Chapter 2

ATM Network and Modeling

Chapter 2: ATM Network and Modeling

This chapter covers a comprehensive literature survey done on ATM network including ATM network topology, ATM switch, Broadband Terminal Equipment, ATM application and physical link. ATM internetworking, traffic management and congestion control is explained. The chapter ends with a brief introduction to various modeling required by ATM network.

2.1 ATM Network Topology

Generally, network topology refers to the physical layout of a network, that is how the network components are connected to each other. In ATM, there four basic ATM network components include:

- ATM Switch
- Broadband Terminal Equipment (B-TE)
- ATM Application
- Physical Link

An ATM switch can be linked to several B-TEes or switches by physical links. A B-TE can have more than one ATM application at user side and attach to only one physical link at network side. An ATM application is unable to link to ATM switch directly but it is bounded to one B-TE.

Single hop topology consists of only one central switch and a numbers of B-TEes. Multihop topology consists of more than one switch in the network. In multihop topology, ATM switches can be interconnected in star topology, ring topology, or mesh topology.

For ATM network, network topology can be referred as either logical or physical. Physical topology is regarding the physical arrangement of an ATM network. Whereas, logical topology is referring to the logical virtual paths constructed on the top of the physical network. The logical paths constructed will form the logical (embedded) network topology for an ATM network.

Physical topology design of ATM network will affect the network performance. This is due to the fact that flexibility of the logical network topology reconfiguration mechanism will rely on physical topology. Physical topology also brings effect in the sense that possible paths for connecting switches depend on the physical link available between them.
An ATM network logical topology can be reconfigured dynamically to adapt to the changing traffic condition of the network. The purpose is to optimize the network performance with existing resources. The physical network should be design in such a way that as many logical topology can be derived as possible in order to provide the flexibility of the VP reconfiguration and dynamic reallocation.

2.2 ATM Switch

2.2.1 Overview

A simple switch is a fabric that routes and buffers cells. A switch fabric is needed to establish the connection between a pair of input and output within a switch. A switching element is the basic unit of a switch fabric. A single switch element or a number of switching elements can implement a switch fabric. A switch element consists of an interconnection network, an input controller (IC) for each incoming line and an output controller (OC) for each output line. Buffers are provided to prevent the internal collisions that may happens when more than one incoming cell competing for the same output. The IC will synchronize arriving cells to the internal clock. The interconnection network will direct the cells to the coupled OC and OC will transport the cells toward the destination.

An ATM switch contains a set of input ports and output ports. Ports connect the switch to other switches, users, or other network elements. There are two main tasks of ATM switch:

- VPI/VCI translation

Virtual path is the connection established through different switches across network. As each cell travels across ATM switch, the VCI will be translated into a new value because VCI is local to each switch port. The VPI may be translated also into a new VPI value. The switch has to build the new header for the cell containing the new VCI/VPI.

- Switching – cells transport from input ports to output ports

The ATM switch has to relay an incoming cell from input port to the appropriate output port. The relay will be made based on a routing table contains logical ATM channel information. Two identifiers characterize the logical ATM channel:

1. The physical input/output port that is characterized by a physical port number
2. The logical channel on the physical port that is identified by the VCI and /or the VPI

2.2.2 Performance

Logical connections exist between the input and output port of a switch since ATM is defined to be connection-oriented. Connection blocking happens when the physical connections between all the input and output port are not enough for all required logical connection to be established.

When more than one cell is to be transmitted through the same link at the same time, only one cell can be transmitted and others will be queued into a buffer. There are many queues for different type of traffics. When queue is currently full, cells that will required the same queue would be lost. The probability of cell loss should be kept in a specified acceptable limit. Typical values for cell loss in ATM are in the range of 10^{-8} to 10^{-10}.

When a cell is sent to the wrong logical connection due to the internal routing error, cell insertion error occurred. The error impact is doubled by the fact that the actual receiver destination will lose one cell and the receiver will accept an additional unused cell. The switch element has to be designed so that cell insertion error probability will be about 1000 times better than a cell loss.

Queuing in a switch will cause the switching delay. The delay values will depend on the cell scheduling policy that sets the order of transmission of cells out of the buffers. A maximum delay has to be guaranteed, and a low values of jitter. Typical delay values are between 10to 1000 μsec, with jitter of 100ηsec or less. A small queue will give better delays but increase the cell loss probability.

2.2.3 Queuing Methods

The queuing methods are categorized according to the buffer placement location as below:

- Input buffers

The buffers are placed at the input controllers (ICs). When using first-in-first-out (FIFO) buffers, a collision happens if more than one head-of-the-queue competing for the same output. Only one of the head-of-the-queue manages to gain the output and others are blocked. Cells in the queue of blocked head-of-the-queue are also blocked even though they are destined for other available output. By replacing the FIFO with a random access memory (RAM), if the first cell is blocked, the other in the queue destined to an idle output can be selected for transmission. But this will require more complex buffer control.

- Output buffers

The buffers are located at the output controllers (OCs). Collision occurs when more than one input is buffered to the same output buffer at the same time. This can be avoided by reducing the buffer access time and speed up the internal pass. In order to have a non-blocking switch, the interconnection network and output buffer have to be capable of handling N (number of ICs) cells at one cell time.

- Crosspoint buffers

The buffers are located at the individual crosspoint of the switching matrix. This will prevent cells that destined to different output from affecting each other. Control logic is applied when more than one head-of-the-queue destined to the same output simultaneously. Each crosspoint requires a small buffer and buffer sharing is not possible. This has become the efficiency drawback of the crosspoint buffers.

Among the three queuing methods, the output buffers give the most efficient operation and are the most widely used.

2.2.4 Buffer Management

Buffer management refers to the discarding policies for the input cells into the buffers and scheduling policies for the output cells from the buffers. Besides that, buffer management also monitors the switch fabric statistics and alert Switch Management when congestion is detected. Switch Management will instruct buffer management to adjust the discarding and schedule policies to response to the congestion detected. Priorities such as Cell Loss Priority (CLP) and delay priority are used in buffer management. CLP is attached in ATM cell header, cell with CLP=1 will be discarded before cell with CLP=0 when a buffer is full. Cell with CLP=0 are admitted into a buffer if some space can be freed by discarding cell with CLP=1. Delay priority can be associated with each virtual circuit connection. Different QoS class will have different cell delay requirements, higher priority needs to be given to the class with more strict constraints.

As ATM network claimed to be high-speed switching network, the design of ATM switch aims to increase speed, capacity and performance as a switch. Switching functions have been incorporated in an ATM switch in order to achieve the aims. The functions are such as traffic management and congestion control functions.

2.3 ATM B-TE

ATM B-TE (Broadband Terminal Equipment) can be a host computer, workstation, router, etc. It is the network component where ATM connection terminated and where ATM application placed. An ATM B-TE can host many ATM applications and one link connected to an ATM switch.

Cells received from application are forwarded to ATM switch through the link connected them. If the link is busy, then the cells will be queued according to their traffic type. If either queue exceeds its size limit, cells will be dropped. ATM B-TE will implement the traffic management for ABR connection with rate-based flow control algorithms.

2.4 ATM Application

ATM application will utilize ATM transport services and become the traffic generator in ATM network. An application can use any traffic type provided by transport services: CBR, VBR, ABR, or UBR. Existing ATM applications are such as below:

- TCP/IP – uses either ABR or UBR service
- MPEG – uses VBR service
- File transfer – uses UBR service

Existing LAN application can also take advantage from the high performance ATM network through ATM LAN emulation. ATM LAN Emulation was designed to allow existing networked applications and network protocols to run over ATM backbone networks in a standardized manner. ATM LAN Emulation is important because it allows multiple LANs to co-exist on the same physically interconnected ATM network.

2.5 Physical Link

The ATM physical link is the physical medium that transmitting cells over network and connecting the network components to each other. The link speed will be measured in megabits persecond (Mbits/sec). The B-ISDN specifies that ATM cells are to be transmitted at a rate of 155.52 Mbits/sec or 622.08 Mbits/sec. These rates were chosen to be compatible with SONET. The Synchronous Optical Network (SONET) is an octet-synchronous multiplex scheme that defines a family of standard rates and formats. For the 155.52 Mbits/sec interface, two approaches are defined in I.413: a cell-based physical layer and SDH (Synchronous Digital Hierarchy) -based physical layer. No framing is imposed for cell-based physical layer. The cell will be transmitted in a continuous stream of 53-octet cells over physical link. For SDH-based, cells will be framed into a specified frame size before transmitting over physical link.

The transmission medium for ATM is normally fiber optics. Coax or category 5 twisted pair are also acceptable for runs under 100 meters. Fiber optic runs can be many kilometers. Each link connects a B-TE and an ATM switch, or two ATM switches. Unlike LANs, which have many senders and receivers on the same cable, ATM links are point-to-point. Each point-to-point link is unidirectional. In the case where full-duplex operation is required, two parallel links are needed, one for traffic each way.

The ATM Physical Medium Dependent (PMD) sublayer in ATM protocol reference model is concerned with getting the bits on and off the wire. Different hardware will require different cables and fibers, relying on the speed and line encoding. The ATM Transmission Convergence (TC) sublayer (above PMD sublayer) provides a uniform interface to the ATM layer in both directions. While sending, PDM encode a sequence of cells provided by ATM layer as needed and pushes them out into the network physical transmission medium as bit stream. Upon receiving, PDM takes incoming bits from the network physical transmission medium and delivers a bit streams to the TC for converting to ATM layer acceptable format.

2.6 ATM Internetworking

2.6.1 Overview

The deployment of ATM network requires the overlay of a highly complex, software intensive protocol infrastructure. This infrastructure is needed for individual switches to be connected to a network, and for ATM network to internetwork with the existing legacy LANs and WANs. As ATM is connection-oriented, ATM specific signaling protocols and addressing structures, as well as protocol to route ATM connection request across the ATM network is needed. This lower level protocol will influence the manner of higher level protocols operation over ATM network.

2.6.2 ATM Network Operation

An ATM network consists of a set of ATM switches interconnected by point-to-point ATM links or interfaces. ATM switch supports two kinds of interfaces: User-Network interface (UNI) and Network-Node interface (NNI). UNI connect ATM B-TEs to an ATM switch. NNI may be imprecisely defined as an interface connecting two ATM switches together. More precisely, an NNI is any physical or logical link across which two ATM switches exchange the NNI protocol.

The basic ATM switch operation is:

- To receive a cell across a link on a known VCI/VPI
- To determine the outgoing link for the cell by looking up a routing table and assign new VCI/VPI value for the cell
- To retransmit the cell on that outgoing link with the appropriate connection identifiers

Before any data transmission, the routing table is set up by external mechanism, this makes the switch operation simple. The manner which the table being set up determines the two fundamental types of ATM connections:

I. Permanent Virtual Connection (PVC)

- Connection is set up by external mechanism usually network management, always present, and can be used at will, like leased line.

II. Switched Virtual Connection (SVC)

- Connection is set up automatically through a signal protocol each time they are used, like making phone calls.

2.6.3. ATM Signaling and Addressing

ATM signaling is needed for achieving two purposes:

- establish, maintain, and release ATM VPCs and VCCs for data transmission
- negotiate or renegotiate the traffic characteristics (QoS parameter values) of a connection

ATM signaling protocols vary by ATM link type:

- ATM UNI signaling is used between an ATM B-TE and ATM switch across an ATM UNI
- ATM NNI signaling is used across NNI links between ATM switches

ATM UNI signaling uses the "one-pass" method for connection establishment, just like the model used by telephone network. A connection set up request from source is propagated through the network. As it goes, the connection is set ut until it reaches the final destination. The routing of the connection set up request is governed by the ATM routing protocols. Such protocols route the destination address and the traffic and Qos parameters request by the source. The destination may choose to accept or reject the request. Since the call routing is purely based on the parameters in the initial connection set up request message, the effect of negotiation scope betwwen source and destination is limited.

In the connection set up process, the source, intermediate switches and the destination will exchange message for communication. There are six of messages being used:

I. SETUP – sent by source to network for requesting connection set up

II. CALL PROCEEDING – responded by network (each hop passed by network) to acknowledge receipt of the request

III. CONNECT – responds from destination for accepting the connection set up request

IV. CONNECT ACK – sent by network (each hop passed by network) and source to indicate that it has receive the CONNECT message

V. RELEASE – sent by host wish to terminate the connection to the other and

VI. RELEASE COMPLETE – acknowledgement message by each hop along the way for releasing

Addressing is required to allow the signaling protocol to identify the source and destination of connections. ITU-T has adopted the telephone number-like E.164 addresses as the address structure for public ATM (B-ISDN) network. ATM Forum has extended ATM addressing to include private networks to complementing E.164 public address. There are two models of addressing evaluated by ATM Forum in private network address:

- Peer model
  ATM protocol layer was viewed in relation to existing network layer protocols such as IP, IPX.
- Subnetwork or overlay model
  Decouple the ATM layer from any existing protocols, all existing protocols would operate over the ATM network.

2.6.4 ATM Routing Protocol

NNI (Network Node Interface) protocols are used within ATM networks to route ATM signaling requests between ATM switches. Due to the connection-oriented nature of ATM, connection set up request needs to be routed from source node to the destination node through the ATM network. Hence, NNI protocols to ATM network are what routing protocols (such as OSPF or

IGRP) to current routed networks. Private-NNI (P-NNI) protocol has been developed by ATM Forum in order to define NNI protocol for private ATM network use.

The P-NNI protocol consists of two components:

I. P-NNI signaling protocol

P-NNI signaling protocol is used to relay ATM connection set up requests within the network, between the source and destination UNI. The UNI signaling request is mapped into NNI signaling at the source switch. The NNI signaling is remapped back into UNI signaling at the destination switch.

P-NNI links are used to connect ATM switching system, which P-NNI protocols will operate. P-NNI links can be physical link or virtual "multi-hop" links. A typical example of virtual link is virtual path that connects two nodes together. The two nodes are logically adjacent in relation to the P-NNI protocols because all the virtual channels would carrying the P-NNI signaling transparently through any intermediate switches between these two nodes on this virtual path.

II. Virtual circuit routing protocol

Virtual circuit routing protocol is used to route the signaling request through the ATM network. This is also the route on which the ATM connection is set up, and along which the data will flow. Due to the fact that no connection is existed for the signaling request to allow, the routing of a signaling request is superficially similar to the routing of connectionless packet within the existing network layer protocols (such as IP). As a result from this, a virtual circuit routing protocol can use some of the existing connectionless routing protocols. However, the P-NNI protocol is much more complex than any of the existing protocols. This complexity arises from two goals of the protocol:

- To allow for much greater scalability than what is possible with any existing protocol
- To support true QoS-based routing.

2.7 Traffic Management and Congestion Control in ATM Network

2.7.1 Overview

ATM networks are connection-oriented, virtual connections are established by virtually connecting all the intermediate switches between two end-systems that desire to communication to each other. The source must inform all the intermediate switches about their service requirements (QoS) and traffic parameters. There are various service categories in ATM network that is classified by different traffic requirements. Traffic management is concerned with ensuring all the users get their desired quality of service during their connection lifetime.

Congestion occurs when the input rate is exceeding the available link capacity. Normally, when a cell reaches a network element (can be switch or B-TE in ATM network) it is queued into a buffer and waits for output. Buffer can become full and if then cells keep on arriving at a rate larger than the output rate, congestion occurs. It can be considered that link is congested as virtual connection is make up through all the intermediate network elements. Congestion can also caused by slow links and slow processors. It will reduce the throughput (actual traffic received by destination) and increase the delays. Congestion control is the most essential part of traffic management. It is concerned with efficiently using a network at a high load.

Congestion control involves discard policy. When a node is saturated, it must start to discard packets. A simple rule would be discarding the most recent arrival. However, there are few considerations can be used to refine the discard policy:

- Fairness

  Fairness needs to be promoted in discarding packets among flows of traffic between different pairs of source and destination. Each traffic flow must suffer from congestion equally. An example of promoting fairness: A node maintains a separate queue for each logical connection or source-destination pair. If all the queue buffers are of equal length, then the queues with highest traffic load will be discard more often, to allow lower-traffic share the capacity fairly.

- Quality of Service

  Different traffic flow might be treated differently by their QoS required. Delay sensitiveness and loss sensitiveness of an application will influence the traffic flow priority. A node will transmit higher-priority packets ahead of lower- priority packets in the same queue, or maintain different queues for different QoS levels and give priority to the most demanding queues.

- Reservation

  A reservation scheme can be provided to avoid congestion. Upon setting up a connection, the network and the user enter into a traffic contract, which specifies a data rate and other traffic characteristics of the traffic flow. If the network is inadequate to meet the traffic requirements, the connection set up request will be denied. After the connection is set up, the traffic flow is given way as long as it is within the contract parameters. Traffic that exceeds the contract will be either discarded or handled on a best effort basis, subject to discard.

2.7.2 Traffic Management Framework

ITU-T Recommendation I.371 (08/96) – Traffic Control and Congestion Control in B-ISDN states the objectives of ATM layer traffic and congestion control as following:

- ATM layer traffic and congestion control should support a set of ATM layer QoS classes sufficient for all foreseeable network services; the specification of these QoS classes should be consistent with network performance parameters currently under study.
- ATM layer traffic and congestion control should not rely on AAL protocols that are network service specific, nor on higher-layer protocols that are application specific. Protocol layers above the ATM layer may make use of information provided by the ATM layer to improve the utility they can derive from the network.
- The design of an optimum set of ATM layer traffic controls and congestion controls should minimize network and end-system complexity while maximizing network utilization.

ITU-T has defined a collection of traffic and congestion controls functions that operate across a spectrum of timing intervals in order to meet these objectives. Four levels of timing are considered:

- Cell insertion time: Functions at this level react immediately to cells as they are transmitted.
- Round-trip propagation time: At this level, the network responds within the life-time of a cell in the network and may provide feedback indications to the source.
- Connection duration: At this level, the network determines whether a new connection at a given QoS can be accommodated and what performance levels will be agreed to.
- Long term: These are controls that affect more than one ATM connection and are established for a long-term use.

Table 2.1 Traffic and Congestion Control Functions

Response Time	Traffic Control Functions	Congestion Control Functions
Long Term	• Resource management using virtual paths	
Connection Duration	• Connection admission control (CAC)	
Round-trip Propagation Time	• Fast resource management	• Explicit forward congestion indication (EFCI) • ABR flow control
Cell Insertion Time	• Usage parameter control (UPC) • Priority control • Traffic shaping	• Selective cell discard • Frame discard

2.7.3 Traffic Control Functions

- Resource management using virtual paths

  Network resources are allocated to separate traffic flows based on their service characteristic by using virtual path. Network provides aggregate capacity and performance on the virtual path connection (VPC) that is shared by group of virtual channel connections (VCCs). QoS parameters that are of primary concern for network resource management are CLR, maxCTD and peak-to-peak CDV. These QoS parameter are affected by the amount of resources devoted to the VPC by the network. With multiple VCCs within a single VPC, the network has two general options for allocating capacity to the VPC:

  - Aggregate peak demand

    The network may set the capacity (data rate) of the VPC equal to the total of the peak data rate of all of the VCCs within the VPC. The advantage of this option is that each VCC can be given a QoS that accommodates its peak demands. However, the VPC capacity will not be fully utilized at most of the time and caused underutilization of network resources.

  - Statistical multiplexing

    The network may set the capacity of the VPC to be equal to or greater than the average data rate of all the VCCs but less than the aggregate peak demand. The VCCs will experience greater cell delay variation and greater cell transfer delay. VCCs may also experienced greater cell loss ratio depending on the size of buffers used for cell queueing. This option will utilize the capacity more efficient and is attractive if VCCs can tolerate the lower QoS.

- Connection admission control (CAC)

  This is the first line defence for the network in protecting itself from excessive load. When a user requests a new VPC or VCC, the user must specify the service required in both directions for that connection. The request consists of:

  - Service category: CBR, rt-VBR, nrt-VBR, ABR or UBR
  - Connection service descriptor: PCR, SCR, MBS, MCR, CDVT, and etc

- ♦ Requested and acceptable value of each QoS parameters: peak-to-peak CDV, max CTD, CLR

The network will accept the connection set up request only if it can commit the resources needed to support that traffic level while at the same time maintaining the agreed QoS of existing connections. By accepting the connection, the network forms a traffic contract with the user. Once the connection is accepted and set up, the network continues to provide the agreed QoS as long as the user complies with the traffic contract.

- Fast resource management

This approach requires source to send a resource management (RM) cell requesting the desired network resources before actually sending the data. If the network is unable to grant the request, the RM cell will be dropped and the source will resend the request after timeout. If the request can be granted, the RM cell will reach the destination and return by destination to the source which can then transmit the data. The data has to wait at least one round trip delay at the source even if the network is idle. To avoid the delay, an "immediate transmission (IT)" mode can be imposed. In IT mode, the data is transmitted immediately following the RM cell. If network cannot satisfy the request, it drops the RM cell and the data and send an indication to the source.

- Usage parameters control (UPC)

Once a connection has been accepted by the CAC function, the UPC function of the network monitors the connection to determine whether the traffic conforms to the traffic contract. The main purpose is to protect network resources from overload on one connection that would adversely affect the QoS on other connections. By detecting violation of assigned parameters and taking appropriate actions, UPC can maintain the connection within the agreed QoS. Peak Cell Rate algorithm and Sustainable Cell Rate algorithm has been developed for this purpose.

- Cell loss priority Control

  Each cell will have CLP bit in its header, which is either set to 0 or 1. Cell loss priority control is applied when cell discarding is necessary. It will choose to discard lower-priority cells (CLP=1) to protect the performance of higher priority cells (CLP=0).

- Traffic Shaping

  Traffic shaping occurs when a flow of data is regulated so that calls that exceed a certain performance level are discarded or tagged. Traffic shaping is used to smooth out a traffic flow and reduce cell dumping. It can result in a fairer allocation of resources and a reduced average delay time. Leaky bucket algorithm is one of the approach for traffic shaping.

2.7.4 Congestion Control Approaches

- Credit-based Approach

  This approach consists of per-link, per-VC, and window flow control. Each link consists of a sender node (can be a source end system or a switch) and a receiver node (can be a switch or a destination end system). Each node maintains a separate queue for each VC. The receiver monitors queue lengths of each VC and determines the number of cells that the sender can transmit on that VC. This number is called "credit", which represents number of cells allowed for transmission. Sources must maintain the credit, so that they can control their data flow based on the credit.

- Rate-based Approach

  This approach consists of end-to-end control using a single-bit feedback from the network. The switches monitor their queue lengths and if congested set a particular bit (such as EFCI) in the cell headers to indicate that congested occurred. The destination monitors these indications for a periodic interval and sends an RM cell back to the source. The sources use an additive increase and multiplicative decrease algorithm to adjust their data rate. "Negative polarity of feedback" refers to algorithm where RM cells are sent only for decreasing data rate. On the other hand, for "positive polarity of feedback" algorithm, RM cells are sent only for increasing data rate. If RM cells are sent for both increasing and decreasing purposes, the algorithm is called bipolar.

2.8 ATM Network Simulation

Based on different time scales chosen for simulation environment, there are two categories of ATM network simulation that permit the measurement of different performance metrics according to [MARS97]. They are:

- Cell-level simulation

  Cell-level simulation is customer-oriented simulation. The relevant events simulated mainly concern the handling of ATM cells and of the PDUs (Protocol Data Units) that are transferred by means of them. The desired simulated result may be the network capacity to handle traffic subject to individual QoS requirements, or the suitable network dimensions (such as buffer memory) to handle a particular traffic load.

- Call-level simulation

  Call-level simulation is network-oriented simulation. The relevant events simulated mainly concern the user access to communication service. The areas of interested may be to evaluate the performance of connection establishment and release strategies, routing algorithms of connection calls, or Connection Admission Control (CAC) techniques.

2.9 ATM Network Modeling

Before an ATM network simulation can be performed, modeling is required. Modeling includes:

- ATM traffic modeling

  Traffic modeling is important because traffic flow characteristics bring great effects in a network. In order to gain meaningful simulated result, traffic model developed to drive the simulation is to be accurate. Although a wide range of traffic models has been developed, not many of them can reflect the real world traffic accurately. One reason behind this is that new type of network data traffic keeps appearing and changes nature of traffic. For example, classical traffic model, Poisson, was proven not appropriate for modern network traffic in [BABI98]. Self-similar model is found to be more accurate in modeling modern network traffic.

  Some important ATM network traffic that need to be modeled includes:

  - Ethernet local area network (LAN) traffic – one of the most widely used current applications of ATM networks backbones.
  - MPEG (Motion Pictures Experts Group) compressed video – one of the most bandwidth-intensive applications that ATM networks are being used for.
  - Internet WWW traffic – the fastest growing and largest consumer of bandwidth on the Internet.

- ATM switch modeling

  ATM switch modeling should be able to reflect the characteristics of cell flow based on the architecture of switch type. Elements that must be represented are following:

  - A dimension (N x N) specifying the number of input ports and output ports of the switch.
  - A switching fabric defining the connections between input port and output ports. For example, Banyan.

- ♦ A set of buffers and buffering strategy that specifies how many buffers are available, and how they are configured and used. For example, input vs. output buffering.
- ♦ Routing tables that is used to map cells from input ports to output ports by using virtual circuit and virtual path indices (VCIs and VPIs).

- Network level modeling

  Network level modeling will be needed only for call-level simulation. Network level modeling involves protocol and link modeling. Protocols that need to be modeled includes ATM switch protocols, call setup and release protocols, and policing and admission control protocols. Links have to be modeled implicitly based on the flow of cells in the network instead of explicitly as separate component.

A broad literature survey of ATM network in general was covered in this chapter. Modeling of ATM network can be broadly classified as traffic, switch and network modeling. Traffic modeling is modeling the cell flow and it is "micro" in scale while network modeling is "macro" and concentrates on the general behavior and performance of the network. Switch modeling is the simulation of the hardware of the ATM network. This research will focus on the cell level and a dynamic flow study will be performed on various network topologies.