Part 5: Link Layer Technologies

CSE 3461: Introduction to Computer Networking
Reading: Chapter 5, Kurose and Ross
Outline

- PPP
- ATM
- X.25
- Frame Relay
Point to Point Data Link Control

• One sender, one receiver, one link: easier than broadcast link:
  – No Media Access Control
  – No need for explicit MAC addressing
  – e.g., dialup link, ISDN line

• Popular point-to-point DLC protocols:
  – PPP (Point-to-Point protocol)
  – HDLC: High level data link control (Data link used to be considered “high layer” in protocol stack!)
PPP Design Requirements [RFC 1557]

- **Packet framing**: encapsulation of network-layer datagram in data link frame
  - Carry network layer data of any network layer protocol (not just IP) at the same time
  - Ability to demultiplex upwards

- **Bit transparency**: must carry any bit pattern in the data field

- **Error detection** (no correction)

- **Connection liveness**: detect, signal link failure to network layer

- **Network layer address negotiation**: endpoints can learn/configure each other’s network address
PPP Non-Requirements

• No error correction/recovery
• No flow control
• Out-of-order delivery OK
• No need to support multipoint links (e.g., polling)

Error recovery, flow control, data re-ordering all relegated to higher layers!
PPP Data Frame (1)

- **Flag:** delimiter (framing)
- **Address:** does nothing (only one option)
- **Control:** does nothing; in the future possible multiple control fields
- **Protocol:** upper layer protocol to which frame delivered (e.g., PPP-LCP, IP, IPCP, etc.)

<table>
<thead>
<tr>
<th>bit 1</th>
<th>bit 1</th>
<th>bit 1</th>
<th>bit 1</th>
<th>bit 2 or 3</th>
<th>variable length</th>
<th>bit 2 or 4</th>
<th>bit 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>01111110</td>
<td>11111111</td>
<td>00000011</td>
<td>protocol</td>
<td>info</td>
<td>check</td>
<td>01111110</td>
<td></td>
</tr>
</tbody>
</table>

- flag
- address
- control
- flag

[The image contains a table with the described fields and their binary representations.]

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PPP Data Frame (2)

- **Info**: upper layer data being carried
- **Check**: cyclic redundancy check for error detection

![PPP Data Frame Diagram]
Byte Stuffing (1)

• “Data transparency” requirement: data field must be allowed to include flag pattern \texttt{01111110}
  
  – \textbf{Q:} Is received \texttt{01111110} data or flag?

• \textbf{Sender:} adds (“stuffs”) extra \texttt{01111101} byte after each \texttt{01111110 data} byte

• \textbf{Receiver:}
  
  – Two \texttt{01111110} bytes in a row: discard first byte, continue data reception
  
  – Single \texttt{01111110}: flag byte
Byte Stuffing (2)

Flag byte pattern in data to send

Flag byte pattern plus stuffed byte in transmitted data
PPP Data Control Protocol

Before exchanging network-layer data, data link peers must:

• **Configure PPP link** (max. frame length, authentication)

• **Learn/configure network layer information**
  
  – For IP: carry IP Control Protocol (IPCP) msgs (protocol field: 8021) to configure/learn IP address
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Asynchronous Transfer Mode: ATM

• 1980s/1990s standard for high-speed (155–622 Mbps and higher) *Broadband Integrated Service Digital Network* architecture

• **Goal:** *integrated, end-end transport of carrier’s 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 analogous 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) (1)

- 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) (2)

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 (e.g., IP datagrams)
AAL5 - Simple And Efficient AL (SEAL)

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

<table>
<thead>
<tr>
<th>CPCS-PDU payload</th>
<th>PAD</th>
<th>Length</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-65535</td>
<td>0-47</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>
# ATM Layer

**Service:** transport cells across ATM network
- Analogous to IP network layer
- Very different services than IP network layer

<table>
<thead>
<tr>
<th>Network Architecture</th>
<th>Service Model</th>
<th>Guarantees?</th>
<th>Congestion Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet</td>
<td>Best effort</td>
<td>None</td>
<td>No</td>
</tr>
<tr>
<td>ATM</td>
<td>CBR</td>
<td>Constant rate</td>
<td>Yes</td>
</tr>
<tr>
<td>ATM</td>
<td>VBR</td>
<td>Guaranteed rate</td>
<td>Yes</td>
</tr>
<tr>
<td>ATM</td>
<td>ABR</td>
<td>Guaranteed minimum</td>
<td>No</td>
</tr>
<tr>
<td>ATM</td>
<td>UBR</td>
<td>None</td>
<td>No</td>
</tr>
</tbody>
</table>
ATM Layer: Virtual Circuits (1)

- **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 to IP routers

- **Switched VCs (SVC)**:
  - Dynamically set up on per-call basis
ATM VCs (2)

• **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 $\Rightarrow$ short cell-creation delay for digitized voice
  - Halfway between 32 and 64 (compromise!)
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
ATM Physical Layer: Sub-Layers

Two pieces (sub-layers) of physical layer:

- **Transmission Convergence Sublayer (TCS):** adapts ATM layer above to PMD sublayer below
- **Physical Medium Dependent:** depends on physical medium being used

**TCS Functions:**
- Header **checksum** generation: 8 bits CRC
- Cell **delineation**
- With “unstructured” PMD sub-layer, transmission of **idle cells** when no data cells to send
ATM Physical Layer

Physical Medium Dependent (PMD) sublayer

- **SONET/SDH**: transmission frame structure (like a container carrying bits);
  - bit synchronization;
  - bandwidth partitions (TDM);
  - several speeds: OC1 = 51.84 Mbps; OC3 = 155.52 Mbps; OC12 = 622.08 Mbps

- **T1/T3**: transmission frame structure (old telephone hierarchy): 1.5 Mbps/ 45 Mbps

- **unstructured**: just cells (busy/idle)
IP-Over-ATM (1)

Classic IP only
- 3 “networks” (e.g., LAN segments)
- MAC (802.3) and IP addresses

- Replace “network” (e.g., LAN segment) with ATM network
- ATM addresses, IP addresses
IP-Over-ATM (2)

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, datagram 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
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X.25 and 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 Layers by IP protocol
X.25

- X.25 builds VC between source and destination for each user connection
- **Per-hop control along path**
  - Error control (with retransmissions) on each hop using LAP-B
    - Variant of the HDLC protocol
  - Per-hop flow control using credits
    - Congestion arising at intermediate node propagates to previous node on path
    - Back to source via back pressure
IP versus X.25

• X.25: reliable in-sequence end-end delivery from end-to-end
  – “intelligence in the network”
• IP: unreliable, out-of-sequence end-end delivery
  – “intelligence in the endpoints”
• gigabit routers: limited processing possible
• 2000–: IP wins
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Frame Relay (1)

• Designed in late 1980s, widely deployed in the 1990s

• Frame relay service:
  – No error control
  – End-to-end congestion control
Frame Relay (2)

• Designed to interconnect corporate customer LANs
  – Typically permanent VCs: “pipe” carrying aggregate traffic between two routers
  – Switched VCs: as in ATM

• Corporate customer leases FR service from public Frame Relay network (eg, Sprint, AT&T)
Summary: Link Layer Technologies

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