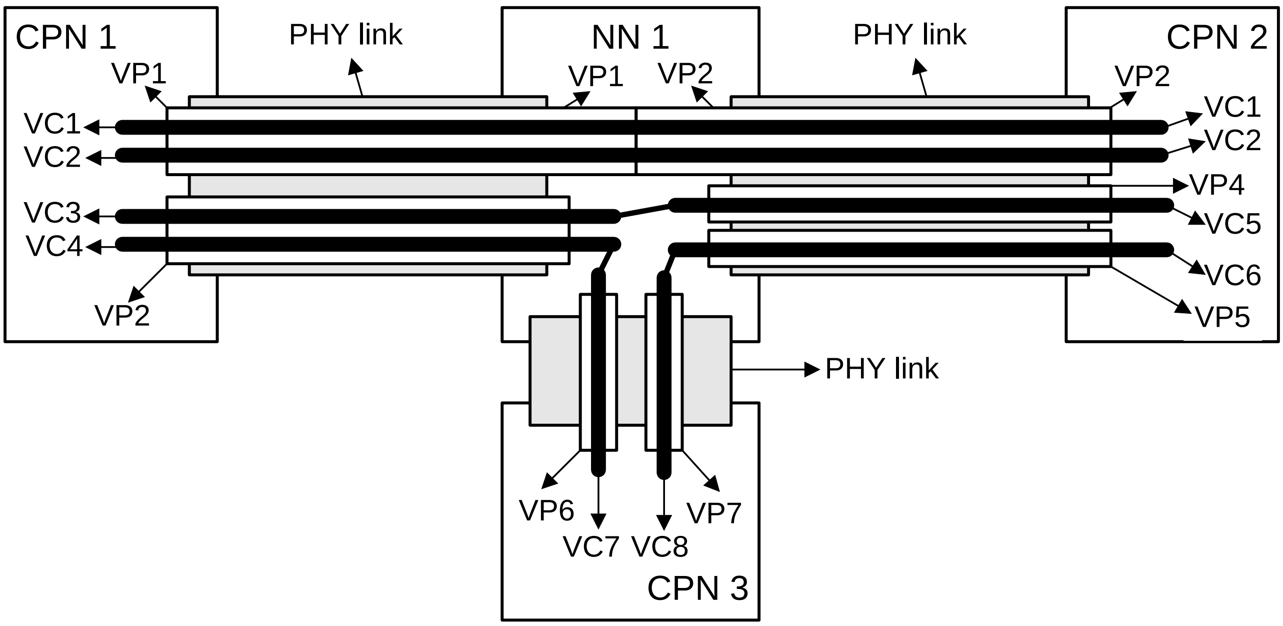
ATM:
A two tiered addressing is used with the following elements being involved in the addressing assignments:

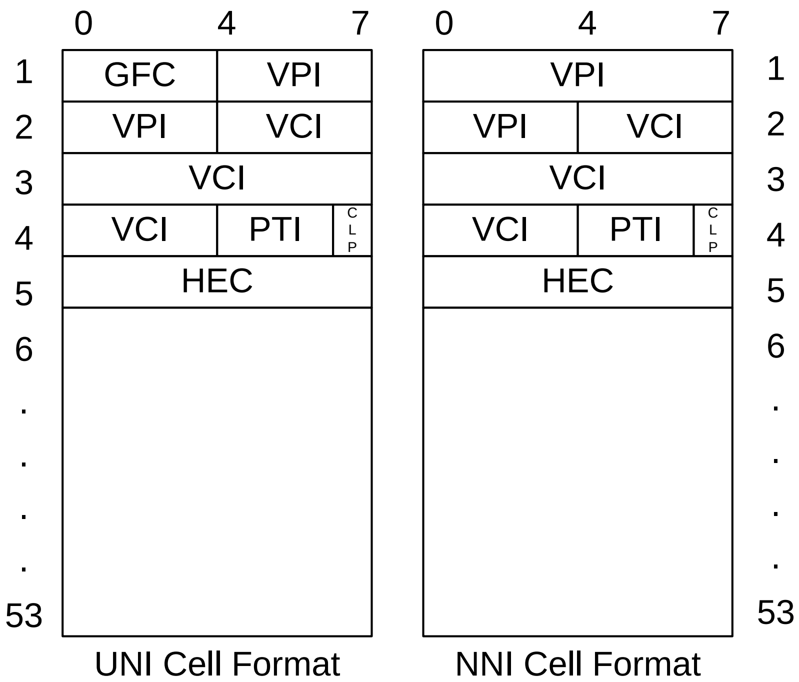
- Virtual Channel: represents the data flow of a single network connection between two ATM end users. The ATM standards define this as a unidirectional connection between 2 end-points on the network.
- Virtual Path: is used to carry one or more virtual channels through the network. It is represented as a bundle of channels between two end-points.

CPN – Customer Premises Network

NN – Network Node



ATM Circuit and Path Connections



ATM Cell Formats

GFC = Generic Flow Control (4 bits; default: 4 zero bits)

VPI = Virtual Path Identifier (8 bits UNI or 12 bits NNI)

VCI = Virtual Channel Identifier (16 bits)

PT = Payload Type (3 bits)

CLP = cell Loss Priority (1 bit)

HEC = Header Error Control (8 bit CRC; polynomial = $X^8 + X^2 + X + 1$)

A UNI (User Network Interface) cell reserves the GFC field for a local flow control/submultiplexing system between users. It is intended to allow several terminals to share a single network connection, in the same way that two ISDN phones can share a single basic rate ISDN connection.

The NNI (Network Network Interface) cell format replicates the UNI format almost exactly, except that the 4 bit GFC field is realocated to the VPI field, extending the VPI to 12 bits. Thus, a single NNI ATM interconnection is capable of addressing almost 2^{12} VPs of up to almost 2^{16} VCs each (in practice some VP and VC numbers are reserved).

- GFC – is used only in the UNI format. No general purpose services have been assigned to this field, and it is significant only for the local site. This flow control information is not carried from end to end. Two modes have been used for GFC based flow control: “uncontrolled access” and “controlled access”. In “uncontrolled access” this field is set to all zeroes. In “controlled access” mode this field is set when congestion has occurred. The receiving equipment will report instances in which the GFC has been set a significant number of times to Layer Management
- VPI/VCI – the distribution of bits between these two fields can be negotiated between the user and the network equipment.
- PT – indicates whether or not the cell contains useful information or Layer Management information. It also carries implicit congestion information.
- CLP – indicates the cell’s priority in the ATM selective loss algorithm. Set by the initiating equipment, when this is set to 0, the cell is given preference over cells with CLP set to 1.
- HEC – provides the capability to correct all single bit errors in the cell header as well as the detection of the majority of multiple bit errors. The use of this field is up to the interpretation of the equipment designers. If most errors are likely to be single bit errors, it can be used for error correction. Using the field for error correction does carry some level of risk of introducing unwanted errant traffic on the network should a mistake be made in the correction process.

Using cells and virtual circuits for traffic engineering

Key ATM concept involves the traffic contract. When an ATM circuit is set up each switch on the circuit is informed of the traffic class of the connection.

ATM traffic contracts form part of the mechanism by which QoS is ensured.

ATM QoS mechanisms provide the best service on a per-flow guarantee. ATM network infrastructure was designed to provide QoS. It uses fixed cell sizes and built-in traffic management. This allows the fine tuning the levels of the services on the priority of the traffic flow.

There are four basic types (and several variants) which each has a set of parameters describing the connection.

1. CBR – Constant bit rate: a Peak Cell Rate (PCR) is specified, which is constant. It provides fixed bandwidth. CBR is generally time-sensitive and it is used for connections that continuously require a specific amount of bandwidth (e.g. high resolution video and audio).
2. VBR – Variable bit rate: an average or Sustainable Cell Rate (SCR) is specified, which can peak at a certain level, a PCR, for a maximum interval before being problematic.

   VBR it is used with bursty connections aand has real-time and non-real-time variants and serves for “bursty” traffic. Non-real-time is sometimes abbreviated to vbr-nrt and real-time is abbreviated vbr-rt.

VBR-rt is used with bursty connections that require closely controlled delay and delay variations (e.g. video conferencing).

VBR-nrt is used with bursty connections that do not require closely controlled delay and delay variations (e.g. non-time sensitive data transfers).

3. ABR – Available bit rate: a minimum guaranteed rate is specified – Minimum Cell Rate (MCR). It is used for bursty data transfers. ABR gives a subscriber a set amount of bandwidth and allows the use of more if it is available. End devices using ABR get feedback from the network and can use flow-control to dynamically adjust transmission rates.

   ABR uses RM (Resource Management) cells to send feedback information from the connection's destination and/or intervening network switches to the connection's source. A source generates forward RM cells, which the destination returns to the source as backward RM cells. Along the way, network switches can adjust the fields in the RM cells depending on the network conditions. Number of Resource Management (NRM) is the maximum number of RM cells a source may send.

4. UBR – Unspecified bit rate: traffic is allocated to all remaining transmission capacity. Is similar to the ABR traffic class for bursty data transfers. While ABR gives subscribers a set amount of bandwidth, UBR doesn't guarantee any bandwidth and only delivers traffic when the network has spare bandwidth.

Traffic policing and Traffic shaping are implemented. Traffic shaping is an agreement between the carrier and the subscriber to regulate the average rate and fluctuations of the data transmission over an ATM network. This agreement helps eliminate congestion, which is important for transmission of real time data such as audio and video connections.

Peak Cell Rate (PCR) is the maximum rate at which the sender can send cells. It may be lower than the maximum line speed.

Sustainable Cell Rate (SCR) is the mean cell rate of each bursty traffic source. It specifies the maximum average rate at which cells can be sent over the virtual connections. SCR may not be greater than PCR.

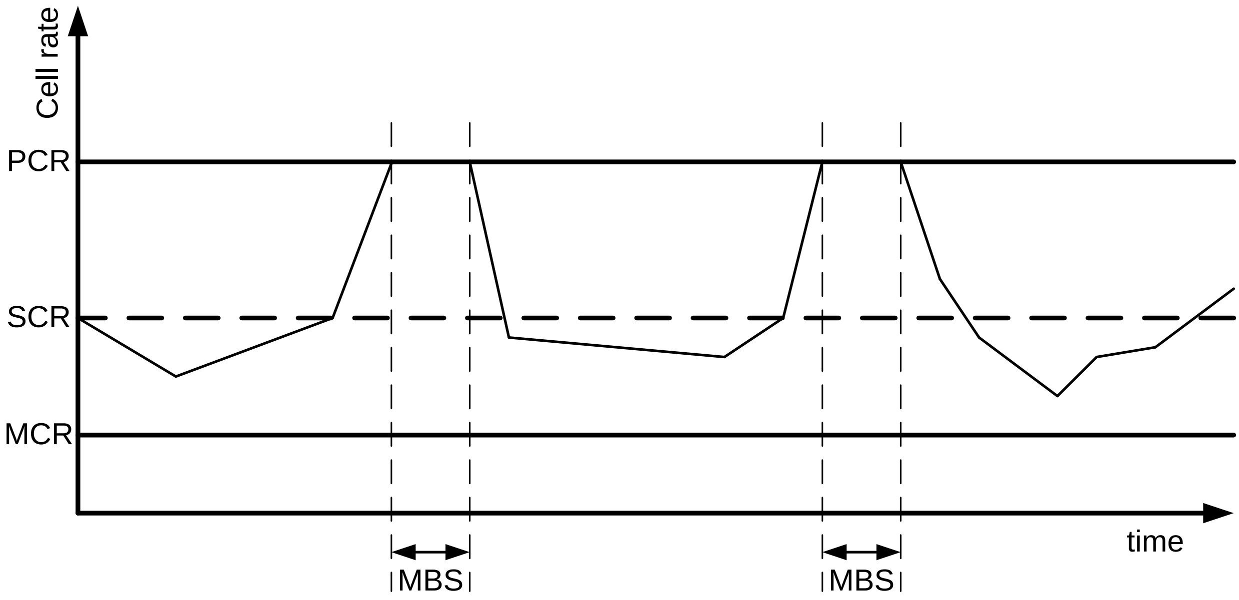
Maximum Burst Size is the maximum number of cells that can be sent at the PCR. After MBS is reached, cell rate falls below SCR until cell rate averages to the SCR again. At this time, more cells (up to the MBS) can be sent at the PCR.

Minimum Cell Rate (MCR) is the minimum rate at which the sender can send cells.

Cell Delay Variation Tolerance (CDVT) is the accepted tolerance of the difference between a cell's transfer delay and the expected transfer delay. CDVT controls the time scale over which the PCR is enforced . CDVT is used to determine if a cell arrived too early in relation to PCR.

Burst Tolerance (BT) is the maximum number of cells that the port is guaranteed to handle without any discards. BT controls the time scale over which SCR is enforced. BT is used to determine if a cell arrived too early in relation to SCR.

Theoretical Arrival Time (TAT) is when the next cell (in an ATM connection) is expected to arrive. TAT is calculated based on PCR or SCR.



ATM traffic parameters

Types of virtual circuits and paths

ATM can build virtual circuits and virtual paths either statically or dynamically. Static circuits (permanent virtual circuits or PVCs) or paths (permanent virtual paths or PVPs) require that the circuit is composed of a series of segments, one for each pair of interfaces through which it passes.

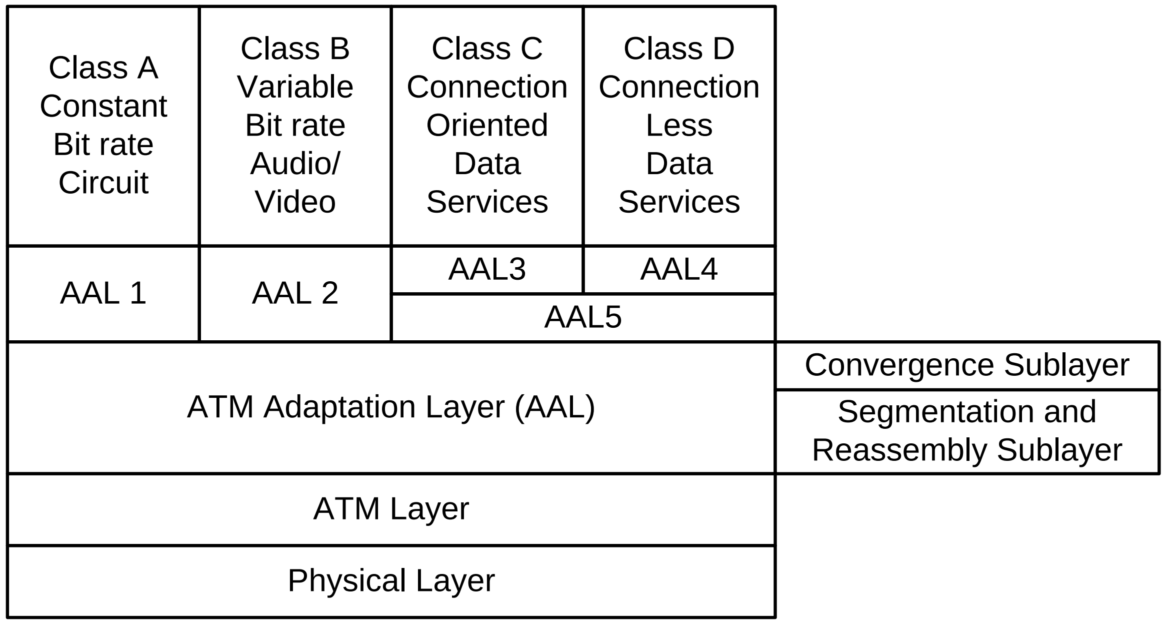
PVPs and PVCs, though conceptually simple, require significant effort in large networks. They also do not support the re-routing of service in the event of a failure. Dynamically built PVPs (soft PVPs or SPVPs) and PVCs (soft PVCs or SPVCs), in contrast, are built by specifying the characteristics of the circuit (the service "contract") and the two end points.

ATM networks create and remove switched virtual circuits (SVCs) on demand when requested by an end piece of equipment. One application for SVCs is to carry individual telephone calls when a network of telephone switches are inter-connected using ATM. SVCs were also used in attempts to replace local area networks with ATM.

Reference Model

ATM defines three layers:

1. ATM Adaptation Layer (AAL)
2. ATM Layer, roughly corresponding to the OSI Data Link Layer
3. Physical Layer, equivalent to the OSI Physical Layer.



ATM protocol architecture

ATM Encapsulation Methods

LLC Encapsulation: is a type of encapsulation where one VC caries multiple protocols with each packet header containing protocol identifying information. Despite the extra bandwidth and processing overhead, this method may be advantageous if it is not practical to have separate VC for each carried protocol, for example, if charging heavily depends on the number of simultaneous VCs.

VC Mux: is a type of encapsulation where, by prior mutual agreement, each protocol is assigned to a specific virtual circuit, for example, VC1 carries IP, VC2 carries IPX, and so on. VC-based multiplexing may be dominant in environments where dynamic creation of large number of ATM VCs is fast and economical.

ENET ENCAP: the MAC Encapsulated Routing Protocol is only implemented with the IP network protocol. IP packets are routed between the Ethernet interface and the WAN interface and then formatted that they can be understood in a bridged environment, i.e., it encapsulates routed Ethernet frames into bridged ATM cells. ENET ENCAP requires specifying a gateway IP address in the Ethernet Encapsulation Gateway field – this information can be obtained from the ISP.

LAN protocols encapsulated over ATM

Upper-layer applications
Upper-layer protocols
Ethernet or TCP/IP
SNAP
802.2 LLC
AAL5
ATM
PHY

* The **Subnetwork Access Protocol** (**SNAP**) is an extension of the IEEE 802.2 Logical Link Control (LLC) to distinguish much more protocols of the higher layer than using of the 8-bit Service Access Point fields (LSAP) present in the IEEE 802.2 header.

Point-to-Point Protocol (PPP)

Is a data link protocol used to establish a direct connection between two nodes. It can provide authentication, transmission encryption and compression.

PPP is used over many types of physical networks including serial cable, phone line, trunk line, cellular telephone, specialized radio links and fiber optic links such as SONET. Internet Service Providers (ISPs) have used PPP for customer dial-up access to the Internet; PPP acts as a Data Link protocol. Two derivatives of PPP, Point-to-Point Protocol over Ethernet (PPPoE) and Pont-to-Point Protocol over ATM (PPPoA), are used most commonly by ISPs to establish Digital Subscriber Line (DSL) Internet service with customers.

Point-to-Point Protocol over ATM (PPPoA)

Is a network protocol for encapsulating PPP frames in AAL5. It is used mainly with DOCSIS and DSL carriers. It offers standard PPP features such as authentication, encryption and compression. If it is used as the connection encapsulation method on an ATM based network it can reduce overhead slightly (around 0.58%) in comparison to PPPoE. It also avoids the issues that PPPoE suffers from, related to having a MTU lower than that of standard Ethernet transmission protocols. It also supports (as does PPPoE) the encapsulation types: VC-MUX and LLC based.

Configuration of a PPPoA requires PPP configuration and ATM configuration. These data are generally stored in a cable modem or DSL modem, and may or may not visible to, or configurable by, an end-user.

PPP configuration generally includes: user credentials, user name and password, and is unique to each user.

ATM configuration includes:

- Virtual Channel Link (VCL) – Virtual Path Identifier & Virtual Channel Identifier (VPI/VCI), such as 0/32 (analogous to a phone number).
- Modulation (Type): such as G.dmt.
- Multiplexing (Method): such as VC-MUX or LLC.

ATM configuration can either be performed manually, or it may be hard-coded (or pre-set) into the firmware of a DSL modem provided by the user's ISP

Point-to-Point Protocol over Ethernet (PPPoE)

Is a network protocol for encapsulating PPP frames inside Ethernet frames. It appeared at the turn of the century in the context of the boom of the DSL connection to the ISP's IP network and from there to the rest of the Internet. PPPoE provides authentication, encryption and compression. PPPoE provides access control and billing functionality similar to dial-up services using PPP. Typical use of the PPPoE involves leveraging the PPP facilities for authenticating the user with a username and password.

PPPoE and TCP/IP protocol stack

Application	FTP, SMTP, HTTP, …, DNS,...
Transport	TCP, UDP
Internet	IP, IPv6
Network access	PPP
	PPPoE
	Ethernet

DSL Line Diagnostic:

- ATM Status - SAR – System Activity Report
- ATM Loopback Test
- DSL Line Status

ATM Status:

- **inPkts:** the number of good ATM cells that have been received;
- **inDiscards:** the number of received ATM cells that were rejected;’
- **inF4Pkts:** the number of ATM Operations, Administration and Management (OAM) F4 cells that have been received;
- **outF4Pkts:** the number of ATM OAM F4 cells that have been sent;
- **inF5Pkts:** the number of ATM OAM F5 cells that have been received;
- **outF5Pkts:** the number of ATM OAM F5 cells that have been sent;
- **txRate:** the number of bytes transmitted per second;
- **rxRate:** the number of bytes received per second.

The main OAM functions:

- Performance monitoring
- Fault detection
- Network protection
- Management information transfer
- Fault locating

The OAM functions in the ATM network are categorized into five levels. Each level has relevant OAM information flows F1-F5. The ATM OAM F5 function is performed on the virtual channel connection (VCC).

Definitions of the five OAM levels in the ATM network.

Layer	OAM level	Definition	OAM inf. flow
ATM layer	VC level	OAM functions performed on the VCC	F5
	VP level	OAM functions performed on the virtual path connection (VPC)	F4
PHY layer	Transmission path level	OAM functions performed on the devices assembling/disassembling payloads of a transmission system. One transmission path consists of multiple digital sections	F3
	Digital section level	OAM functions performed between digital section endpoints of the transmission network.	F2
	Regenerator section level	OAM functions performed between regenerator section endpoints of the transmission network.	F1

Mechanisms to Provide OAM Flows

At the ATM layer, dedicated cells that support the ATM OAM functions provide OAM flows for VCs and VPs.

OAM cells in an F5 flow have the same virtual channel identifier/virtual path identifier (VCI/VPI) values as the user cells of the VCC. An end-to-end F5 flow and a segment F5 flow can exist in the same VCC. The OAM cells for both directions of the F5 flow must follow the same permanent virtual connection (PVC). A VCC segment is the cascading of one or more VCC links. One or more OAM segments may be defined along a VCC. Neither overlapped nor embedded OAM segments can be defined.

Lists the main ATM OAM functions.

OAM function	Main application
Alarm indication signal (AIS)	Indicates alarms
Remote defect indicator (RDI)	Indicates defects at the remote end.
Continuity check (CC)	Check continuity
Loopback (LB)	Detects loopbacks
Forward performance monitoring	Assesses forward performance
Back reporting	Reports performance assessment in the backward direction
Activation/deactivation	Activates/Deactivates performance monitoring and continuity check

OAM functions:

- **AIS**

  The VC connection point that detects a VCC defect through instruction signals generates and sends (in the forward direction) VC-AIS cells on all affected active VCs.

  Instruction signals will be sent when transmission path-AIS defect indications are received from the physical layer, when defect indications are received at the VP level, or when loss of continuity (LOC) is detected at the VC level.

- **RDI**

  The VC-RDI cells are generated and transmitted periodically while the VC-AIS status persists or CC fails (that is, an LOC defect is declared) in order to indicate in the backward direction an interruption of the cell transfer capability at the VC level in the forward direction.

Figure 1 shows the AIS and RDI transmission after the failures of different connection points between the SGSN and the RNC. The SGSN is connected to the RNC through an ATM switch. Each VC has two directions, transmission and reception, corresponding to the transmission and reception of one optical fiber. A dotted line in Figure 1 indicates that the connection is disconnected. The serial number before a message indicates the message generation sequence.

Take case 2 as an example. After detecting the VC transmission fault in the SGSN, the ATM switch sends an AIS to the RNC in the forward direction. After receiving the AIS, the RNC sends an RDI to the SGSN in the backward direction through the ATM switch.

Figure 1 AIS and RDI functions