Lecture 13
ATM, SONET, and MPLS

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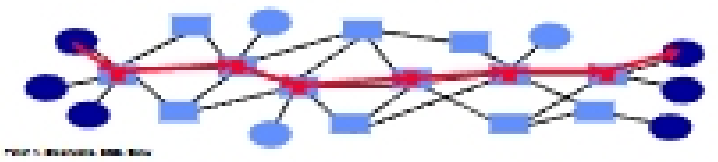
Outline

- Circuit switching.
- ATM overview.
- SONET.
- MPLS.

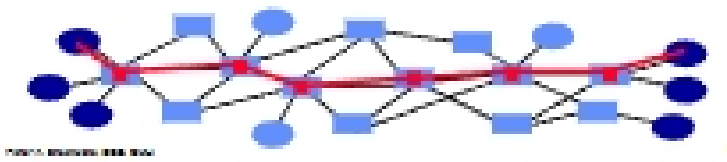
Packet Switching

- Source sends information as self-contained packets that have a destination address.
  - Source may have to break up single message in multiple
- Each packet travels independently to the destination host.
  - Routers and switches use the destination address in the packet to determine how to forward the packets
- Destination recreates the message.
- Analogy: a letter in surface mail.

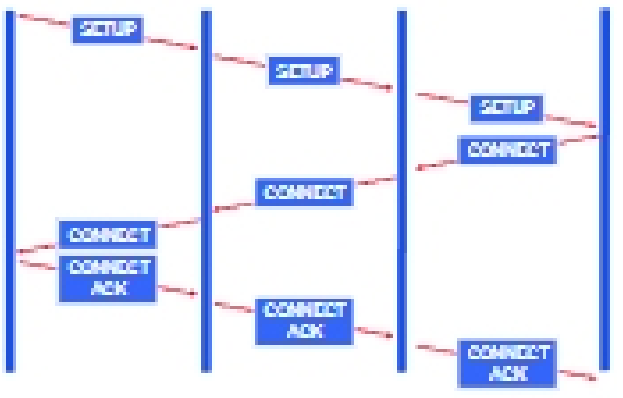


Circuit Switching

- Source first establishes a connection (circuit) to the destination.
  - Each router or switch along the way may reserve some bandwidth for the data flow
- Source sends the data over the circuit.
  - No need to include the destination address with the data since the routers know the path
- The connection is torn down.
- Example: telephone network.



Connection Setup

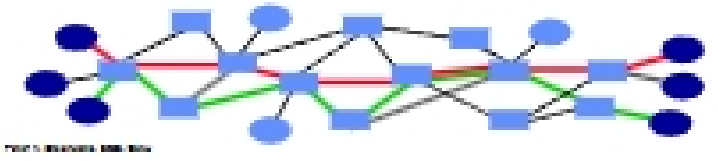


Circuit Switching Discussion

- Traditional circuits: on each hop, the circuit has a dedicated wire or slice of bandwidth.
  - Physical connection - clearly no need to include addresses with the data
- Advantages, relative to packet switching:
  - Implies guaranteed bandwidth, predictable performance
  - Simple switch design: only remembers connection information, no destination address look up
- Disadvantages:
  - Inefficient for bursty traffic (wastes bandwidth)
  - Delay associated with establishing a circuit
- Can we get the advantages without (all) the disadvantages?

Virtual Circuits

- Each wire carries many "virtual" circuits.
  - Forwarding based on virtual circuit (VC) identifier
  - A path through the network is determined for each VC when the VC is established
  - Use statistical multiplexing for efficiency
- Can support wide range of quality of service.
  - No guarantees: best effort service
  - Weak guarantees: delay < 300 msec, …
  - Strong guarantees: e.g. equivalent of physical circuit



Packet Switching and Virtual Circuits: Similarities

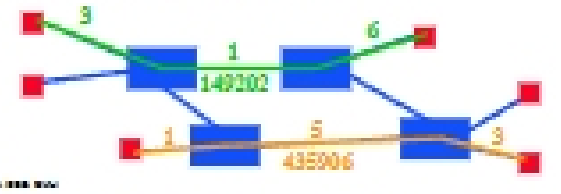
- "Store and forward" communication based on an address.
  - Address is either the destination address or a VC identifier
- Must have buffer space to temporarily store packets.
  - E.g. multiple packets for same destination arrive simultaneously
- Multiplexing on a link is similar to time sharing.
  - No reservations: multiplexing is statistical, i.e. packets are interleaved without a fixed pattern
  - Reservations: some flows are guaranteed to get a certain number of "slots"

Virtual Circuits Versus Packet Switching

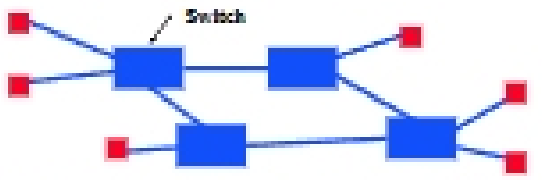
- Circuit switching:
  - Uses short connection identifiers to forward packets
  - Switches know about the connections so they can more easily implement features such as quality of service
  - Virtual circuits form basis for traffic engineering: VC identifies long-lived stream of data that can be scheduled
  - Requires "hard" state in the network
- Packet switching:
  - Use full destination addresses for forwarding packets
  - Can send data right away: no need to establish a connection first
  - Switches are "stateless": easier to recover from failures
    - Only have "soft" state
  - Adding QoS is hard
  - Traffic engineering is hard: too many packets!

How To Assign VC Ids?

- Easy solution: globally unique VC identifiers.
  - But very large number of VCs makes this inefficient
    - Requires large ids that have to be stored in header
    - Centralized assignment of ids to avoid conflicts
- Better solution: use ids that have only local significance for a link.
  - Smaller number of VCs on a link reduces the id space
  - Allows local selection of VC identifiers
  - But requires "VC id remapping"



VC Packet Forwarding



VC ID	Next Hop	Info
3	3	13
8	3	2
	0	-
	1	(2,34)

- Lookup based on VC identifier.
  - Short, fixed-sized ids.
  - Easier than MAC addresses (48 bits) or hierarchical IP addresses
- Next hop: output port for packet.
- Info: priority, VC id, ..
- Table is filled in by routing protocol.
  - Similar to IP, but applies to setup request only

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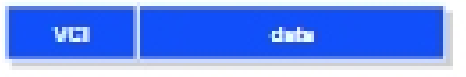
ATM History

- Telephone companies supported voice telephony: 4 kHz analog, 64 kbs digital.
- They provided lines for data networking.
  - ISDN: 64 kbps and faster channels
  - T1 (1.544 Mbps)
  - T3 (44.736 Mbps)
- They wanted to become the primary service provider for data networking services.
  - file transfer: bursty, many Mbps peak
  - database access: bursty, low latency
  - Multimedia: asynchronized
  - Video: 6 MHz analog, 1.2-200 Mbps digital
- How?

ATM

- Asynchronous Transfer Mode
  - Replace Synchronous Transfer Mode, which used slots in fixed frame structure (circuits)
- Instead of predefined TDM slots, tag each slot with a virtual connection ID.
  - Bandwidth can change dynamically

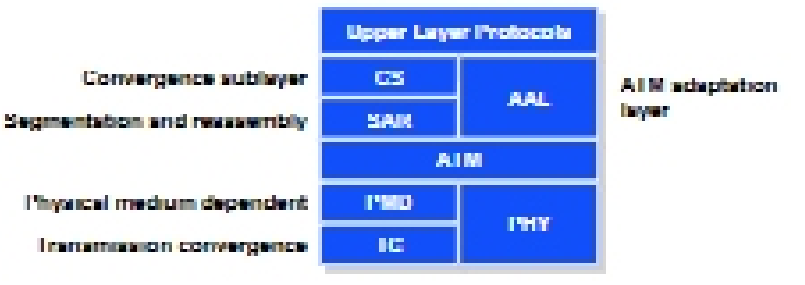


- Small packets allow good real time behavior.
- Fixed sized packets (cells) support fast switching

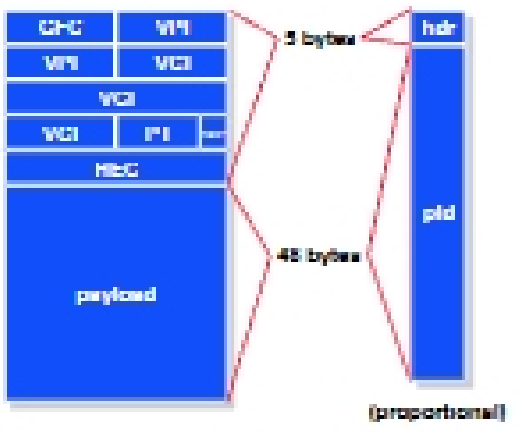
ATM Features

- Fixed size cells (53 bytes).
- Virtual circuit technology using hierarchical virtual circuits (VP,VC).
- Physical layer processing delineates cells by frame structure, cell header error check.
- Support for multiple traffic classes by adaptation layer.
  - E.g. voice channels, data traffic
- Elaborate signalling stack.
  - Backwards compatible with respect to the telephone standards
- Standards defined by ATM Forum.
  - Organization of manufacturers, providers, users

ATM Standard Protocol Layers



The ATM Cell (UNI)



Why 53 Bytes?

- Small cells favored by voice applications
  - delays of more than about 10 ms require echo cancellation
  - each payload byte consumes 125 µs (8000 samples/sec)
- Large cells favored by data applications
  - Five bytes of each cell are overhead
- France favored 32 bytes
  - 32 bytes = 4 ms
  - France is 3 ms wide
- USA, Australia favored 64 bytes
  - 64 bytes = 8 ms
  - USA is 16 ms wide
- Compromise