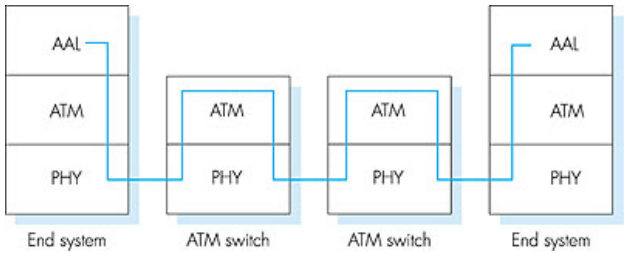
Asynchronous Transfer Mode: ATM

- **1980s/1990's standard for high-speed** (155Mbps to 622 Mbps and higher) *Broadband Integrated Service Digital Network* architecture
- Goal: *integrated, end-end transport of carry voice, video, data*
  - meeting timing/QoS requirements of voice, video (versus Internet best-effort model)
  - "next generation" telephony: technical roots in telephone world
  - packet-switching (fixed length packets, called "cells") using virtual circuits

ATM architecture

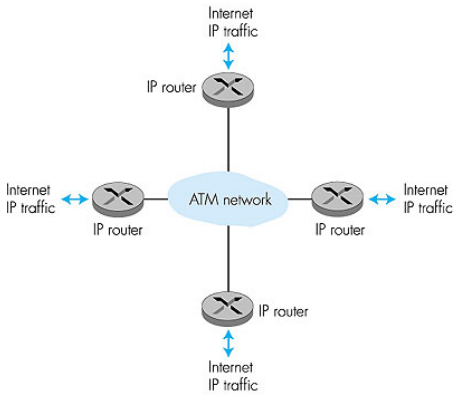


- **adaptation layer: only at edge of ATM network**
  - data segmentation/reassembly
  - roughly analagous to Internet transport layer
- ATM layer: "network" layer
  - cell switching, routing
- physical layer

ATM: network or link layer?

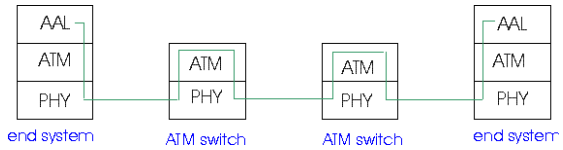
Vision: end-to-end transport: "ATM from desktop to desktop"
- ATM *is* a network technology

Reality: used to connect IP backbone routers
- "IP over ATM"
- ATM as switched link layer, connecting IP routers



ATM Adaptation Layer (AAL)

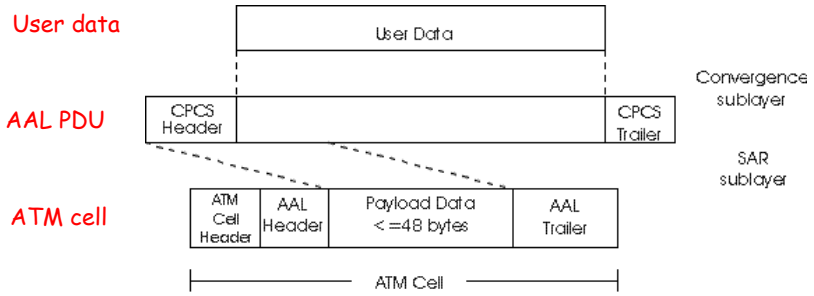
- ATM **Adaptation Layer** (AAL): "adapts" upper layers (IP or native ATM applications) to ATM layer below
- AAL present **only in end systems**, not in switches
- AAL layer segment (header/trailer fields, data) fragmented across multiple ATM cells
  - analogy: TCP segment in many IP packets



ATM Adaption Layer (AAL) [more]

Different versions of AAL layers, depending on ATM service class:

- AAL1: for CBR (Constant Bit Rate) services, e.g. circuit emulation
- AAL2: for VBR (Variable Bit Rate) services, e.g., MPEG video
- AAL5: for data (eg, IP datagrams)



AAL5 - Simple And Efficient AL

- **AAL5**: **low overhead** AAL used to carry IP datagrams
  - 4 byte cyclic redundancy check
  - PAD ensures payload multiple of 48bytes
  - large AAL5 data unit to be fragmented into 48-byte ATM cells

CPCS-PDU payload	PAD	Length	CRC
0-65535	0-47	2	4

ATM Layer

Service: transport cells across ATM network

- analagous to IP network layer
- very different services than IP network layer

Network Architecture	Service Model	Guarantees ?				Congestion feedback
		Bandwidth	Loss	Order	Timing	
Internet	best effort	none	no	no	no	no (inferred via loss)
ATM	CBR	constant rate	yes	yes	yes	no congestion
ATM	VBR	guaranteed rate	yes	yes	yes	no congestion
ATM	ABR	guaranteed minimum	no	yes	no	yes
ATM	UBR	none	no	yes	no	no

ATM Layer: Virtual Circuits

- VC transport: cells carried on VC from source to dest
  - call setup, teardown for each call *before* data can flow
  - each packet carries VC identifier (not destination ID)
  - *every* switch on source-dest path maintain "state" for each passing connection
  - link,switch resources (bandwidth, buffers) may be *allocated* to VC: to get circuit-like perf.
- Permanent VCs (PVCs)
  - long lasting connections
  - typically: "permanent" route between two IP routers
- Switched VCs (SVC):
  - dynamically set up on per-call basis

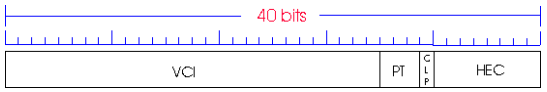
ATM VCs

- Advantages of ATM VC approach:
  - QoS performance guarantee for connection mapped to VC (bandwidth, delay, delay jitter)
- Drawbacks of ATM VC approach:
  - Inefficient support of datagram traffic
  - one PVC between each source/dest pair) does not scale (N*2 connections needed)
  - SVC introduces call setup latency, processing overhead for short lived connections

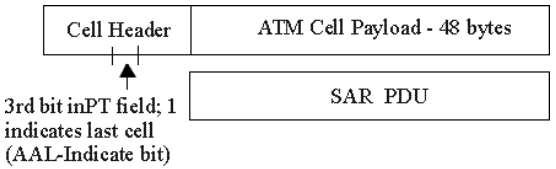
ATM Layer: ATM cell

- 5-byte ATM cell header
- 48-byte payload
  - Why?: small payload -> short cell-creation delay for digitized voice
  - halfway between 32 and 64 (compromise!)

Cell header

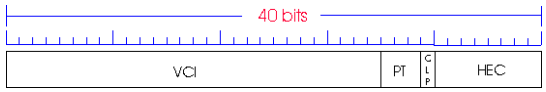


Cell format



ATM cell header

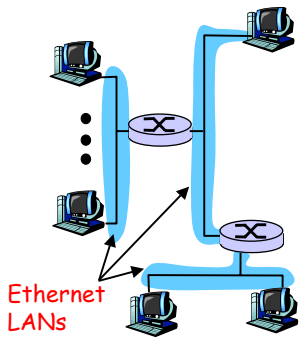
- **VCI:** virtual channel ID
  - will *change* from link to link thru net
- **PT:** Payload type (e.g. RM cell versus data cell)
- **CLP:** Cell Loss Priority bit
  - CLP = 1 implies low priority cell, can be discarded if congestion
- **HEC:** Header Error Checksum
  - cyclic redundancy check



IP-Over-ATM

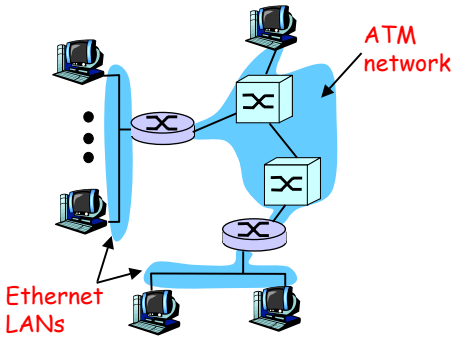
Classic IP only

- 3 "networks" (e.g., LAN segments)
- MAC (802.3) and IP addresses



IP over ATM

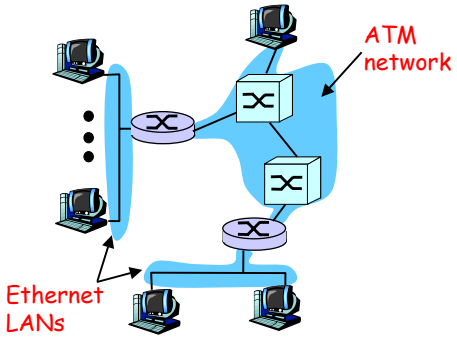
- replace "network" (e.g., LAN segment) with ATM network
- ATM addresses, IP addresses



IP-Over-ATM

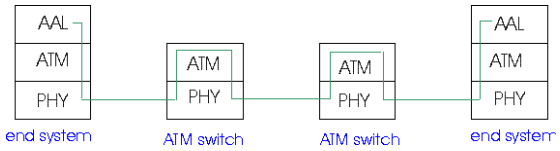
Issues:

- IP datagrams into ATM AAL5 PDUs
- from IP addresses to ATM addresses
  - just like IP addresses to 802.3 MAC addresses!



Datagram Journey in IP-over-ATM Network

- at Source Host:
  - IP layer finds mapping between IP, ATM dest address (using ARP)
  - passes datagram to AAL5
  - AAL5 encapsulates data, segments to cells, passes to ATM layer
- ATM network: moves cell along VC to destination
- at Destination Host:
  - AAL5 reassembles cells into original datagram
  - if CRC OK, datgram is passed to IP



ARP in ATM Nets

- ATM network needs destination ATM address
  - just like Ethernet needs destination Ethernet address
- IP/ATM address translation done by ATM ARP (Address Resolution Protocol)
  - ARP server in ATM network performs broadcast of ATM ARP translation request to all connected ATM devices
  - hosts can register their ATM addresses with server to avoid lookup

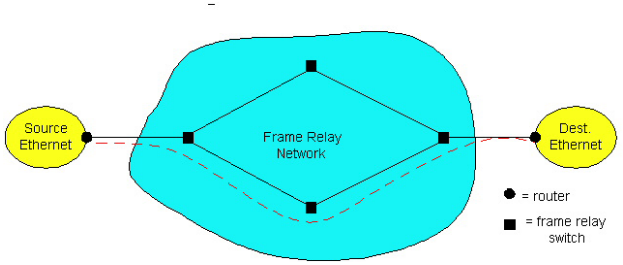
Frame Relay

Like ATM:

- wide area network technologies
- virtual circuit oriented
- origins in telephony world
- can be used to carry IP datagrams
  - can thus be viewed as Link Layer by IP protocol

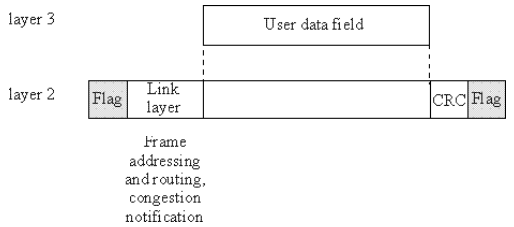
Frame Relay

- Designed in late '80s, widely deployed in the '90s
- Frame relay service:
  - no error control
  - end-to-end congestion control

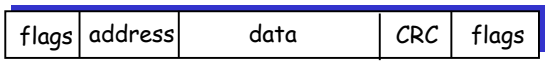


Frame Relay (more)

- Designed to **interconnect** corporate customer LANs
  - typically permanent VC's: "**pipe**" carrying aggregate traffic between two routers
  - switched VC's: as in ATM
- corporate customer **leases** FR service from public Frame Relay network (eg, Sprint, ATT)



Frame Relay (more)



- Flag bits, 01111110, delimit frame
- address:
  - 10 bit VC ID field
  - 3 congestion control bits
    - FECN: forward explicit congestion notification (frame experienced congestion on path)
    - BECN: congestion on reverse path
    - DE: discard eligibility

Frame Relay -VC Rate Control

- Committed Information Rate (CIR)
  - defined, "guaranteed" for each VC
  - negotiated at VC set up time
  - customer pays based on CIR

- DE bit: Discard Eligibility bit
  - Edge FR switch measures traffic rate for each VC; marks DE bit
  - DE = 0: high priority, rate compliant frame; deliver at "all costs"
  - DE = 1: low priority, eligible for discard when congestion

Frame Relay - CIR & Frame Marking

- **Access Rate**: rate **R** of the access link between **source router** (customer) and **edge FR switch** (provider); 64Kbps < **R** < 1,544Kbps

- Typically, **many VCs** (one per destination router) multiplexed on the same access trunk; each VC has own **CIR**
- Edge FR switch **measures** traffic rate for each VC; it **marks**
- frames which **exceed** CIR with DE = 1 (these may be later dropped)

Chapter 5: Summary

- principles behind data link layer services:
  - error detection, correction
  - sharing a broadcast channel: multiple access
  - link layer addressing, ARP
- various link layer technologies
  - Ethernet
  - hubs, bridges, switches
  - IEEE 802.11 LANs
  - PPP
  - ATM
  - X.25, Frame Relay
- journey down the protocol stack now *OVER!*
  - Next stops: security, network management