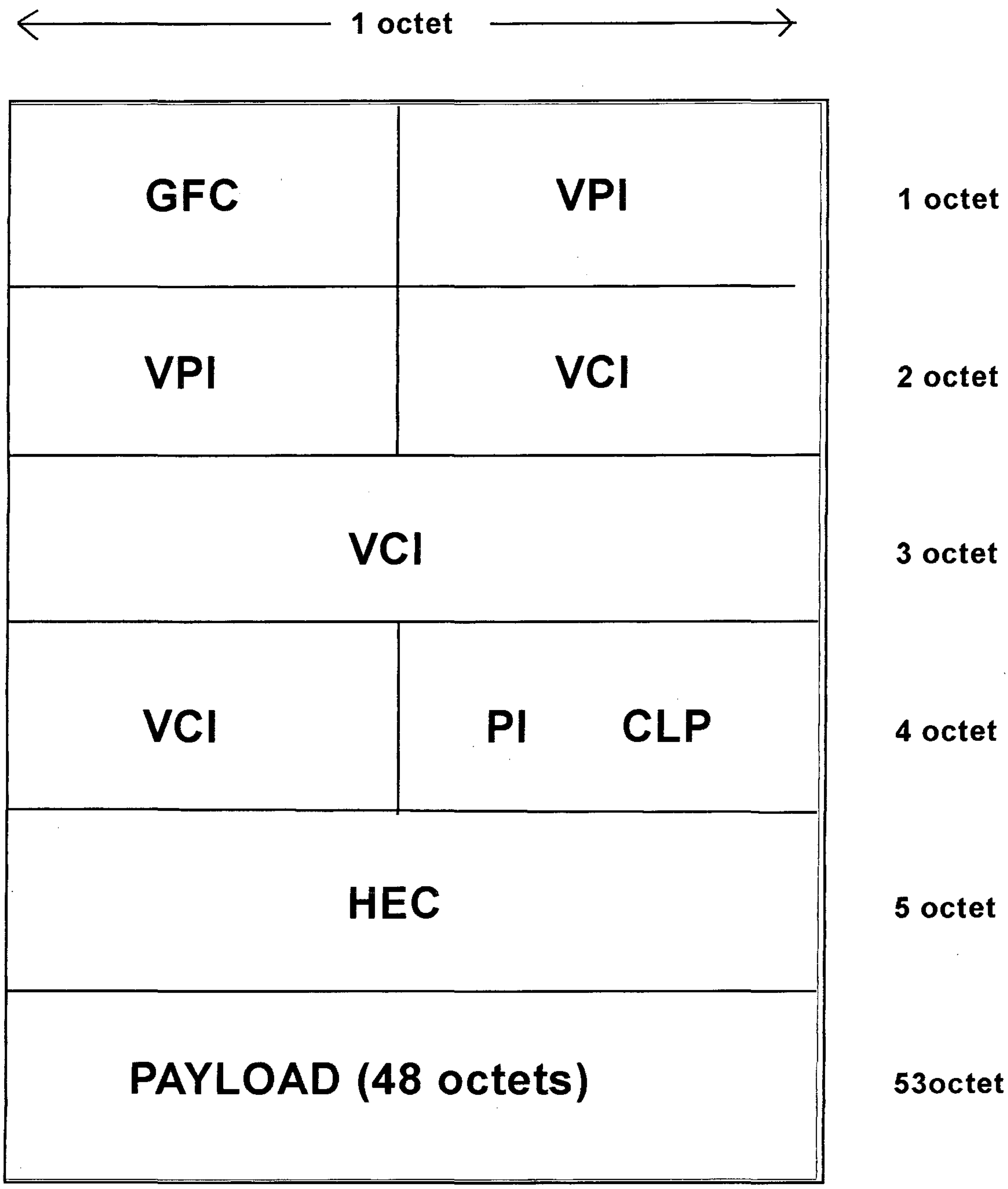


Fig. (1)

A.T.M. Cell at the UNI.

3.2. B-ISDN architecture :-

A.T.M is expected to play an important role in expanding the network capabilities towards B-ISDN. Fig 2 illustrates the significance of B-ISDN and A.T.M on the network evolutionary path.

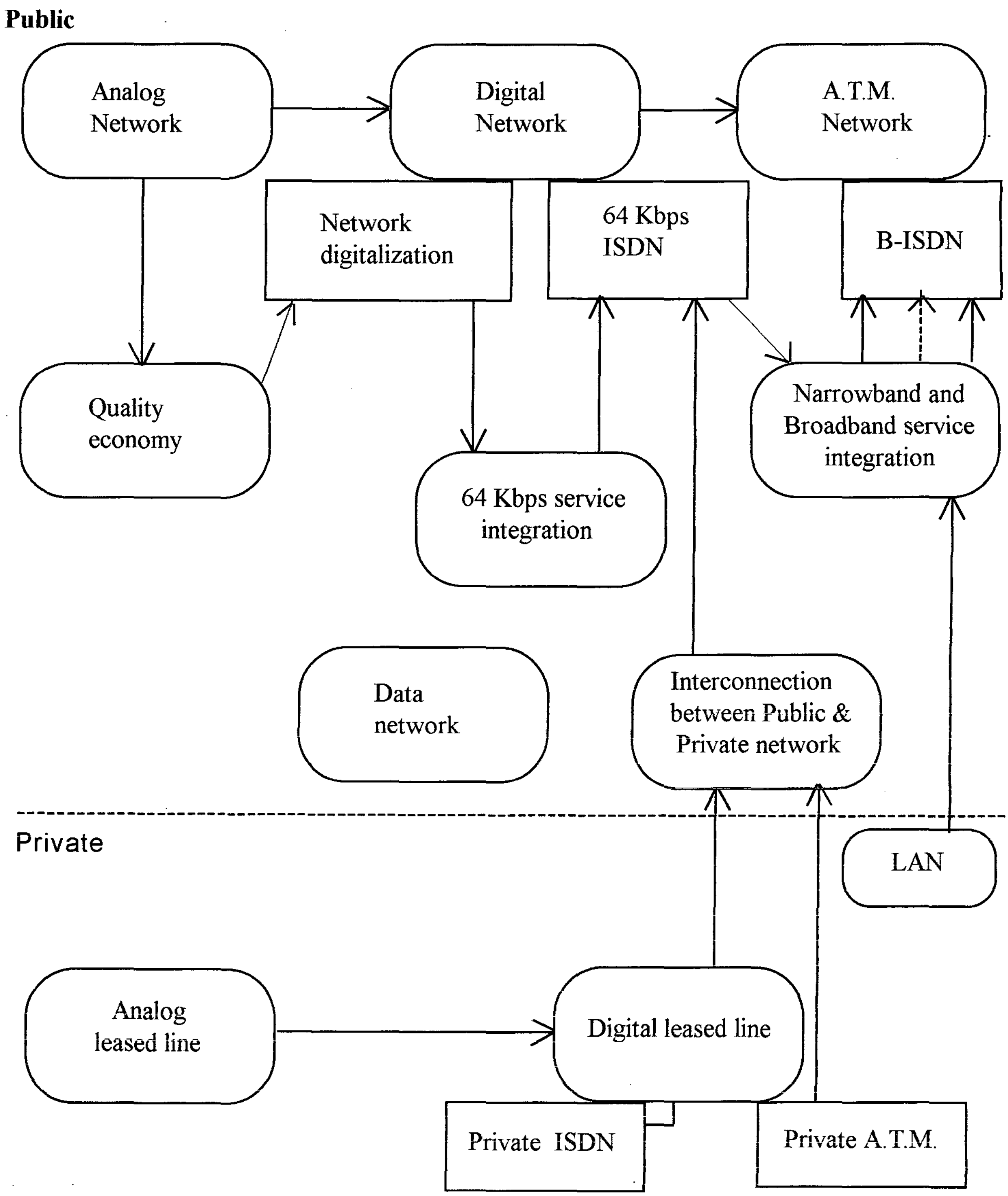


Fig. 2

Network evolution and B-ISDN.

The main characteristics of A.T.M are

i) To use a fixed size cell as an information transfer unit ; and

ii) To identify each communication unit by a cell header label (labeled multiplexing). A label in the A.T.M cell header is structured as two fields to identify the virtual chanel (VC) and the virtual path (VP). A VP is a collection if VC'S to be switched as a unit. These attributes lead to an integrated switching architecture for various rates of VC'S and/or VP'S. The B-ISDN architecture basedon A.T.M provides certain advantages while labeled multiplexing enables efficient use of network bandwidth through statistical gain, it may require additional traffic and quality of service (QOS) control.

The A.T.M based B-ISDN architecture is shown in fig. (3) for efficient network management, the transport network is structured at three levels namely VC level, VP level and transmission medium level. The introduction of VP in addition to VC provides advantages in networking as well as in service capabilities. More specifically, by managing the network in the VP level, the VC level can concentrate on service handling. VC'S are typically established, released, and reconfigured on a customer demand basis. The VP - level network formulates the VP cross- connect backbone network which interconnects VC switching nodes.

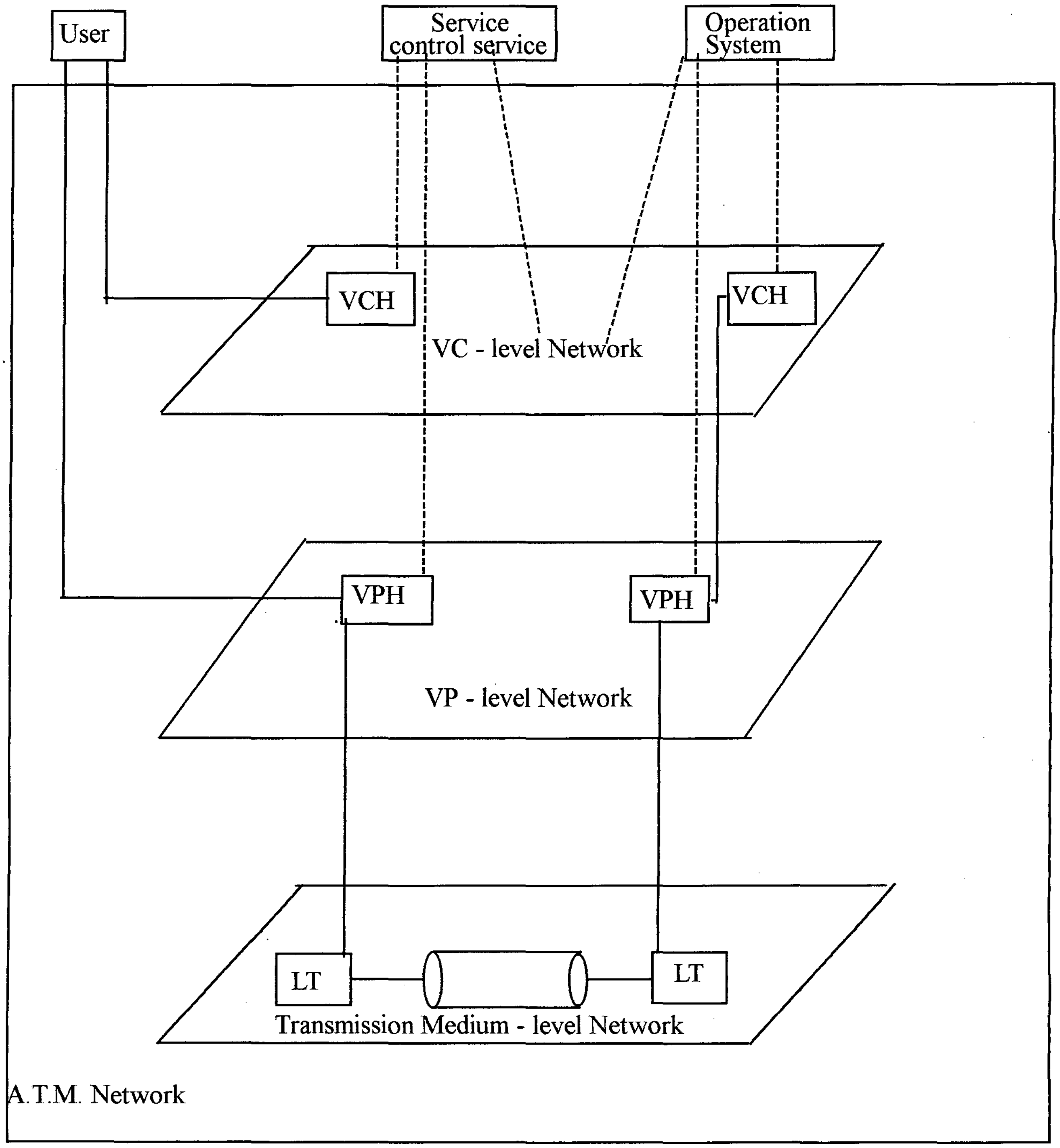


Fig. (3)

B-ISDN architecture.

VCH: Virtual Channel Handler

VPH: Virtual Path Handler

LT : Line Transmission.

Fig (4) shows the network layering and layer - to - layer relationship. Each level of the network consists of four transport elements, namely connection, link, endpoint, and connecting point. Links are concatenated to form a connection, which is defined between two endpoints. Endpoints are located at the boundary between two levels where the information is exchanged and transport service is provided to the next higher layer. That is a connection in a given network level provides transport service to a link in the next higher network level (Server and client relationship). For example, terminal equipment corresponds to the endpoint in the VC - level connection and a VC switch corresponds to the endpoint in the VP - level connection as well as to the connecting point in the VC - level connection.

A virtual channel identifier (VCI) identifies a particular VC link for a given VP connection. A VC link is originated or terminated by the assignment or removal of the VCI value VC routing is performed at a VC connecting points (e.g. VC switch), which translates the VCI values of the outgoing VC links. VC links are concatenated to form a VC connection (VCC). At the VCC endpoints, the cell information field is exchanged between the A.T.M layer and the user of the A.T.M layer service. AT the VC connecting point, the VP connection (VPC) supporting the incoming VC links are terminated first and a new VPC is created. Cell sequence integrity is preserved by the A.T.M layer for cells belonging to the same VCC.

Similarly, a virtual path identifier (VPI) identifies a collection of VC links that share the same VPC. A VP link is orignated or terminated by the assignment or removal of the VPI value. Routing functions of VP'S take place at a VP connecting point (e.g., Vp cross connect) which translates the VPI values of the incoming VP links into the VPI values of the outgoing VP links. VP links are concatenated to form a VPC. At the VPC endpoints, the VPC is terminated and the VCI'S are or originated . Cell sequence integrity is preserved by the A.T.M layer for cells belonging to the same VPVirtual Channel connection

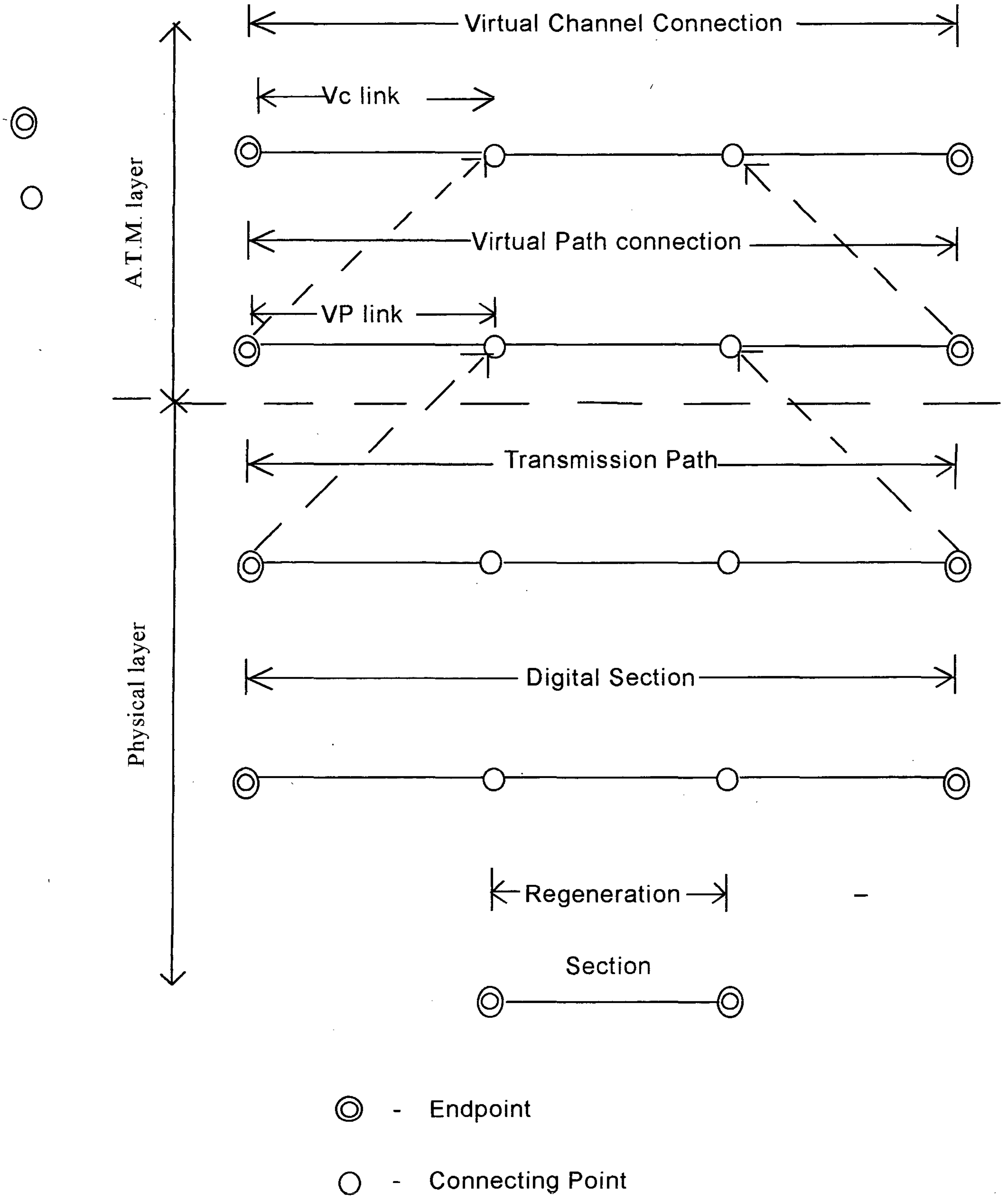


Fig. (4)

B-ISDN Transport network model.

The transmission medium level network is further subdivided into three levels in terms of transport function, namely the transmission path level, the digital section level, and the regenerator section level. The transmission path extends between network elements that assemble and disassemble the payload of a transmission system. The digital section extends between network elements which assemble and disassemble a continuous bit or byte stream. As shown in fig 4. each network level is expressed by a common model with the same hierarchical relationship between levels. This leads to the same management method being applied to each network level ; e.g. the management of VCI / VPI assignment, the management of VC / VP bandwidth allocation, and the fault and performance managment of VC / VP . For each management type, the integrated method should be applied to both VC and VP . From a managed object point of view, there is no functional difference between VP & VC. This is the key characteristic in B-ISDN networking.

3.3. B-ISDN PROTOCOL

A.T.M is asynchronous in the sense that cells related to a specific call do not occupy a fixed slot in a frame. The VCI field together with the VPI field uniquely identify the VC on a link , but there values have only local significance on a link and can change at switching nodes .

B-ISDN Protocol layering is essential to specify internetworking and signaling.

3.3.1 Protocol Layering

In the B-ISDN protocol structure, two specific layers are related to A.T.M functions.

1) An A.T.M layer that is common to all services and provides cell transfer capabilities.

2) An A.T.M adaptation layer that is service dependent and supports higher layer functions of user, control, and management planes.

The boundary between the A.T.M layer and AAL corresponds to the boundary between functions in the cell header and functions in the cell information field.

The physical layer is divided in two sublayers : The layer one is the physical media sublayers (PM), and the upper one the transmission convergence (TC) sublayer. The functions at the PM sublayer are related to the transmission media used and include such items as bit timing and line coding. The TC sublayer contains functions related to the transmission system and the adaptation of the transmission media to the transport of A.T.M cells from the A.T.M layer. The A.T.M layer is only concerned with operations on A.T.M cells, and since the TC sublayer handles adaptation between the A.T.M layer and the media , the functions of the A.T.M. layer are independent of the physical media. The functionality of the A.T.M layer includes generation and extraction of the cell header, translation of the

VCI/VPI values in the cell header and transfer of cells from incoming links to outgoing links at switching nodes in the network, multiplexing and demultiplexing of cells and so on.

The service provided by the A.T.M layer to the layer above is the transfer of fixed - size A.T.M cells between end systems. To adapt this transfer method to the requirements of any service, the A.T.M adaptation layer is introduced on top of the A.T.M layer. The AAL is divided into two sublayers. The upper one, the convergence sublayer (CS), is responsible for providing the actual AAL service to the higher layers, while the lower segmentation and reassembly (SAR) sublayer is responsible for segmenting, if necessary, the CS-PDUS to fit the 48 octet payload field of an A.T.M. cell . The purpose of the AAL is to adapt the information transfer service of the A.T.M layer to any service, so the AAL is therefore dependent on the service.

The timing relation specifies whether the timing of the data delivered by the sending AAL user should be maintained when delivering the data to receiving AAL user. Example of different services for the different AAL classes would include normal telephony for class A, VBR - coded video for class B, connection - oriented data services for class C, and connectionless data services for class D.

The protocol structure of B-ISDN is shown in fig (5).

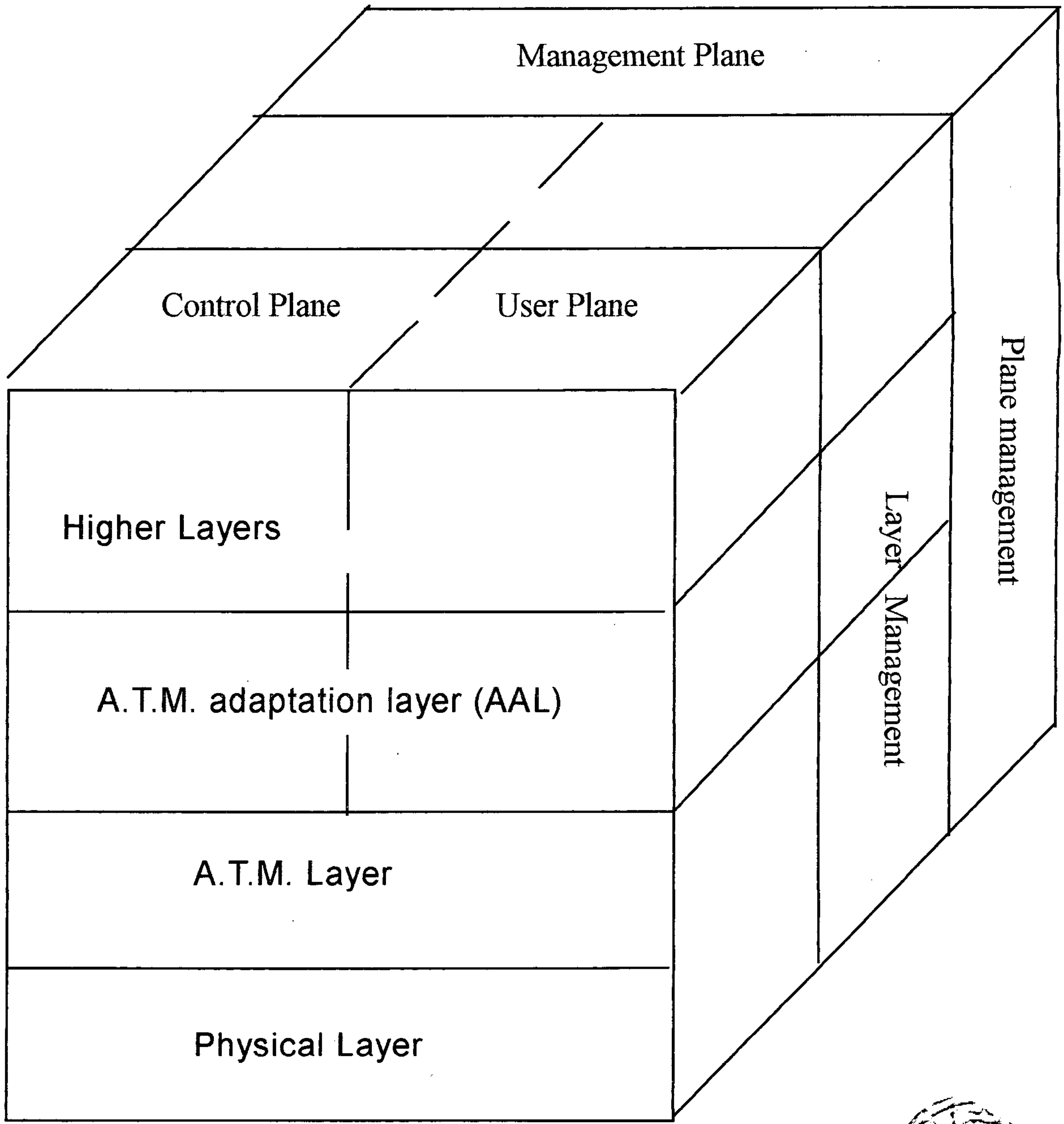


Fig. (5)

B-ISDN A.T.M. protocol refrence model.

3.3.2 A.T.M Basic Parameters :-

Cell format and user network interface (UNI) structure, at the T & S reference points, are the key parameters of A.T.M. At the first stage, two interface bit rates were selected for broadband - UNI ; 155.52 Mb/s and 622.20 Mb/s in harmonization with the network node interface (NNI) bit rates. The A.T.M basic parameters were defined as shown in fig. (6).

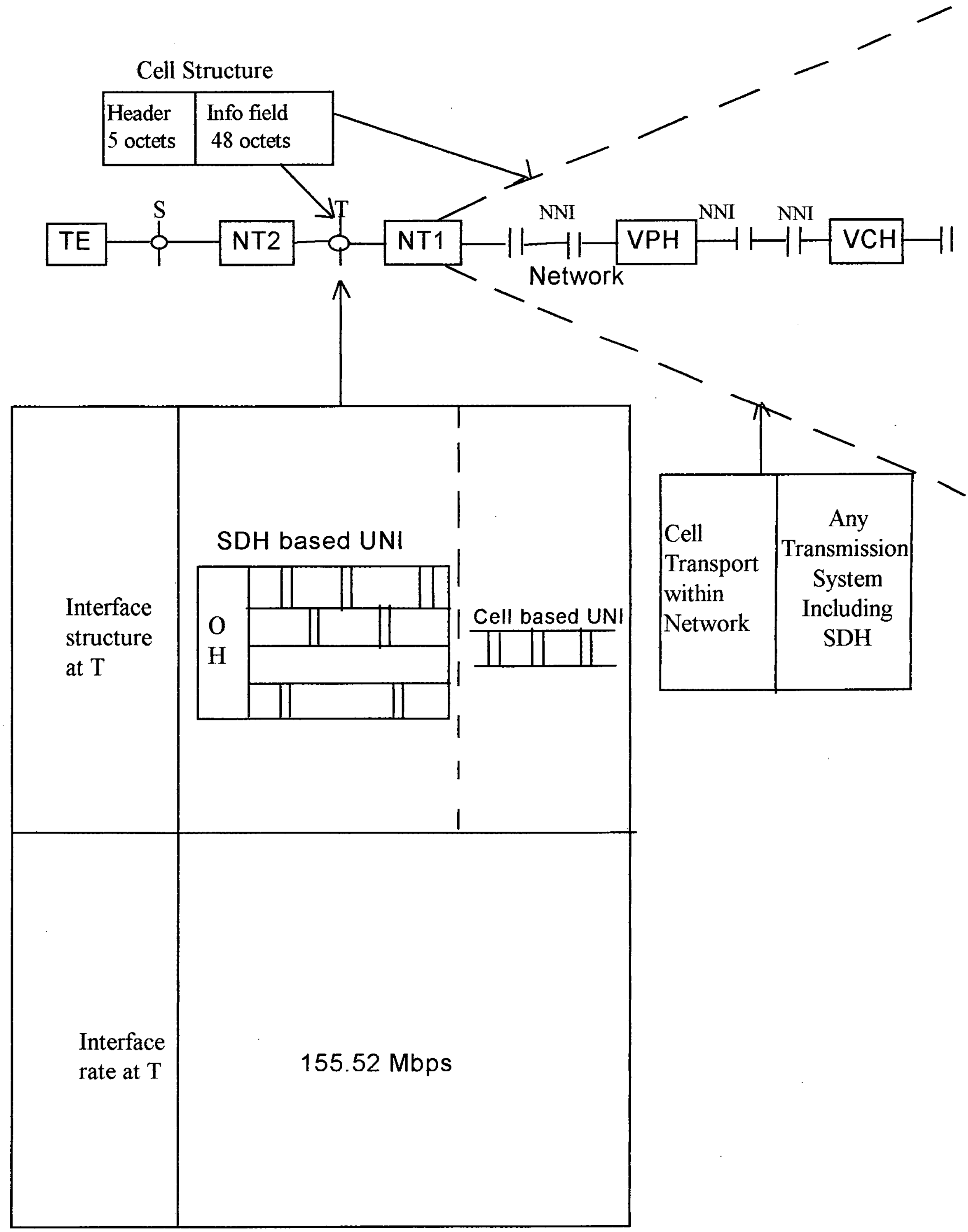


Fig 6

A.T.M. basic Parameters

3.3.3 Information transport protocol of B-ISDN :-

To achieve high speed transport capability, the B-ISDN transport network offers the minimum functions required to transfer cells in order to reduce protocol processing such as flow control or error recovery. Thus, network functions for user information transport are limited at the A.T.M layer. AAL functions are provided by users or at the edge of the network. This is illustrated as fig.(7)

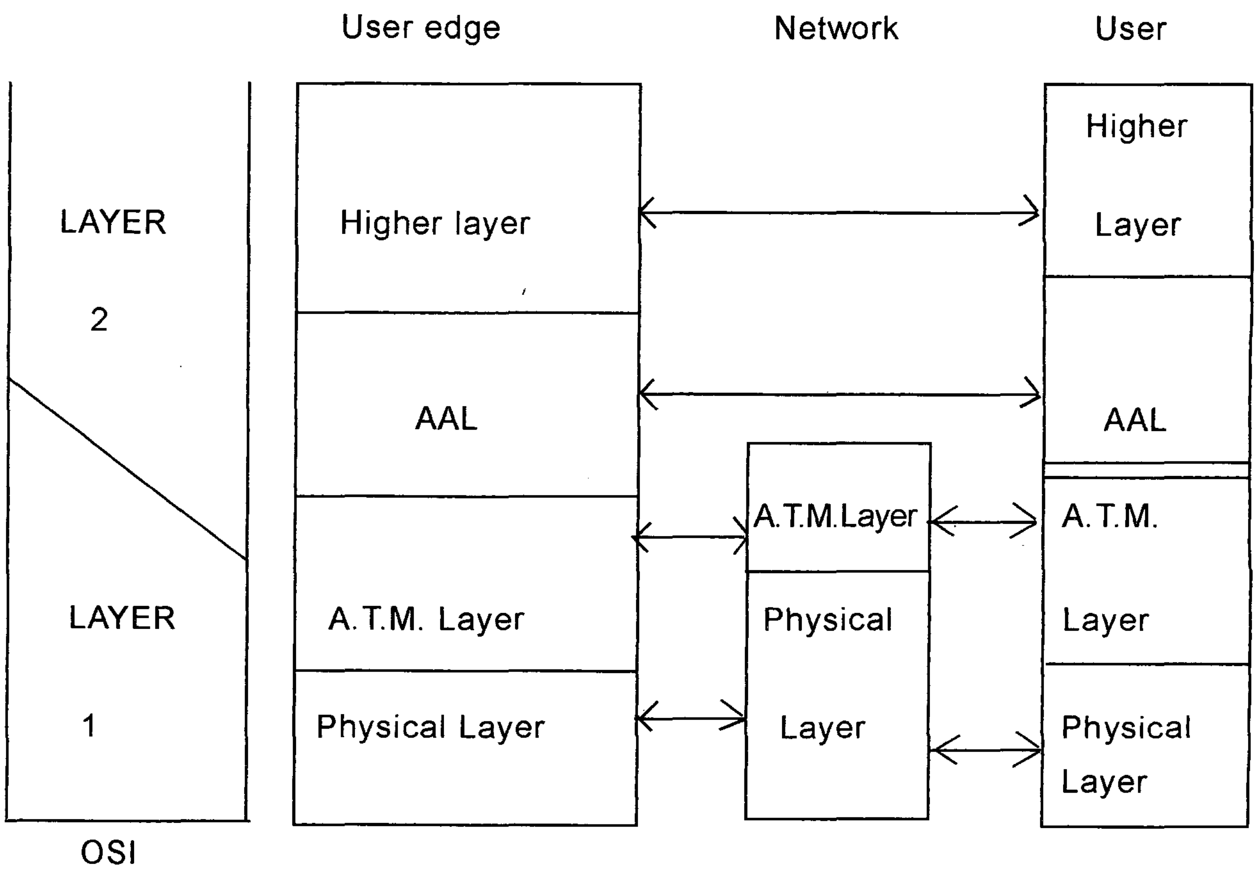


Fig. (7)

B-ISDN information transport protocol.

AAL	:	Cell segmentation and reassembly, timing control, flow control
A.T.M layer	:	Cell transport VC/VP routing and multiplexing)
Physical layer	:	Transmission payload to carry A.T.M cell stream.

CHAPTER 4

A.T.M Switch in B-ISDN Technology

4.1 Introduction :-

The asynchronous transfer mode is the transport mechanism to be adopted in the lower layers of the protocol architecture for this purpose. The B-ISDN protocol architecture includes three layers that, bottom up, are referred to as physical layer, A.T.M layer, and A.T.M adaptation layer. The task of the physical layer is to provide a transmission capability for the transfer of data units called cells. Its functionalities include some basic tasks such as timing, cell delineation, cell header verification etc. The A.T.M. layer includes the virtual channel identifier/ virtual path identifier (VCI/VPI) translation, the header generation and extraction, and the multiplexing - demultiplexing of cells with different (VCI/VPI) onto the same physical layer connection. The purpose of the A.T.M. adaptation layer is to add different sets of functionalities to the A.T.M layer, so as to differentiate the kind of services provided to the higher layers.

There are four services classes

a) class 1 through class3 support connection oriented service

b) Class 1 services used for variable bit rate source

c) Classes 1and 2 are expected to provide a timing relationship between source and destination.

d) Class 4 is used for connectionless services.

4.2 SWITCH ARCHITECTURE

The general architecture of the proposed broadband packet switch is given in fig. (8). An interconnection network provides connectivity between port controllers (PC), each supporting an input and output packet channel whose rate is C Mb/s. The main functions of a port controller are.

* Storage of the cells received on the input channel in an input queue.
* Processing the cells received according to the supported protocol functionalities ; a mandatory task is the routing function in which a switch outlet and a virtual channel identifier are assigned to each cell.
* Storage in an output queue of the packets switched through the interconnection network before their transmission to the output channel.
* Rate matching between the channel rate C and the fabric rate F (F>C)

The functions related to the setup and teardown of virtual connections are carried out by a centralized call Processing (CP) unit located in a port controlled board, so that this unit communicates with the PC'S through the same interconnection network. About the support of class 4 services directly via a B-ISDN connectionless service, the CP unit should also performed the routing of connectionless data unit if the node terminates AAL connections devoted to class 4 service.

The interconnection network transfer packets between PC'S without buffering them internally. It makes available more than one path between any pair of port controllers and no conflicts arise between packets for the use of interstage communication links.

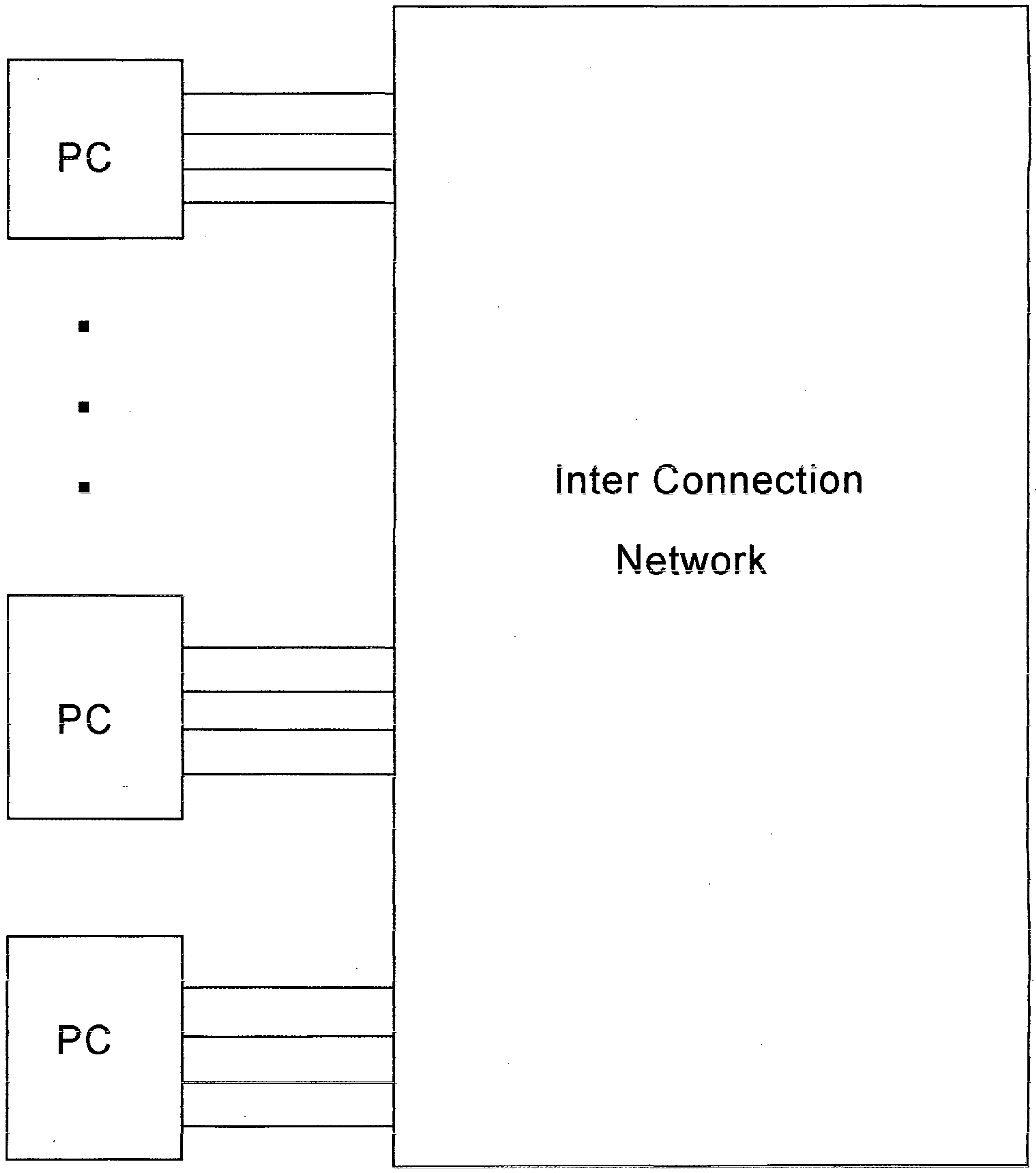


Fig. (8)

Switch Architecture

4.3 Services Provision by the Switching fabric :-

In order to support the different service classes within the specific quality of service they require in terms of cell delay and loss, the field SI of PP packets plays a key role. It carries the class index of the correspondent HOL cell with the code : SI = 0, 1, 2, 3, for class 1, 2, 3, 4 respectively. Thus, bandwidth is allocated at cell time so that priority is always given to classes with lower indexes whenever a contention occurs.

4.3.1 Class 1 service :-

Referring to a switching fabric, port controllers receive cells on specific slots of the external frame and transmit cells on specific slots of the external frame. A slot of the internal frame in the switch inlet (outlet) is said to be saturated when a bandwidth of 1 (M) cells per frame has been reserved on it. A switching bandwidth of SC/Gb/S (S = 1,......G) can be booked for a class 1 connection to be setup; say between inlet I_i and outlet O_j. Reserving such a bandwidth within the switch means :

a) finding S specific nonsaturated internal slots both in I_i and O_j.

b) Mapping each of S external upstream slots in which the cells of the connection will be received by the inlet I_i onto one of these S internal slots.

c) Selecting S slots on the external frame of O_j for the down stream transmis sion of S cells per frame. Fig (9) gives an example of slot reservation for M = 3 G = 8 in the internal frame of inlet I_i and outlet O_j between which two connections with band width 1 and 2 slots/frame are setup.

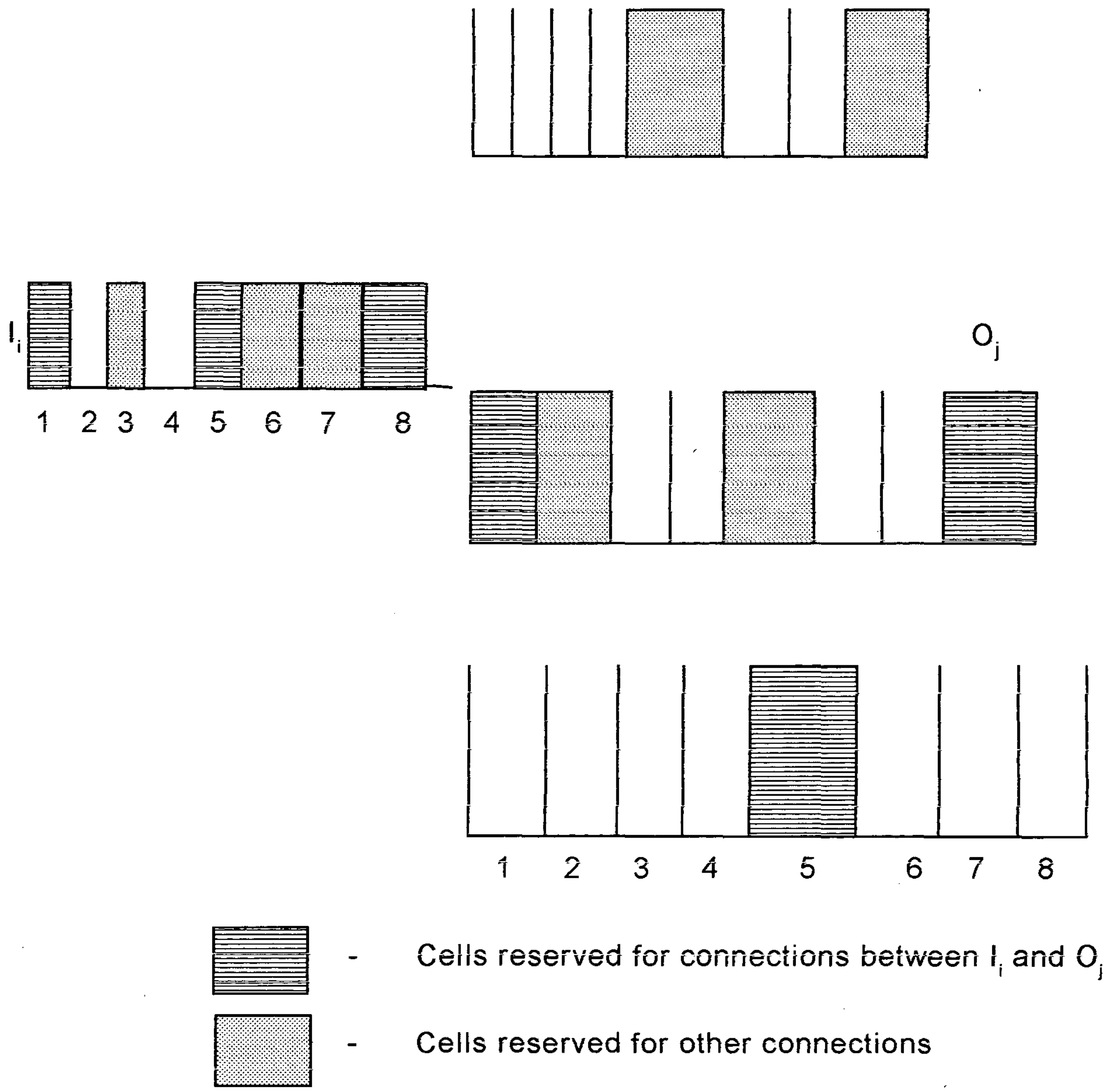


Fig (9)

Ex. of cell reservation in the internal frame.

The cells received in the external slots by Pc_i will be stored in the input queue before being switched to the output queue in the reserved internal slots. In the same way, the cells received by PC'S through the IN will remain stored on the output queue before their transmission to the downstream node in the reserved slot. This mechanism means that a FIFO service is not applied in both queues as far as the class 1 cells is concerned.

4.3.2 Class 2 and 3 service :-

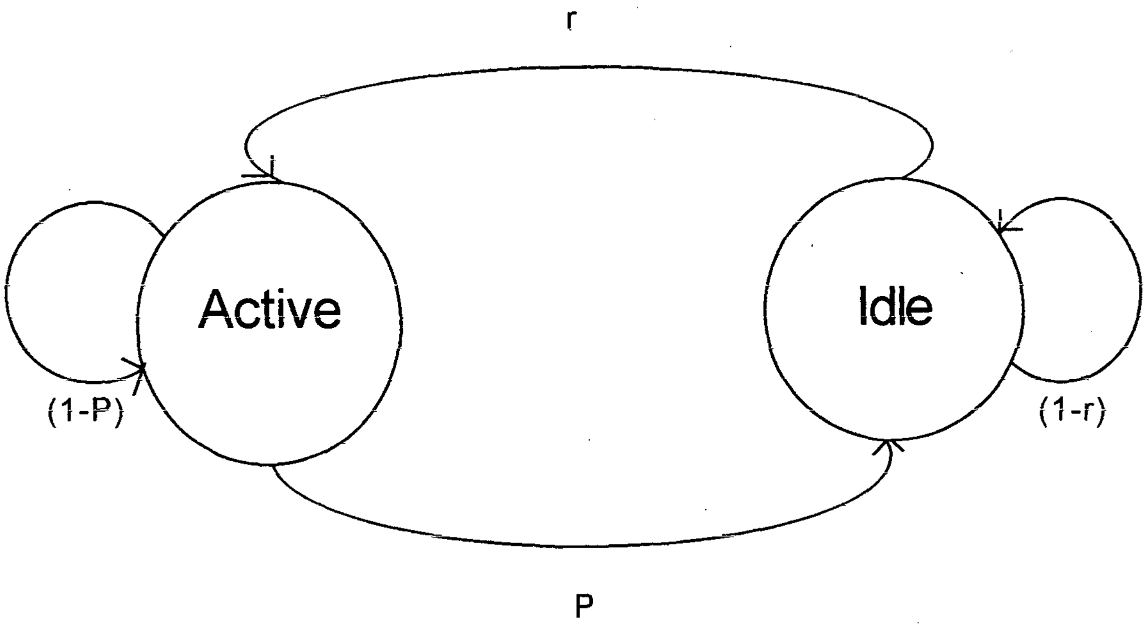
There are no rules to determine the bandwith to be reserved for each class 2 and Class 3 call, so on to take full advantage of the statistical multiplexing and still provide the required grade of service. In this service the actual available capacity can be higher, as the bandwidth allocation at cell time allows Class 2 and 3 cell to use the reserved slots by Class 1 calls that are left unused. Owing to the coding adopted for field SI of PP, Class 2 cells are given priority over Class 3 cells. However, when congestion conditions occur that require cell discarding in the input queue, the port controller can discard Class2 cells first, as cell loss requirements are much more stringent for Class 3 than for class 2. This result can easily be achieved as each cell can be associated with its proper Class index (the same contained in the SI field of the corresponding PP'S).

4.3.3 Class 4 service :-

We refer to connectionless data service supported directly by a B-ISDN connectionless service. If an A.T.M switching node terminates AAL class 4 connections, it must be capable of routing the datagrams, each carried in a sequence of A.T.M cells. We have assumed that the routing entity is located in the CP unit, which thus contains the routing table needed to map a datagram network address to a switch outlet. Down stream class 4 connections can be either semipermanent or set up on demand. In the former case, a connection is always available between the node and any other downstream node supporting the routing entity for class 4 services.

4.4 Performance evaluation :-

In this section performance of multicast schemes as applied to shared memory based A.T.M switching system is evaluated under bursty traffic conditions which consist of mix of unicast and multicast cells (i.e. mixed traffic). To study the comparative performance of various multicast schemes, bursty traffic is generated using the two state ON - OFF model, that is, alternating a geometrically distributed period during which no arrivals occur with a geometrically distributed period during which arrivals occur in a Bernoulli fashion and vice versa. Which is shown as in fig.(10).



Where P - Duration of the active period.

r - Duration of the idle period.

Fig (10)

A two - state on - off model.

4.4.1 Performance evaluation of class 1 service :-

An evaluation of the switching bandwidth that can be booked for class 1 connections is obtained assuming that each connection requires a bandwidth equal to 1 cell/frame and that the class 1 traffic uniformly loads all switch ports that is, all input and output ports support the same no. of connections. Let r(x) & s(x) denote the no. of reserved cells and saturated slots, respectively, in the internal frame associated to the switch inlet (or outlet) x. Hence, the no. of idle cells in the internal frame is G - r(x) for the inlets and MG - r(x) for the outlets. The worst case of call setup blocking between inlet I_i and outlet O_j occurs when

$$G - r(I_i) \leq r(O_j) / M$$

$$S(O_j) = r(O_j)/M$$

where M - Switching speedup

G - No. of frame slot

4.4.2 Performance evaluation of class 2-4 service :-

The performance study is carried out by assuming a random traffic. That is, a cell is received by a PC in a slot with probablity q and cells are uniformly destined for any of the switch outlets O_j. This kind of traffic can reasonably model a traffic pattern generated by a connection - oriented network as the one assumed in the standard recommendations, as long as the peak bandwidth of each call is much less than the channel capacity. The analysis in this section assumes that only class 2-4 traffic is carried by the A.T.M switch. If Class 1 traffic is carried by the switch, then the analysis is no more exact, even if it can be used to get a reasonably estimate of the real performance figures. As far as the maximum throughput is concerned, the maximum offered load should only be referred to the amount of bandwidth left unreserved by class 1 traffic.

A model is now developed to compute the average packet delay T which is defined as the average no. of slots it takes for a packet received at a switch inlet to be transmitted to the required switch outlet, thus including the time spent in the output queue. The minimum average cell delay is T = 1 slot. We assume that the input and output queue sizes are large enough that buffer overflow never occurs.

4.5 ANALYTIC MODEL

In the random traffic assumption, we can evaluate T as the average delay incurred by packets received at a specefic port controller, say Pc_i. We further assume that the HOL packet in Pc_j in a specific slot is addressed to output channel O_j. Let η_i and η_o denote the waiting time in the input and output queue, respectively., Since the packet transmission time is 1 slot, we can write :

$$T = E[\eta_i] + E[\eta_o] + 1 \qquad (1)$$

The model we use to compute $E[\eta_i]$ is as in fig. (11). The input queue can be modeled as Geom/G/1 queue in which the server is represented by that portion of switch resources used to transport packet from Pc_i to the desired output queue. Since a number M of paths is available to reach each output queue, we can say that a virtual queue VQ_j with M virtual servers gives service to the HOL packets in the Geom/G/1 queue destined for output channel j.

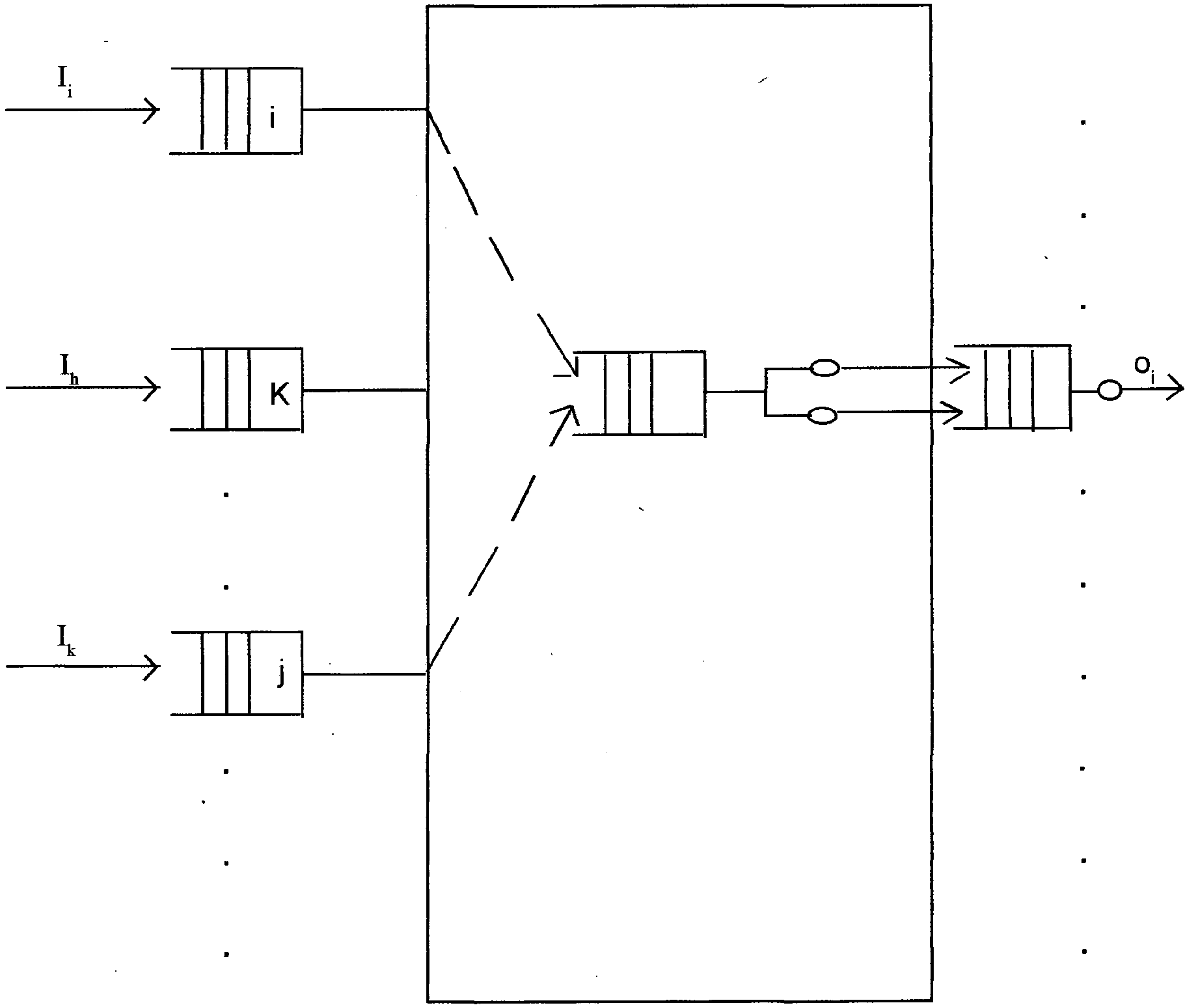


fig (11)

Queue model to evaluate the packet delay.

Discrete - time queues have been widely used as a modelling tool in many areas of computer communication systems. A.T.M will provide a means of integrating voice, video and data operations by transforming information into packets consisting of cells. In all these systems, events (arrivals and departures) are allowed only at regularly spaced points in time, and hence to evaluate the performance measures of these systems one needs to consider discrete - time queue rather than continuous - time queues.

4.6 Performance analysis of the Discrete - time Geom/G/1 Queue :-

We consider a single - server discrete - time queueing system with a finite buffer of size N. It is assumed that the system has a clock such that time is slotted in intervals of equal length, separated by slot boundaries, without loss of generality, we assume each slot as unity. Arrivals are considered to occur on slot boundaries according to a late arrival system with delayed access. Let the time axis be marked by 0, 1, 2, 3, ...m. The customer are served according to first - come first-served (FCFS) discipline. A customer can only materialize as a demanded at a time mark. The commencement and completion of service for a customer also can only occur at time marks. It follows that the waiting time, i.e. the time between arrival and commencement of a service for a particular customers, is restricted to values equal to integral multiples of the time interval, Δt between two consecutive time marks. There are following assumptions are valid.

1) No more than one customer may arrive at a given time mark.

2) The arrival of a customer at a given time mark is an event which is statisti cally independent of the arrival of customers at any previous time marks. P_r (arrival of a customer at a time mark) is affixed value P : P_r (no arrival at a time marks) is consequently of fixed value 1-P =q

3) Customers are served in then order of arrival.

4.6.1 The service time distribution :-

A service time θ can only assume values which are integral multiples of Δt. The probablity distribution for θ may therefore be given as a set of probablities C_k (K = 0, 1, ---- ----) such that

$$P_r\left(\theta = K \cdot \Delta t\right) = C_k$$

$$P_r\left(\theta = K \cdot \Delta t\right) = C_k \text{ ----------- (2)}$$

Where the interval $K \cdot \Delta t$ includes its rightmost but not its leftmost endpoint. We must,of course,demand that

$$\sum_{K=0}^{K=\infty} C_k = 1 \text{ ------------(3)}$$

We may derive,

$$E(\theta) = \sum_{K=0}^{K=\infty} C_K \, K\Delta t$$

$$E(\theta) = \Delta t \sum_{K=0}^{K=\infty} C_K k \qquad \text{------------ (4)}$$

$$E[\theta(\theta - \Delta t)] = \sum_{K=0}^{K=\infty} C_K K\Delta t\,(k-1)\,\Delta t$$

$$E[\theta(\theta - \Delta t)] = \Delta t^2 \sum_{K=0}^{K=\infty} C_K \, k(k-1) \qquad \text{------------(5)}$$

Traffic density $\rho = \varphi E(\theta)$

$\rho = \varphi E(\theta)$

Where φ = Poisson Rate

$\varphi = P/\Delta t$

$\varphi = P/\Delta t$: No. of arrival Per Unit time.

$$\rho = P \sum_{K=0}^{K=\infty} K\,C_K \qquad \text{------------------------------(6)}$$

Where $\rho < 1$

4.6.2 The Matrix of transition probablities :-

The probablity of having a queue length n when the system is in equilibrium will be called P_n (n=0, 1, 2, ------). We will now obtain a set of equn. from which the values of P_0, P_1, P_2, -------) can be found, at least in principal.

$$R = \begin{vmatrix} r_{00} & r_{01} & r_{02} & - & - & - \\ r_{10} & r_{11} & r_{12} & - & - & - \\ r_{20} & - & - & - & - & - \\ - & & & & & \\ - & & & & & \\ - & - & - & - & - & - \end{vmatrix} \qquad \text{----------(7)}$$

Where $r_{ij} = P_r$ (next state will be j if the last state where i)

In the statistical equ. we must have

$$P_j = \sum_{i=0}^{i=\infty} P_i \, r_{ij} \qquad \text{---------------------------(8)}$$

If we introduce a vector P then,

$$P = \begin{vmatrix} P_0 \\ P_1 \\ P_2 \\ -- \\ -- \end{vmatrix} \qquad \text{-------------------------- (9)}$$

Now, Customer X has just completed service and we know that there is a customer Y who will enter service at the next time mark. The next determination of the state, i.e., of the queue length, will be when Y leaves service. Y has been included in the queue length i after Y leaves service the new queue length j will be

j = i-1 + no. of customers having arrived while Y was in service.

$$b_m = r_{i,i-1+m} \quad , (i \geq 1) \quad \text{----------------------------} \quad (10)$$

$$r_{i,j} = b_{j-i+1} \quad , (i \geq 1) \quad \text{————————————} \quad (11)$$

if i = 0 , when X departs there is no customers waiting to go into service. When the next customers , Y finally , arrives he begins services immediately. The queue length j , after Y departs will be equal to the no. of customers who have arrived while Y was in service.

from this follow .

$$\left.\begin{array}{l} r_{ij} = b_j \\ \& \quad r_{ij} = r_{1j} \end{array}\right\} \quad \text{————————————} \quad (12)$$

Eqn. (8) now may be written as using eqn. (9), (11) & eqn. (12)

$$\begin{vmatrix} P_o \\ P_1 \\ P_2 \\ - \\ - \end{vmatrix} = \begin{vmatrix} b_o & b_o & 0 & 0 & - & - \\ b_1 & b_1 & b_o & 0 & - & - \\ b_2 & b_2 & b_1 & b_o & - & \\ - & - & - & - & - & - \\ - & - & - & - & - & - \end{vmatrix} * \begin{vmatrix} P_o \\ P_1 \\ P_2 \\ - \\ - \end{vmatrix} \quad \text{--------} \quad (13)$$

4.6.3 Determinationof the mean queue length :-

Equ. (13) will yield the mean queue length E(n) by application of the method of generating function . We introduce a function g(z) defines as follows

$$g(z) = \sum_{n=0}^{n=\infty} P_n Z^n \quad \text{-------------------- (14)}$$

We proceed formally by multiplying the left side of the equ. contained in (13) by power of Z in such a way that g(z) is formed by summing the left sides.

$$g(z) = P_0 \sum_{n=0}^{n=\infty} b_n Z^n + P_1 \sum_{n=0}^{n=\infty} b_n Z^n + \text{-----}$$

$$= \left(\sum_{n=0}^{n=\infty} b_n Z^n\right) (P_0 + P_1 + ZP_2 + Z^2 P_3 + \text{----})$$

$$g(z) = \left(\sum_{n=0}^{n=\infty} b_n Z^n\right) (1/Z) \, (P_0(Z-1) + g(z)) \quad \text{----------- (15)}$$

Now solve equ. (15) with respect to g(z),

$$g(z) = \left(\sum_{n=0}^{n=\infty} b_n Z^n\right) P_0 (Z-1) \Big/ \left(Z - \sum_{n=0}^{n=\infty} b_n Z^n\right)$$

$$g(z) = \left[h(Z) \cdot P_0 (Z-1) \right] \Big/ \left[Z - h(Z) \right] \quad \text{-----------(16)}$$

Where for converience we have introduced

$$h(Z) = \sum_{n=0}^{n=\infty} b_n Z^n \quad \text{----------------(17)}$$

Now,

$$h(Z) = \sum_{n=0}^{\infty} Z^n \sum_{K=n}^{\infty} \binom{K}{n} P^n q^{K-n} C_k$$

$$h(Z) = \sum_{k=0}^{k=\infty} C_k (Z_p + q)^K \quad \text{--------------- (18)}$$

We shall make use of equ. (16) & (18) to obtain limiting values for g(Z) & g'(Z) as Z approaches the value 1 from the left. The actual values of g(Z) & g'(Z) for Z = 1 are

$$g(1) = \sum_{n=0}^{n=\infty} P_n = 1 \quad \text{---------- (19)}$$

$$g'(1) = \sum_{n=0}^{n=\infty} nP_n = E(n) \quad \text{--------- (20)}$$

Consider g(Z) as defined in equ. (14) since the service converges for Z = 1. We know that the radius of convergence is larger than or equal to 1. We also know by an elementry theorem that g'(Z) has the same radius of convergences as g(Z).

Next we may determine P_0 by finding the limit of the right side of equ.

(16) as $Z \rightarrow 1$

$$g(1) = 1 = \frac{Z \rightarrow 1 \left[h(Z)\, P_0\, (Z-1) \right]}{\left[(Z - h(Z) \right]}$$

$$g(1) = \frac{P_0}{1 - \rho} \quad \text{---------- (21)}$$

$$h(1) = \sum_{k=0}^{k=\infty} C_k\, (p+q)^K = 1 \quad \text{----------- (22)}$$

$$h'(1) = \sum_{k=0}^{k=\infty} C_k\, P_k\, (p+q)^{K-1} = \rho \quad \text{—— (23)}$$

From this we find, $\boxed{P_0 = 1 - \rho.}$ -------- (24)

In order to obtain g'(Z), which will yield E(n) according to equ. (20) we differentiate equ. (16).

$$g'(Z) = \frac{P_0 \left\{ (z-h)\,[\,h'\,(z-1) + h\,] - h\,(z-1)\,(1-h') \right\}}{(z-h)^2}$$

Which may be simplified,

$$g'(Z) = \frac{P_0 [\, z(z-1)\, h' + h(1-h) \,]}{(z-h)^2} \qquad \text{--------(25)}$$

Both the numerator and the denominator are 0 and have first derivatives of value 0 for Z = 1. We therefore find the limit of g' (Z) as $Z \rightarrow 1$ as the ratio between the second derivative of numerator $\phi(Z)$ and denominator $\psi(Z)$, evaluated at Z = 1, We find,

$$\phi'(Z) = 2h'(z-h) + z(z-1)\, h''$$

$$\psi'(z) = 2(z-h)(1-h')$$

$$\phi''(1) = 2h'(1-h') + zh'' \qquad \text{------------- (26)}$$

$$\psi''(1) = 2(1-h')^2 \qquad \text{------------ (27)}$$

We need to evaluate h"(1), using equ. (18) & equ. (5) we get,

$$h''(1) = \sum_{k=0}^{k=\infty} C_k\, P^2 k\,(k-1)\,(p+q)^k$$

$$= q^2 E[\theta\,(\theta-\Delta t)\,] \qquad \text{--------- (28)}$$

Where q = Poisson Rate

The result may now be written as,

$$E(n) \lim_{Z \to 1} g'(z) = \frac{P_0 \left\{ 2\rho (1-\rho) + \varphi^2 E\left(\theta (\theta - \Delta t)\right) \right\}}{[2 (1-\rho)^2]}$$

Simplifying and using equ. (24),

$$E(n) = \frac{\rho + \varphi^2 E\left(\theta (\theta - \Delta t)\right)}{[2 (1-\rho)]} \quad \text{---------} (29)$$

Equ. (29) gives the mean queue length .

For the continious-time case we need only let $\Delta t \to 0$ keeping ρ and φ constant. The service time distribution goes into a continuous distribution, then equ. (29) became

$$E(n) \xrightarrow[\Delta t \to 0]{} \frac{\rho + \varphi^2 E(\theta^2)}{[2 (1-\rho)]} \quad \text{---------} (30)$$

4.6.4 Waiting Time :-

The mean waiting time may be derived by a consideration in the continuious case. The mean no. of customers arriving during the mean waiting time, E(W). Plus the mean service time E (θ), must be equal to the mean queue length E (n).

$$[E(W) + E(\theta)]\, \varphi = E(n)$$

This equ. give,

$$E(W) = \frac{1}{\varphi} [\, E(n) - \rho \,]$$

Using equ. (29) gives,

$$E\,(W) = \frac{\varphi\, E\,[\,\theta\,(\theta - \Delta t)\,]}{[\,2\,(1-\rho)\,]} \qquad \text{---------- (32)}$$

4.6.5 Average packet delay T :-

In input channel There are no. of packet comes in the first slot and then go to another slot. In class 2 services C/G is equal to 1, Then using equ. (32) in equ. (1), time delay.

$$T = \frac{\varphi\, E\,[\theta_i\,(\theta_i - 1)]}{2(1 - \varphi\, E\,[\theta_i])} + E\,(\theta_i) + \frac{\varphi}{2(1-\varphi)} + 1$$

$$\boxed{T = \frac{\varphi\, E\,[\theta_i\,(\theta_i - 1)]}{2(1 - \varphi\, E\,[\theta_i])} + E\,(\theta_i) + \frac{\varphi}{2(1-\varphi)} + 1} \qquad \text{------------ (33)}$$

& switch throughput $\rho = \varphi E\,(\theta)$

Where $\rho < 1$

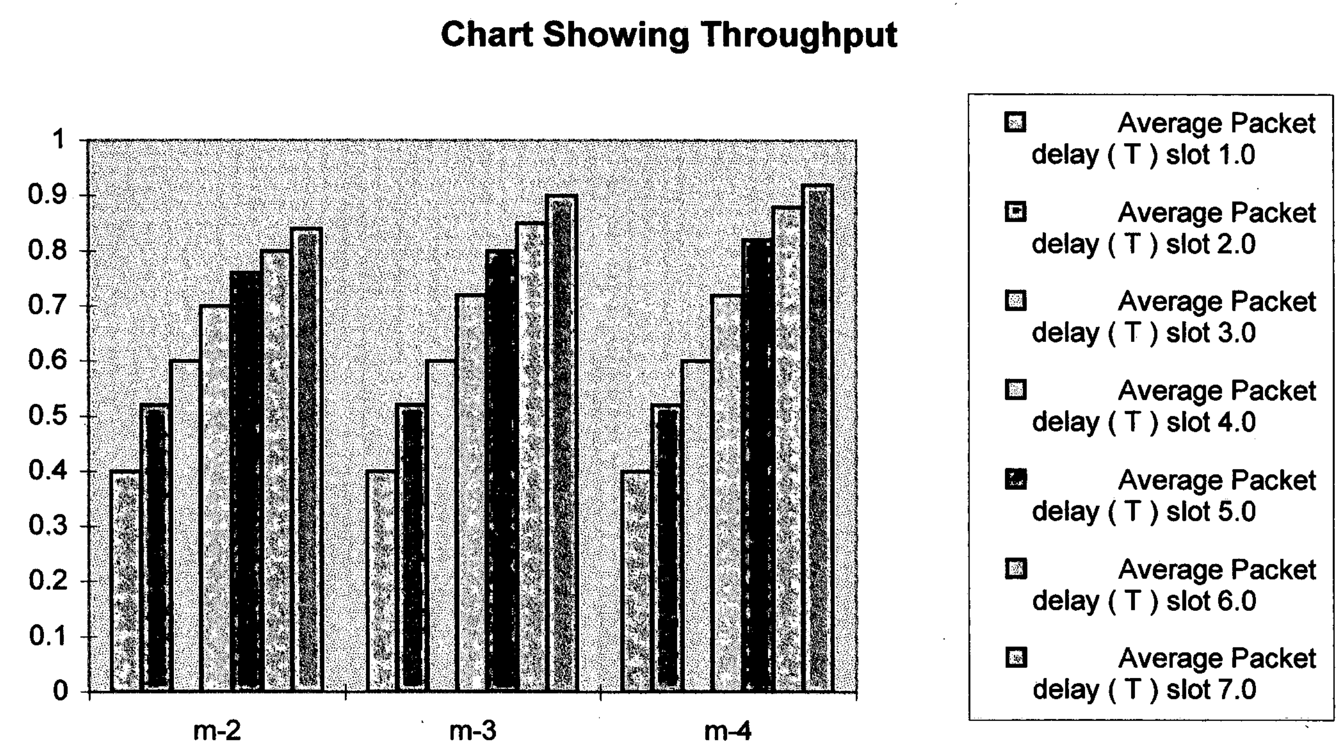
The maximum throughput carried by the switch is given by smallest φ value that makes infinite the delay T.

4.7 Numerical discussion :-

To obtain optimal throughput ρ, We draw the following table output for M =2, 3 & 4 respectively.

From these table we draw the graph between average packet delay, T (Slot) and switch throughput ρ.

	Average Packet delay (T) slot						
Switch Throughput ( )	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**
m-2	0.4	0.52	0.6	0.7	0.76	0.8	0.84
m-3	0.4	0.52	0.6	0.72	0.8	0.85	0.9
m-4	0.4	0.52	0.6	0.72	0.82	0.88	0.92



Graph 1: Average Packet delay Versus Switch Throughput

The first term of equ. (33) become infinite for φ = 0.885, 0.876, 0.996 when M = 2, 3, 4. The analysis turns out to be very precise for ρ< 0.9. It became less accurate for high throughputs but, according to our expectations, conservative values are always provided. T results to be smaller than 6 slots for M =2, by limiting throughput ρ = 0.8. The largest switch configuration examined , M = 4 , provides an average packet delay smaller than 6 and 11 slots for throughputs $\rho < 0.9$ and $\rho < 0.95$, respectively . Hence the limiting value of ρ = o.8.

CHAPTER 5

Result and Conclusion :-

In this project we calculate the limiting value of $\rho = 0.8$ which is less than one. We know that the numerical value of throughput is always less than one (1). Hence we get the result at T = 6 slots for M = 2, by limiting the throughput to $\rho = 0.8$.

We have shown that it is possible to design an A.T.M switch capable of supporting a set of services characterized by quality - of services figures compatible with those foreseen for the B-ISDN. The proposed architecture is nonblocking, self-routing structure with mixed queueing that transfer packets from switch inlets to switch outlets. Regarding the performance with traffic generated by other classes (class 1 to another) we have shown that the combined use of input and output queueing result in a carried load that can be easily made very close to the theoretical maximum throughput $\rho = 1$.

APPENDIX A

Consider a time period, t_k containing k time marks and let p_r (m arrival within t_k) = $A_{m,k}$

therefore $A_{m,k} = \binom{K}{M} p^m q^{k-m}$ ---------- (1)

When ($0 \leq m \leq k$)

& $A_{m,k} = 0$ ---------- (2)

When m>k

Equ. (1) expresses the binomial distribution. It is easily seen that

$$E(m) = \sum_{m=0}^{m=\infty} A_{m,k.m} = k \cdot p \qquad \text{---------- (3)}$$

$$\& \; E[m(m-1) = \sum_{m=0}^{m=\infty} A_{m,k\,m(m-1)} = k(k-1)p^2$$

from (3) we may determine the mean no. of arrivals λ per unit time

$$\lambda = E(m) / (k.\Delta t) = P/\Delta t \qquad \text{----------- (4)}$$

APPENDIX B

The expectation, E[x], of a random variable X is defined by

$$E(X) = \begin{cases} \sum_i X_i P(x_i), & \text{if x is descrete} \\ \int_{-\infty}^{\infty} x\, f(x)\, dx, & \text{if x is continuous} \end{cases}$$

provided that the relevant sum or integral is absolutely convergent.

Throughput is computed from the packet size (M_n) and packet rate (R_n) ;

$$\text{throughput} = R_n \times M_n$$

Bernoulli trials :- Consider a random experiment that has two possible outcomes. "Success" and "failure". Let the probabilities of the two outcomes be P and q , respectively, with p + q = 1. Now consider the combined experiment consisting of a sequence, is known as a sequence of Bernoulli trials.

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