ATM and Label Switching

Outline
- ATM.
- IP over ATM.
- Label switching.

History
- Telephone companies supported voice telephony: 4 kHz analog, 64 kbps digital.
- They already provided lines for data networking.
  - ISDN: 64 + 64 + 16 kbps
  - 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: synchronized
  - Video: 6 MHz analog, 1.2-200 Mbps digital
- How?

One BISDN: STM
(Broadband Integrated Services Digital Network)
- Synchronous Transfer Mode
- Provide multirate frame structure:
  \[ iH_4 + jH_3 + kH_2 + lH_1 + mH_0 + nB + D \]
- e.g.

Problems
- complex channel assignment/subdivision
- poor support for bursty connections

More Flexible Solution: ATM
- Asynchronous Transfer Mode
  - 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).
- PHY (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 signaling stack.
  - Backwards compatible with respect to the telephone standards
- Standards defined by ATM Forum.
  - Organization of manufacturers, providers, users
ATM Standard Protocol Layers

Convergence sublayer
- CS
- SAR
- ATM

Segmentation and reassembly
- PMD
- PHY

Physical medium dependent
- TC

Transmission convergence

Upper Layer Protocols
- AAL
- ATM adaptation layer

ATM Cell (UNI)
- GFC
- VPI
- VCI
- PT
- HEC
- payload

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

Virtual Circuit Switching
- Signaling establishes mapping from (Port<sub>i</sub>, VCI<sub>i</sub>) to (Port<sub>j</sub>, VCI<sub>j</sub>) at each switch on path.
  - VCI remapping
  - Cells in a VC arrive in order.

Virtual Paths
- Virtual path is a bundle of virtual circuits.
  - VCs in a virtual path follow the same route
- Benefits:
  - route and rerouting at the virtual path level
  - fast connection set up
  - bandwidth management

Virtual Path Trunking
- Allows aggregated resource management and fault recovery.
ATM Adaptation Layers

- AAL 1: audio, uncompressed video
- AAL 2: compressed video
- AAL 3: long term connections
- AAL 4/5: data traffic

AAL3/4 Adaptation Layer (Telco)

- Includes length prediction
- Header
- Data
- Trailer
- ATM header
- SAR header
- Payload (44 bytes)
- SAR trailer
- Length, CRC

SEAL (AAL5) Adaptation Layer (computer mfr.)

- Includes EOF flag

AAL Relative Merits

- AAL3/4
  - Cell by cell data integrity promotes pipelined processing
  - Packet multiplexing within VC supported
  - Length prediction makes smart buffer allocation possible
- AAL5
  - 48 byte cell makes better use of bursts on host buses, e.g. 32+16 vs. 32+8+4
  - Cell processing simpler
  - CRC32 more robust (?)
  - Lost cell means lost packet – very significant

ATM Traffic Classes

- Constant Bit Rate (CBR) and Variable Bit Rate (VBR).
- Guaranteed traffic classes for different traffic types.
- Unspecified Bit Rate (UBR).
- Pure best effort with no help from the network
- Available Bit Rate (ABR).
- Best effort, but network provides support for congestion control and fairness
- Congestion control is based on explicit congestion notification
- Binary or multi-valued feedback
- Fairness is based on Max-Min Fair Sharing.
  (Small demands are satisfied, unsatisfied demands share equally)

UBR Challenges

- Cell loss results in packet loss.
  - Cell from middle of packet: lost packet
  - EOF cell: lost two packets
- Even low cell loss rate can result in high packet loss rate.
  - E.g. 0.2% cell loss > 2% packet loss
  - Disaster for TCP
- Solution: drop remainder of the packet, i.e. until EOF cell.
  - Helps a lot: dropping useless cells reduces bandwidth and lowers the chance of later cell drops
  - Slight violation of layers
**ABR: Max-Min Fair Sharing**

- Flows are divided in two groups:
  - Flows that are bottlenecked elsewhere
  - Flows that are bottlenecked here
- The max-min fair share rate $R_{\text{fair}}$ of a network link is defined such that:
  - Flows bottlenecked at the link have rate $r = R_{\text{min}}$
  - Flows bottlenecked elsewhere have rate $r$, where $r < R_{\text{fair}}$
  - $r$ is the max-min fair share rate of the bottleneck link
- Two implementations:
  - Multi-valued feedback: switch returns rate
  - Single bit feedback: use congestion bit in the header

**Max-Min Fair Sharing Example**

**Connections and Signaling**

- Permanent vs. switched virtual connections
  - static vs. dynamic
  - services often start with PVCs (Permanent Virtual Circuits)
- Call = bundle of connections, e.g. voice + video + data
- Topology
  - point to point
  - point to multipoint
  - multipoint to multipoint
- Signaling VCs
  - dedicated
  - reassigned, i.e. dynamically allocated

**Connection Setup**

**Q.SAAL: Signaling ATM Adaptation Layer**

**IP over ATM and SONET**

- Many options!
- IP over ATM, with signaling support.
- IP over ATM, using statically configured ATM pipes.
- IP over SONET (Packets over SONET).
- Differences in efficiency and flexibility in bandwidth management.
IP over ATM
- When sending IP packets over an ATM network, set up a VC to destination.
- ATM network can be end to end, or just a partial path
- ATM is just another link layer
- Virtual connections can be cached.
  - After a packet has been sent, the VC is maintained so that later packets can be forwarded immediately
  - VCs eventually times out
- Properties.
  - Overhead of setting up VCs (delay for first packet)
  - Complexity of managing a pool of VCs
  - Flexible bandwidth management
  - Can use ATM QoS support for individual connections (with appropriate signaling support)

LAN Emulation
- Motivation:
  - support many protocols
  - reuse software interfaces
- Chosen: IEEE 802.x, (specifically Ethernet, token ring)
- Issues
  - MAC - ATM mapping
  - multicast and broadcast
  - VC lifetime
  - bridging
  - ARP

ATM ARP
- ARP server with well-known address (or PVC) - one per logical subnet.
- Hosts communicate with ARP server directly instead of using broadcasting
- IP hosts register.
- Requests for IP-ATM bindings are sent to server.
- IP-ATM bindings are time out.
- “Classical IP”

IP over ATM (2)
- Establish a set of “ATM pipes” that defines connectivity between routers.
- Routers simply forward packets through the pipes.
  - Each statically configured VC looks like a link
- Properties.
  - Some ATM benefits are lost (per flow QoS)
  - Flexible but static bandwidth management
  - No set up overheads

Packets over SONET
- Same as statically configured ATM pipes, but pipes are SONET channels.
- Properties.
  - Bandwidth management is much less flexible
  - Much lower transmission overhead (no ATM headers)

ATM Discussion
- At one point, ATM was viewed as a replacement for IP.
  - Could carry both traditional telephone traffic (CBR circuits) and other traffic (data, VBR)
  - Better than IP, since it supports QoS
- Complex technology.
  - Switching core is fairly simple, but
  - Support for different traffic classes
  - Signaling software is very complex
  - Technology did not match people’s experience with IP
  - deploying ATM in LAN is complex (e.g. broadcast)
    - supporting connection-less service model on connection-based technology
  - With IP over ATM, a lot of functionality is replicated
    - Currently used as a datalink layer supporting IP.
IP Switching

- How to use ATM hardware without the software.
- ATM switches are very fast data switches.
- Software adds overhead, cost.
- The idea is to identify flows at the IP level and to create specific VCs to support these flows.
- Flows are identified on the fly by monitoring traffic.
- Flow classification can use addresses, protocol types, ...
- Can distinguish based on destination, protocol, QoS.
- Once established, data belonging to the flow bypasses level 3 routing.
- Never leaves the ATM switches.
- Interoperates fine with “regular” IP routers.
- Detects and collaborates with neighboring IP switches.

IP Switching Example

IP Switching Example

IP Switching Example

IP Switching Discussion

- IP switching selectively optimizes the forwarding of specific flows.
- Offloads work from the IP router, so for a given size router, a less powerful forwarding engine can be used.
- Each data unit carries two addresses: IP and fast path.
- Can fall back on traditional IP forwarding if there are failures.
- IP switching couples a router with an ATM switching using the GSMP protocol.
- General Switch Management Protocol.
- IP switching can be used for flows with different granularity.
- Flows belonging to an application / Organization.
- Controlled by the classifier.
- Introduces a notion of flows/connections in IP.

An Alternative: Tag Switching

- Instead of monitoring traffic to identify flows to optimize, use routing information to guide the creation of “switched” paths.
- Switched paths are set up as a side effect of filling in forwarding tables.
- Generalize to other types of hardware.
- Also introduced stackable tags.
- Made it possible to temporarily merge flows and to demultiplex them without doing an IP route lookup.
- Requires variable size field for tag.
IP Switching versus Tag Switching

- Flows versus routes.
- Tags explicitly cover groups of routes.
- Tag bindings set up as part of route establishment.
- Flows in IP switching are driven by traffic and detected by "filters."
  - Supports both fine grain application flows and coarser grain flow groups.
- Stackable tags.
  - Provides more flexibility.
  - Generality.
  - IP switching focuses on ATM.
  - Not clear that this is a fundamental difference.

Multi-Protocol Label Switching (MPLS)

- Map packet onto Forward Equivalence Class (FEC) based on its header.
  - Simple case: longest prefix match of destination address.
  - More complex if QoS of policy routing is used.
- In MPLS, a label is associated with the packet when it enters the network and forwarding is based on the label in the network core.
  - Label is swapped (as ATM VCIs).
- Potential advantages.
  - Packet forwarding can be faster.
  - Routing can be based on ingress router and port.
  - Can use more complex routing decisions.
  - Can force packets to follow a pinned route.

MPLS Mechanisms

- Implementation of the label is technology specific.
- Could be ATM VCI or an extra header.
- Label Distribution Protocols distribute information on label/FEC bindings.
  - Extensions of existing protocols (routing, RSVP) or stand-alone protocols.
  - Can be upstream or downstream.
  - Supports stacked labels.