ATM

This lecture describes ATM, a transmission and switching technology based on a hybrid of circuit-switching and fixed-length packets. It was meant to integrate data and telephone networks but was not competitive with conventional packet-based networks. Today ATM is primarily used to route packets along virtual circuits in other networks.
After this lecture you should be able to: encapsulate a sequence of bytes into ATM cells using AAL5 SAR and describe the path followed by an ATM cell given the switching table contents for a set of ATM switches.

Introduction

Asynchronous Transfer Mode (ATM) was an attempt by telephone companies to design a network architecture that could efficiently transport both voice and data. It used very short (53-byte) packets to minimize queuing delay and a concept called "virtual circuits" to simplify the design of high-speed packet switches.

ATM was a short-lived solution. As data rates on fiber optic links increased, the duration of much-larger packets (e.g. 1500-byte Ethernet frames) became short enough that they did not introduce significant delay. Thus the need for short packets disappeared. Advances in computer hardware also allowed conventional IP routers to keep up with increases in core network data rates. These developments made ATM technology uncompetitive.

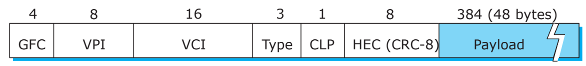
We will study ATM because it is still used for routing packets in some access networks (e.g. ADSL) and the concept of virtual circuits is now used by an IP-specific protocol, Multi-Protocol Label Switching (MPLS).

ATM Cells

ATM breaks data up into fixed-length cells consisting of a 5-byte header and a 48-byte payload. The purpose of using such short frames was to minimize the queuing delay that would be experienced by speech during phone calls.

Exercise 1: How long does it take to transmit a 1500-byte packet over a store-and-forward network with 10 hops at the DS1 rate? At a 1 Gb/s rate? How does this compare to the propagation delay for a 2000 km path?

An ATM cell header is short for efficiency. ATM uses a 5-byte (40-bit) header as shown below[1]:



The meanings of the fields are:

- GFC: used for flow control, typically set to zero.
- VPI, VCI: virtual path (8/12 bits) and circuit (16 bit) identifiers: the destination address. All packets on the same virtual path flow through the same sequence of ATM switches.
- Payload Type: flag bits, the third bit is set to '1' to indicate that this is the last ATM frame of a higher-level frame.
- CLP: Cell Loss Priority bit. Indicates the cell is lower priority and can be dropped if the network is congested.
- HEC: header error check, an 8-bit CRC on the header only.

Exercise 2: What fraction of an ATM frame is overhead? How large does the payload of an Ethernet frame need to be to achieve the same efficiency (an Ethernet frame has two 6-byte address fields, a 2-byte length/type field and a 4-byte CRC)?

Note that there is no error detection on the payload. ATM is typically operated over wired physical layers such as SONET that have low error rates and error control at the link layer would not improve efficiency. Instead, higher-level protocols do error control (detection and retransmission) if required.

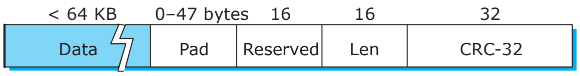
Adaptation Layers

Various ATM Adaptation Layers (AALs) define ways that different types of traffic (TDM PCM speech, Ethernet packets, etc) are converted to and from ATM cells. For example, AAL1 defines how constant bit rate traffic (e.g. a T1) is broken up into ATM cells.

[1] From L. Peterson, "Computer Networks", 2003. This is the User-Network Interface (UNI) cell. The Network-Network Interface (NNI) uses a 12-bit VPI instead of a GFC.

The most widely used AAL is probably AAL5. It is used for segmentation and reassembly (SAR) of data packets such as IP frames. The segmentation process is as follows:

- the packet is divided into 48-byte pieces and the last cell is padded to a length of 40 bytes.
- an 8-byte trailer is added to this last cell that contains a 2-byte length field, a 4-byte CRC and 2 unused bytes. The result is as shown below:



- the packet is then split into 48-byte cells and an ATM header with the appropriate VPI/VCI is added to each cell.
- the last (third) bit of the payload Type field in the header of the last cell is set to 1.

Reassembly reverses the process. Bytes from incoming cells are buffered until the last bit of the Type field is set to 1. Then the length field is used to remove the padding and the CRC is checked before passing the received frame to the next protocol level.

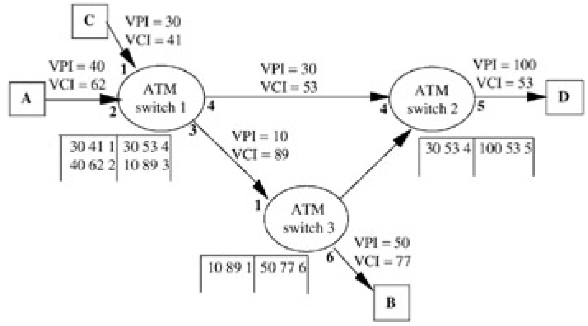
Exercise 3: A 96-byte Ethernet frame is being transmitted over ATM to VPI/VCI 0.33. How many ATM cells are required to transmit this frame? Calculate the contents of the ATM cell headers and contents of the final cell (set GFC, Type/CLP and CRCs to zero).

ATM Switches

Originally the VPI/VCI were intended to implement flexible routing of frames in a large-scale (global) circuit-switched data network similar to the PSTN. ATM switches (routers) use the VPI/VCI of each incoming frame to look up (1) a replacement VPI/VCI and (2) the physical port the frame should be sent back out on. The VPI/VCI can also be replaced at each switch in case different parts of the network use different sets of addresses ("label swapping"). However, in a private network with a limited number of endpoints the same VPI/VCI can be retained for simplicity.

Exercise 4: The diagram below[2] shows the switching tables at each port of a small ATM network. Where do the frames labelled A and C end up?

[2]Taken from Perros, Connection-Oriented Networks: SONET/SDH, ATM, MPLS and Optical Networks, Wiley, 2005.



ATM Signalling

One of the goals of ATM was to replace the PSTN with a network capable of handling both voice and data[3]. A signalling protocol was defined that could set up switching tables in ATM switches so that ATM cells would be correctly routed along this virtual circuit.

There was little interest in this approach and today the majority of ATM applications use "permanent virtual circuits" (PVCs) rather than dynamic "switched virtual circuits" (SVCs).

ATM QoS

At the same time as circuits were being set up, bandwidth resources could be reserved at each switch to ensure Quality of Service (QoS). A flexible mechanism was defined to give different priorities to different types of traffic. For example, delay-sensitive speech packets would be forwarded before data packets. In case of congestion lower-priority packets could be dropped.

For this purpose each connection can specify the type of service required, for example constant or variable bit rate (CBR, VBR), real-time (rt) or non-real-time (nrt), and guaranteed frame rate.

Unfortunately, identifying and prioritizing IP traffic flows is difficult and in many cases the bottleneck is the access network. Thus the QoS feature provided by ATM have not proved to be a significant advantage.

[3]Controlled by the telephone companies, of course!