Broadband Integrated Services Digital Networks (B-ISDN) and ATM Networking

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Outline

- Introduction to the evolution of B-ISDN
- Transfer modes
- B-ISDN reference model
- The physical layer
- The ATM layer
- The ATM adaptation layer
- Broadband ATM switching
- Traffic control in ATM networks
- Conclusions
**Introduction to the evolution of B-ISDN**

- Traditional networks have been designed and optimized for a single application (e.g., voice, video, data, telegraph)
- A large number of services have emerged, e.g., HDTV, video conferencing, medical imaging, distant learning, video on demand, electronic commerce, etc.
- It is more economical and cost effective to serve all these applications by one network
- This trend is facilitated by the evolution in the semiconductor, optical technologies, and the shifting transport functions to network periphery, which reduced cost of services
The (narrowband) Integrated Services Digital Network (ISDN) was one step in this direction:

- integrated voice & data services

Problems:

- limited maximum bandwidth (2 Mbits/sec max)
- based on circuit switching (64 Kbits/sec)
- advances in data compression are not directly supported by (N)ISDN switches
The Broadband ISDN (B-ISDN) overcame the problems of the N-ISDN by providing:

- **service independence**: the network implementation is not based on a certain network platform
- **flexibility**: adaptability to varying bit rates (new applications, or new compression algorithms)
- **efficiency**: the resources can be used & shared by all applications
- **semantic transparency**: the data is delivered error free from end-to-end
- **time transparency**: satisfy the delay and jitter requirements of all applications

**Range of Services Expected in B-ISDN:**
• Services differ in their traffic characteristics:
  - average rate
  - burstiness (peak rate/average rate)
  - tolerance to discarding & loss
**Transfer Modes:**

- A transfer mode is a technique which is used in a telecommunication network covering aspects related to transmission, multiplexing and switching.
- A transfer mode should provide flexibility & adaptability to varying bit rates.

- Since B-ISDN required flexibility, but at the same time must employ network wide lightweight protocols,
  
  \[ \therefore \text{ modes near the middle of the spectrum were a good compromise} \]
Operational Characteristics:

- No error protection inside the network (handled by higher layers)
- No flow control on a link-by-link basis
- Connection-oriented mode:
  - Quality of Service (QOS) guarantees
  - Lightweight routing decisions
- Reduced header functionality (mainly routing):
  - fast processing & high throughputs
- The information field is relatively small:
  - high degree of pipelining (emulation of cut-through)
  - small delay & delay jitter
Performance Characteristics:

(1) Time transparency:

Dependent on the propagation delay, packetization delay, switching delay and queuing delay

(2) Semantic transparency:

Inside the network, only header errors are handled (necessary for routing):

- Single errors are corrected
- Error bursts are not corrected

∴ Header must have an independent checksum
Variable versus Fixed Length Packets

**Variable Length**  
**Fixed Length**

*Efficiency:*  
Higher  
slightly lower
### Switching speed:

<table>
<thead>
<tr>
<th></th>
<th>Variable time availability ((&gt;=533) ns)</th>
<th>Constant time (2.8(\mu)sec@ 150Mb/s)</th>
</tr>
</thead>
</table>

### Queue memory dimensioning & management:

|          | More complex                             | Simpler                                  |

### Conclusion:

Fixed length packets are better suited for high-speed operation:

**Asynchronous Transfer Mode (ATM)**
ATM Cell (Packet) Size:

- Long cells lead to echo in voice communications
- Long cells lead to more time availability for processing, but requires more memory

**Conclusion:**

cell size = 48 byte data + 5 byte header = 53 bytes
**Header Functionality:**

- **Virtual connections:**
  - Designation of route from source to destination
  - Reservation of resources on route

- **Virtual path:**
  - A concept in which Virtual Connections that traverse the same route are grouped together in a semi-permanent connection
- Virtual paths simplify admission control:

  *Check resources in VP's instead of on all nodes on the path*

- Cell loss priority:
  
  lower priority to cells which may be discarded during congestion

- Payload type: data or resource management

- Cell header protection
The B-ISDN Reference Model

- **Management Plane**
- **Control Plane**
- **User Plane**

**Higher Layers**
- (end-to-end protocols)

**ATM Adaptation Layer**
- (service dependent)

**ATM Layer**
- (common to all services)

**Physical (Transmission) Layer**

- **Transport**
- **Service**
  - call control
  - Higher layers
    - LAP-D

**B-ISDN & ATM Networking**

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3 Planes:
- User plane: user information flow & control
- Control plane: connections & signaling
- Management plane:
  - Plane management: coordination between planes
  - Layer management: operations and maintenance of layers
- In each plane, a layered approach is employed:
  - Each layer may be further subdivided into sub-layers
**Physical (Transmission) Layer:**

- Transformation between packets & bits:
  - embedding packets in SONET frames
  - scrambling & de-scrambling
- Transmission of bits on transmission medium:
  - bit timing & alignment
  - coding
  - E/O and O/E conversion
- Possible transmission systems:
  (1) SONET: STS-3c (155 Mbps) (an STS-12 @ 620Mbps is also recommended)
(2) Cell based interface:
   - Cells are transported continuously without framing

(3) FDDI: 100 Mbps
The Asynchronous Transfer Mode (ATM) Layer

- The layer responsible for switching, multiplexing & transporting data:
  parts of functions in layers 1 & 2 in OSI model
- Connection-oriented and guarantees cell sequence integrity, and QOS through reservation of resources
- Uses fixed length packets (cells):
- VPI & VCI: Virtual Path & Virtual Circuit Identifiers
- Payload Type: data/resource management
  Congestion indication
  End of Message (EOM)
- Cell Loss Priority: 1 for higher loss priority
- CRC: Head Error Check
Virtual Path Switching

- At a VP switch, VCI's are not translated: only VPI's

![Diagram of VP Switching](image-url)
**Virtual Circuit Switching:**

- Occurs at VP terminating points: combined VP & VC switches
- Requires translation of both VCI's and VPI's
The ATM Adaptation Layer

- Adapts different services to the ATM layer:
- Performs common functions:
  - Segmentation & reassembly; boundary flagging
- Performs service specific functions:
  - Error checking; control of packetization delay; synchronization & timing information
- Supports four classes of applications:
### Four AAL protocols:

1. **AAL 1 for class A (Constant Bit Rate):**
   - Transfer of data units at a constant bit rate
   - Delivery of timing information (source clock recovery)
   - Handling of cell delay variation
   - Correction of cell losses & bit errors

<table>
<thead>
<tr>
<th>Class</th>
<th>Rate</th>
<th>Synchronization</th>
<th>Connection Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A</td>
<td>Constant</td>
<td>YES</td>
<td>Connection-oriented</td>
</tr>
<tr>
<td>Class B</td>
<td>Variable</td>
<td>NO</td>
<td>Connection-orientless</td>
</tr>
<tr>
<td>Class C</td>
<td>Variable</td>
<td>NO</td>
<td>Connection-orientless</td>
</tr>
<tr>
<td>Class D</td>
<td>Variable</td>
<td>NO</td>
<td>Connection-less</td>
</tr>
</tbody>
</table>
2. AAL 2 for class B (Variable Bit Rate):
   - Delivers timing information for variable length frames

3. AAL 3/4 for classes C&D (merger of types 3 & 4):
4. AAL 5 for class C (can also be used for class D):

- Uses the EOM bit in the PTI in the cell header
Broadband ATM Switching:

- The Synchronous Transfer Mode (STM) switching architectures are not directly applicable to broadband ATM:
  - The statistical behavior of ATM streams
  - The use of small cells

- The high-speed switches should allow cells on any of $N$ inlets to be routed to any of $M$ outlets (logical channel flow):
• Each logical channel is identified by:
  - A physical inlet/outlet
  - A logical channel (VCI and VPI)

• Requirements:
  - support for a large number of information rates
  - broadcast/multicast support
  - large throughput, low switching delay & delay jitter
  - low probability of cell losses

• Multistage interconnection networks are well suited
ATM Switch Building Blocks

Input Queues

Switching Fabric

Output Queues
• Output queues are used to hold cells destined to the same output port & cannot be served simultaneously

• Input queues are used to hold cells arriving at the same input port & cannot be routed simultaneously

• Switching fabric routes cells from input to output ports:
  - Should be non-blocking
  i. e., cells going to different output ports should be delivered
Input Queuing

.: Head Of the Line (HOL) blocking
Output Queuing

Input

Output

PORT #

1

1

∴ Better performance
The graph illustrates the relationship between queue size and output queue size for different input queue sizes. The curves represent the input queue and output queue at various percentages of the input queue size.

The x-axis represents the percentage of the input queue size, ranging from 0% to 100%. The y-axis represents the queue size, which increases with the percentage of the input queue size.

- The upper curve represents the input queue size.
- The lower curve represents the output queue size.

As the percentage of the input queue size increases, both the input and output queue sizes increase, with the output queue size being generally smaller than the input queue size.
The Switching Fabric:

- Should be internally non-blocking

Cell from 3 to 1 is blocked by bottl
Techniques for internal non-blocking:
- Replication of switching fabric
- Crossbar switching
- Sorting according to output port number before switching:

\[ \text{if cells are sorted in ascending order by output port} \ # \]
\[ \therefore \text{no internal blocking} \quad \textbf{Example:} \quad \text{Batcher-Banyan (multistage network)} \]
**ATM Switch Fabric Examples**

*The Knockout Switch:*
- Output buffering
- Crossbar switching
- Knockout strategy for input concentration

*The Gauss Switch:*
- Similar to Knockout switch but simpler
- Switching fabric uses a high-speed slotted bus

*The Starlite Switch:*
- Uses a Batcher-Banyan approach
- Implemented using $2\times2$ switching elements as building blocks
Traffic Control in ATM Networks

• Role:
  To protect the network & the user in order to achieve predefined network objectives (loss, delay, etc)

• Objectives:
  - Flexibility in supporting different QOS
  - Simplicity in designing ATM traffic control
  - Fast responsiveness to changes in traffic conditions
  - Robustness to different traffic conditions
Control functions:

1. *Call Admission Control* (CAC):
2. *Usage Parameter Control* (UPC)
3. *Flow Control*
Call Admission Control:

• Call setup phase to accept or reject a call subject to resource availability for QOS satisfaction

• Requires the description of the source traffic:
  - peak rate
  - mean rate

• Subject to negotiation & renegotiation between the source & the network
Usage Parameter Control:

- Performed at UNI
- Set of actions taken by the network to monitor the user traffic & enforce the admission contract (policing)
- The Generic Cell Rate Algorithm (GCRA) is a standard UPC algorithm that detects conformance to traffic contract
• Continuous-state version of the Leaky Bucket:

ARRIVALS

MAX. LEVEL L

CURRENT LEVEL X

LEAKAGE AT RATE 1 UNIT/TIME UNITS
- Let time of cell arrival is $T_a$ & last conformance time is $T_c$

  if $X - (T_a - T_c) < L$ then
  
  the cell will be accepted & $X = X - (T_a - T_c) + 1$

  else
  
  discard the cell

  \[ \therefore \text{ supports a certain Sustained Cell Rate (1/time unit) & limits the maximum burst size (function of } L) \]

- cells that violate the contract are discarded or marked

- GCRA can also be used to limit the Peak Cell Rate (PCR)
Flow Control:

- Defined for Available Bit Rate (ABR) services:
  
  services with vague requirements for throughput and delay, but may have sharply defined cell loss

- End-to-end control

- Rate-based:
  
  - Each source transmits @ rates between Minimum Cell Rate (MCR) & Peak Cell Rate (PCR)
  
  - The current rate is the Allowed Cell Rate (ACR)
  
  - Every N data cells, the source sends a Resource Management (RM) cell to the destination indicating:
* MCR and a requested *Explicit Cell Rate* (ECR)

* Congestion Indication bit (CI) = 0

- Switches (& destination) on the route may modify ECR & CI

- The destination returns back the RM cell to the source

- The source when it receives the RM cell:
  * If there is no congestion, then increments ACR
  * If there is congestion, then decrement ACR
  * Set ACR to the max (min (ACR, ECR), MCR)
ATM LANs:

- Local and Metropolitan Area Networks are used in business, industrial and educational environments to interconnect computers, terminals, printers, etc
- Standard LANs use the shared medium approach:
  - IEEE 802.3 CSMA/CD
  - IEEE 802.5 Token Ring
- Standard LANs are limited in distance and bit rates
- High-speed LANs are needed to accommodate an increasing demand for bit rates
- The ATM switching approach can be used in the LAN environment:
  - High-speed operation (scalable)
  - Low delay (no MAC layer)
  - Easy interface to public ATM networks  - More security
A number of ATM LAN switches exist:

- AN2 (DEC)
- FALCON (IBM)

Proprietary switching & multiplexing designs

ATM Forum is concerned with defining ATM LANs:

- Physical layer:
  * DS3 @44 Mb/s
  * 100 Mb/s on multimode fibre (FDDI)
  * 155 Mb/s on STS-3c
  * 155 Mb/s on multimode fibre
- AAL: type 5 for signalling & data
  types 1 & 2 for voice and video applications
- Signalling: based on Q.93B and allow:
  * point-to-point connections

  ![Diagram of point-to-point connections]

  * point-to-multipoint connections

  ![Diagram of point-to-multipoint connections]

  * multipoint-to-point

  ![Diagram of multipoint-to-point connections]
**ATM LAN Emulation:**

- A solution to the existing large base of legacy networks (Ethernets, FDDIs, etc):
  - The ATM Forum's L-UNI defines how Ethernets or token rings can connect to their counterparts over ATM networks
  - An ATM network looks like a legacy LAN
- The ATM network emulates the connectionless service of the LAN
- LAN Emulation Client
- LAN Emulation, Configuration & Broadcast servers

Works as a client server model:
Conclusions

- B-ISDN is a concept by which one network can support all current and future services
- It is flexible & future safe
- The B-ISDN layers are lightweight layers, therefore providing high speed and high throughput
- The ATM is the transport service provider in B-ISDN
- ATM switches have been implemented and deployed
- The ITU is the standard body concerned with ATM:

  http://www.itu.org for B-ISDN & ATM standards

  http://www.atmforum.com/ The ATM Forum