# Chapter 4
# Subnetwork Technology

Yu-Chen Kuo

- analyze how well different networking technologies satisfy the requirements of distributed multimedia applications
- use yardstick to evaluate different network technologies

# 4.1 Networking Requirements of Multimedia Applications

- Throughput
  - compressed video data to reduce bandwidth
    - MPEG (I/II)

      1.2 ~80Mbps
    - H.261

      64k~2Mbps

  ⇨ throughput at least 0.4 ~1.4Mbps for simplex

- End-to-End delay
  - Round-trip delay around 0.6 sec. will make people difficult to have normal conversation

    ⇨ below 0.3 seconds is more desired

    ITU standards suggest 150 milliseconds

    – Source compression and packetization delay to handle 25 to 30 frames/s video streams

    → compression not exceed 30 to 40 ms

– Network delay (access, transmission, transit) long distance LAN-WAN-LAN topology forwarding delay not exceed 10~15ms/hop

– End-system queuing and playout delay

– Sink decompression, depacketization, output delay

- class of synchronous communication
  - Asynchronous : unrestricted transmission delay
  - Synchronous : bounded transmission delay for each message
  - Isochronous: constant transmission delay for each message

⇨ could be accomplished by using a very low delay bound asynchronous communication with **playout buffer**

- Multipoint Communication
- Reliability
  - checksum, sequence numbering for error control
    - ⇨ done by hardware at MAC or link layer
- acknowledgment and retransmission for error recovery
    - ⇨ add round-trip delay

- subnetwork should provide proper error control and recovery to higher layers taking delay into account
- Forward error correction (FEC) in Chap. 5

- Channel Synchronization

  video and audio from different channels via different routers

  synchronize the different streams

    - presentation time stamp
    - playout buffer ( overcome the different delay )

# 4.2 Networking Technologies

- Relevant Parameters (as a yardstick)
  - Throughput : at least 1.4 Mbps /each direction
  - Transmission delay : a maximum of 10~15ms
  - Multipoint communication: available broadcasting or multicasting

- Reliability: error control or recovery

LAN : support hardware

checksum and drop

corrupted frames

WAN: more difficult, multicast

reliability

- Ethernet (Fig. 4.5)
  - CSMA/CD

    (Carrier Sense Multiple Access with Collision Detection)
  - 10Mbps, 5~6Mbps while keeping collision at an acceptable level

    ⇨ no more than 4 parallel compressed video streams

- max frame size 1518 bytes
- max physical length 2500m
- nondeterministic behavior no control for access delay or availability bandwidth
- not give preferred treatment to real-time traffic or fair bandwidth distribution
- missing delay guarantees
- Ethernet adapter can manager multicast addresses
- Evaluation

  perfectly suitable for experimental multimedia applications

- 100 Base-T (Fast Ethernet)
  - extended from Ethernet
  - use the same CSMA/CD protocol as Ethernet
  - frame-compatible with Ethernet
    - multicast
    - missing delay guarantees
  - configurable frame size
  - utilization from 50%~90% depending on frame size
  - drawback : max physical length 250
  - Evaluation

- Isochronous Ethernet (Iso-Ethernet)
  - IEEE 802.9a Integrated Voice Data LAN (IVD LAN)
  - provide 802-like MAC service with ISDN-like isochronous channel on UTP(unshielded twisted pair)
  - keeping regular 10Mbps bandwidth unchanged but adding another channel for isochronous communications

- 96 B-channels (64Kbps) + D-channel for signaling and management B-channel (like ISDN circuit-switch)

  Fig. 21.11

  - A given station may establish a number of 64Kbpscircuits (128Kbps or 384Kbps) to any other station.
  - Evaluation

- Token Ring (Fig. 4.6)
  - much better suited than Ethernet for supporting multimedia
  - 16Mbps bandwidth
  - MAC level priority

  ⇨ separate real-time data (high priority) and normal data
  - Access Control to avoid overcommitment
    - token — token priority
      — reserved priority

- message — message priority

  message priority >=token priority ⇨ sending

- access delays consideration for 1.4Mbps video stream
  - packet size

    large packet →

    low system overhead, increase packetization delay

4-Kbyte packet in a 1.4Mbps video → 24 ms≅30ms

- Packet transmission time :

  4Kbyte/ 16Mbps≅2ms

- Token forwarding time: 100us (negligible)

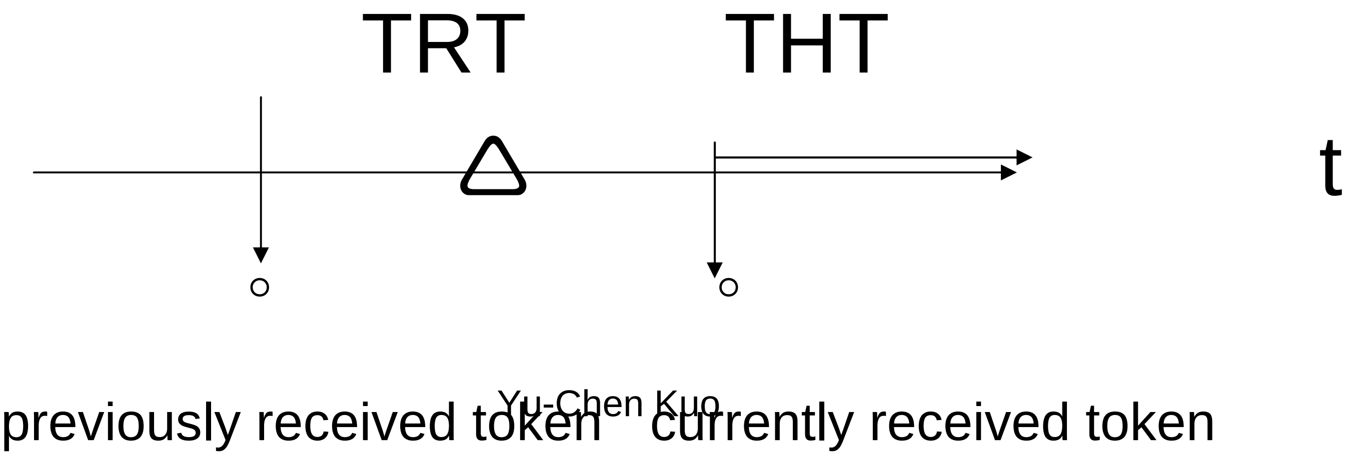
- Max Access Delay:

  when to transmit a large, low-priority packet with 8 waiting stations, 8*2ms ≅ 16ms

- Multicast address (similar to Ethernet)
- Evaluation

- Demand Priority
  - IEEE 802.12, 100Base-VGAnyLAN over VG cableing (four wires)
  - Access Protocol: Fig. 4-1
  - two-level priority
  - supports both Ethernet and Token Ring frames
  - multicast mechanism is available
  - Evaluation

- FDDI
  - a time token protocol
  - TRT (Token Rotation Time): reset when receives token
  - THT (Token Holding Timer): THT=TRT when receives
  - TTRT (Target Token Rotation Time) :a predefine constant



- send message when THT <=TTHT

  THT=THT+message transmission time

  See Fig. 4-2
- support synchronous transmission with TTRT/n interval

  See Fig. 4-3

  ⇨ token rotation time becomes 2*TTRT
- Evaluation

- FDDI-II
  - slotted ring protocol (8kHz) to better support real-time traffic
  - 100Mbps splitted up to 16 isochronous 6.144Mbps WBC and asynchronous bandwidth (dynamic)
  - Each WBC (wide-band channel) contains 96 isochronous 64Kbps B-channels (similar to in Iso-Ethernet and ISDN)
  - a backbone network for Iso-Ethernet
  - only partially compatibility with original FDDI
  - Evaluation

- X.25 Packet-Switching
  - connection-oriented telecommunication service in 1970
  - reliable data transport over lower-speed, unreliable link
  - up to 2Mbps
  - network regulates end-to-end flow control (speed match)

- sliding window-based flow control (store frames )

⇨ handle error detection and recovery (ack.)

- no congestion control and network utilization control
- unpredictable delay
- Evaluation

- Packet switch vs. circuit switch
  - packet switch
    - chop data stream into small units (packets)
    - several data streams can transmit over a physical wire
    - post office system
    - efficient multiplexing

- drawback: statistical behavior (unpredictable)
  - bit rate not easily guaranteed
  - transit delay may vary
- Example: Ethernet, Token Ring, FDDI, X.25

- circuit switch
  - reserve a path of physical wires between two end-system
  - the wires are not shared even nothing to transmit
  - data stream is sent as a continuous stream of bits (FIFO)

- usually need setup connection and allocation bandwidth
- bit rate will be guaranteed during the connection period (modem)
- inefficient multiplexing
- Example: telephone network, ISDN

- Connection oriented vs. Connectionless
  - connection oriented
    - setup connection before starting to exchange data
    - network is aware of communications between two systems
    - easily to make sure performance
    - Example: TCP

– connectionless
  - two end-systems transmit without any caution (connection)
  - network will not aware of each independent packet
  - reduce transit overhead → improve network utilization
  - Example: IP, UDP

- IP Packet-Switching Networks
  - most popular layer 3 protocol
  - IP packet can traverses over LAN, X.25, ..., subnetwork Fig. 22.2
  - connectless protocol, datagrams, unreliable (loss)
  - best-effort packet delivery services ( no resource reserved)

- store-and-forward transmission
  - → different paths packets may through different paths
  - → variable transit delays, out of order
- IP next generation (IPng, IPv6) flow concept
  - → software connection mode
  - → identify high-priority real-time packets

- multicast support, not all routers implement them

| 1 | 1 | 1 | 0 | group ID |
|---|---|---|---|---|

32bits

class D address

- Mbone (multicast backbone) Fig. 22.8
- IGMP manages multicast address groups
- Evaluation

- ISDN (Integrated Services Digital Network)
  - circuit-switch
  - synchronous
  - 64Kbps channels
    - BRI (Basic Rate Interface)

      2B1D (B-channel : 64Kbps for data

      D-channel: 16Kbps for control message)
    - PRI (Primary Rate Interface)

      24B1D (US)

      30B1D (Europe)

- packetization delay in LAN/WAN
  Table 4-1 (delay not exceed 30ms)

- advantages
  - wide availability (Europe)
  - bandwidth scalability, in steps of 64Kbps
  - Isochronous
  - support for CBO as well as packetized traffic

- point-to-point communication, not support multicast unless MCU (multicast Control Units)
  - Each station in conference session builds a connection to MCU
  - MCU mixes all incoming audio channels and distributed to all stations
    (★ video can‘t be mixed)
- Evaluation

- ATM
  - cell-based multiplexing and switching (B-ISDN)
  - protocol stack

    Fig. 4-5
  - physical layer

    Table 4-2

- ATM layer
  - switching and multiplexing layer
  - cell: 53 bytes (5 bytes: cell header; 48bytes: payload)
  - low latency, reduce segmentation
  - connection-oriented (label swapping)
    - VCI (virtual circuit identifier)
    - VPI (virtual path identifier)
    - VCI/VPI cell address

- ATM Adaptation Layer (AAL)
  - bridge the gap between AP and cell-oriented service
  - ATM service classes, Table 4-3
  - Class A for CBT synchronous stream
  - Class B for VBT audio/video stream
  - Class C for data communication (ftp, telent)
  - Class D for data communication (query info. SNMP)

- AAL 1 for class A
  - convert CBT into cell-based traffic
  - packetization/depacketization
- AAL 2 for class B
  - difficult (VBT)
  - reserve peak bandwidth (not efficient)
  - delay, loss if not

- AAL 3/4 for class C and D
  - provide message interleaving (MID) over same VC
  - Payload: 44 bytes/cell
- AAL 5 for class C and D
  - not provide message interleaving
  - better utilization of available bandwidth ( reduce cell header and CRC: per message)
    Payload: 48 bytes /cell
  - toward to support synchronization of MPEG-II and MPEG-II transport stream

- Traffic Management
  - ATM traffic description
    - PCR: peak cell rate
    - SCR: substainable cell rate
    - MBS: max burst size (cell)
    - MCR: min cell rate
    - user specify
    - discard nonconforming cells
  - QoS specification
    - CLR: cell loss ratio
    - CTD: cell transfer delay
    - CDV: cell delay variation

- ATM traffic classes
  - CBR :
    continuous bit rate traffic with fixed delay and cell rate for synchronous services
  - Real-time VBR:
    variable bit rate traffic for compressed audio and video with CDV specified
  - Non-real-time VBR:
    without CDV specified

- ABR:
  available bit rate for data communication with negligible cell loss
- UBR:
  unspecified bit rate for traffic without known characteristic

- IP-switching
  - IPv6 (label switching like ATM)
  - IPSC (IP switching controller)
  - flow -oriented scheme
  - See Fig. 4-7

- Summary of network characteristics
  - CBO support: Iso-Ethernet, FDDI-II, ISDN ATM (AAL1)
  - packetized multimedia: Token ring, FDDI, ISDN, demand priority, ATM (AAL 3/4, 5) IP-Switching
  - See Table 4-5

# ❑4.3 Networking Infrastructure Evolution

- The gap between LAN/WAN
  See Fig. 4-8
  - new networking technologies
    - cabling
    - end-system and adapters
    - switching and interconnection units

– network management and operation
– exiting networked services and applications

- WAN evolution
  – packet switched data networks based on X.25, Frames Relay
  – public telephone infrastructure for telephone, fax, ISDN
  – Higher speed lines for PBX connection
  – Cable TV networks

- Satellite distribution networks
- ATM HFC

  Fig. 4-9
- HDSL (high bit-rate digital subscriber line)
- ADSL (asymmetric digital subscriber line)
- ATM WAN backbone

- LAN topology evolution
  - linear topology LAN
    - moving system requires rewiring and interrupted when adding new connection
  - star-wired LAN
    - HUB
  - multisegment LAN
    - bridge and router to interconnect LANS
    - intelligent hub

– backbone-connected LAN
  - hierarchical network structure
  - shared resources are located on backbone
  - workgroup communication is kept on LAN

– LAN switching

- learning transparent bridge
- switching on MAC address
- address table on each port (filter and forward)
- Figure 4-11
- full duplex mode: 16ports $\rightarrow$ 8$\times$10Mbps
- provide high bandwidth but not manage bandwidth

- Integration of ATM into LAN infrastructure
  - ATM dominates future network technology
  - how ATM can support existing protocols and Aps
  - to interoperate with existing networks

- Classical IP over ATM(connectionless to connection-oriented)
  - RFC 1577
  - mapping ATM (VPI/VCI) to IP (140.XXX.XX.X)
  - implement ARP (address resolution protocol) over ATM

    IP ↔ ARP server (physical address)

    broadcast (LAN)

    unicast (ATM)

– establish and terminate of ATM connection(VCs) between two IP end-systems
– multiplexing different protocols over the same ATM VC providing protocol identification in IP packets

- connection management
  - CBR, VBR, ABR traffic not specified
  - transparent above IP layer
  - suitable for multimedia when bandwidth is abundant and traffic management is not needed
  - solved (improved) in IPv6

- IP multicast over ATM
  - not available with RFC 1557 even ATM supports point-to-multipoint
  - IP multicast router maintaining point-to-multicast VC for every multicast group (IGMP)
    - local multicast packets has to travel one extra hop
    - multicast router may become a bottleneck  Fig. 4-12

- general solution
  - direct mesh configuration
    - ARP-Server & MARS

      mapping IP ↔ ATM address
    - client management multicast VCs Fig. 4-13
  - multicast server configuration
    - MCS to management multicast VCs

      Fig. 4-14

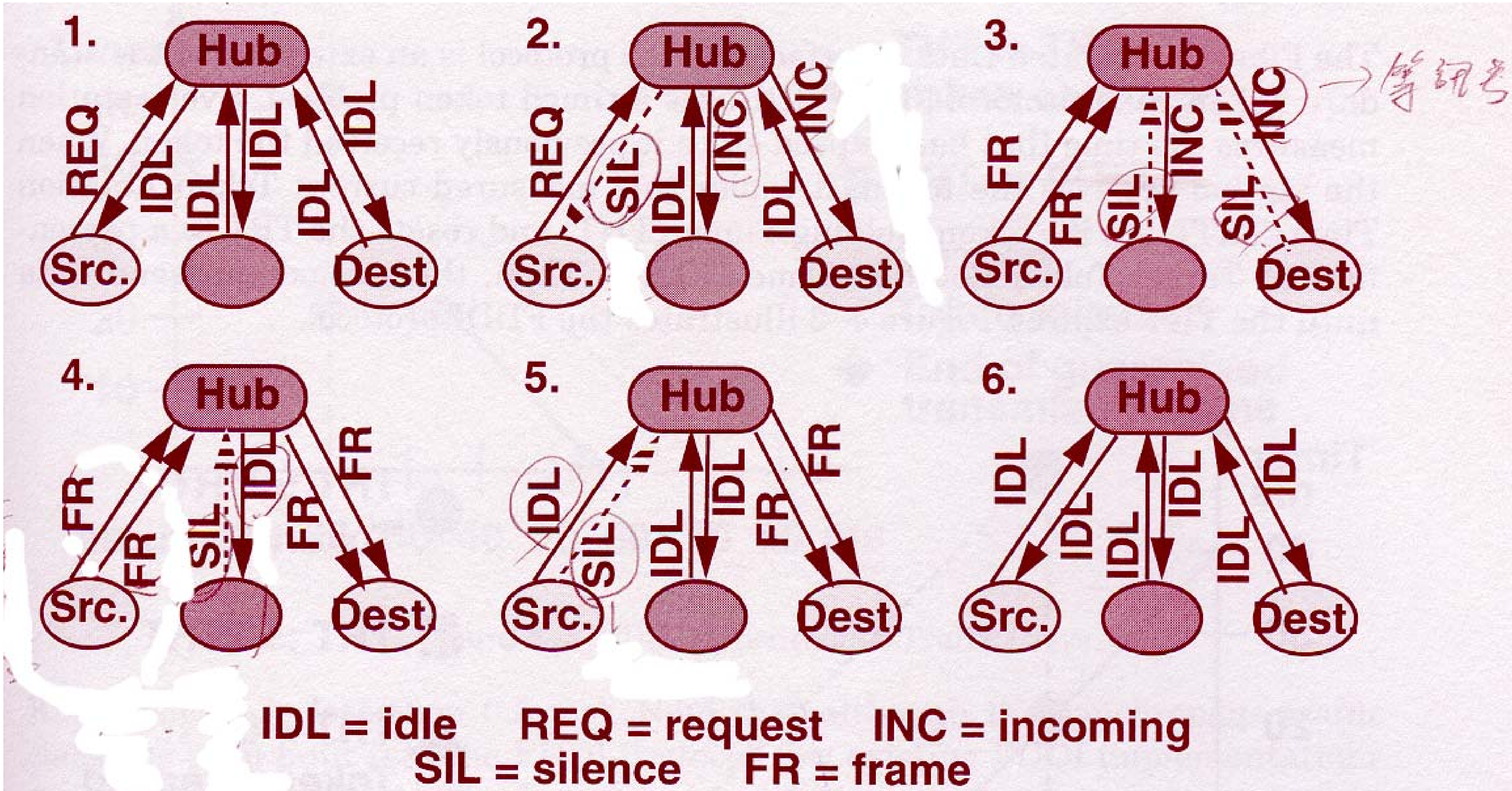



**Figure 4–1** Demand Priority Access Protocol

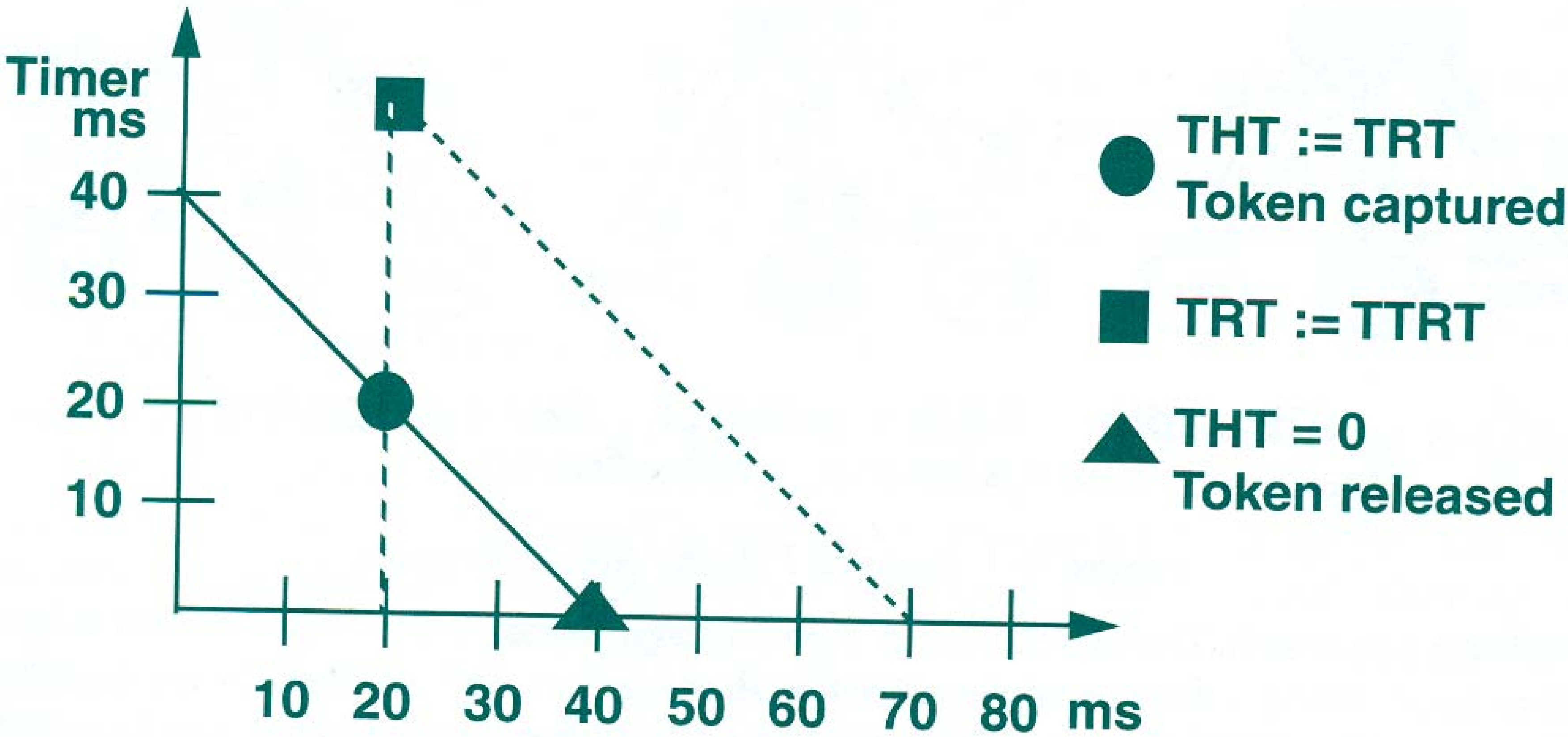



**Figure 4–2** FDDI Timed Token Protocol

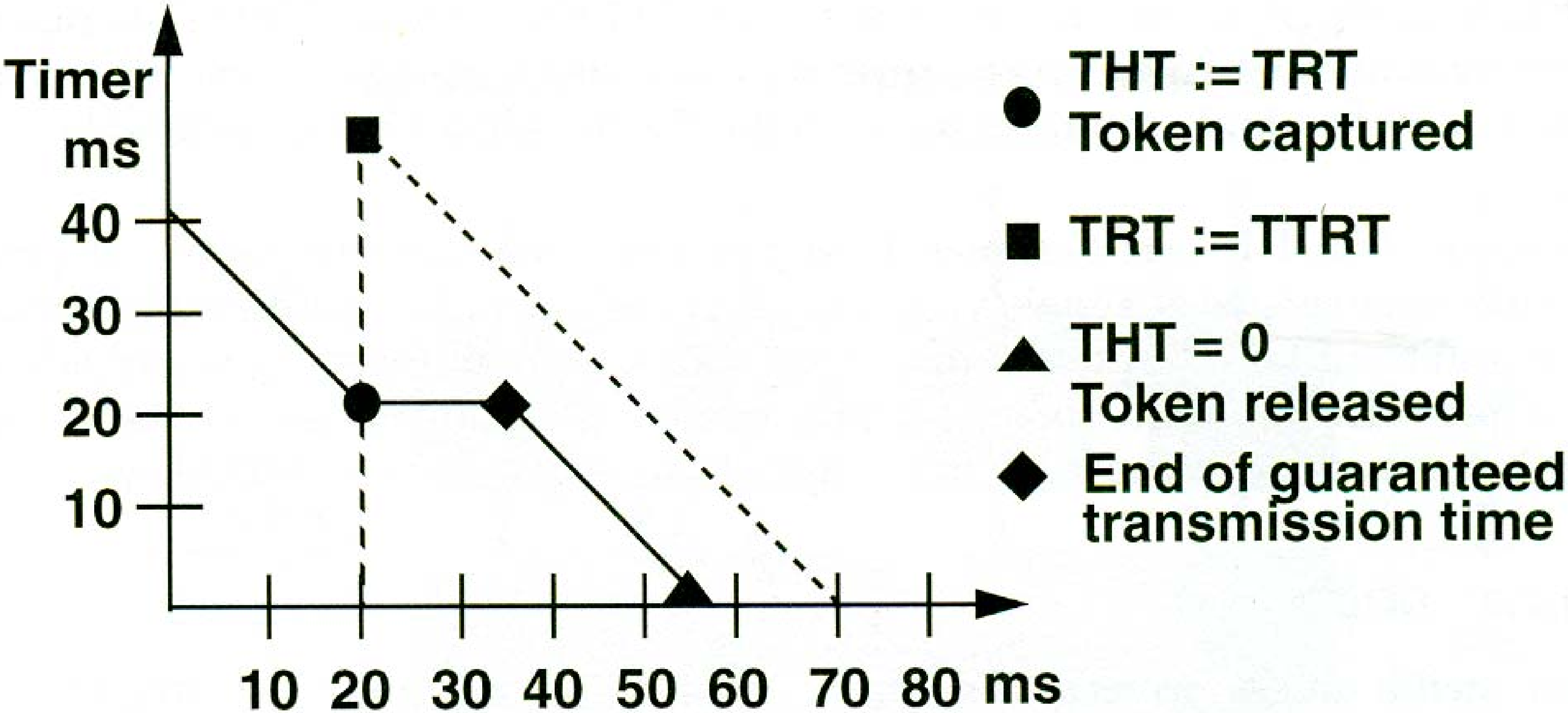
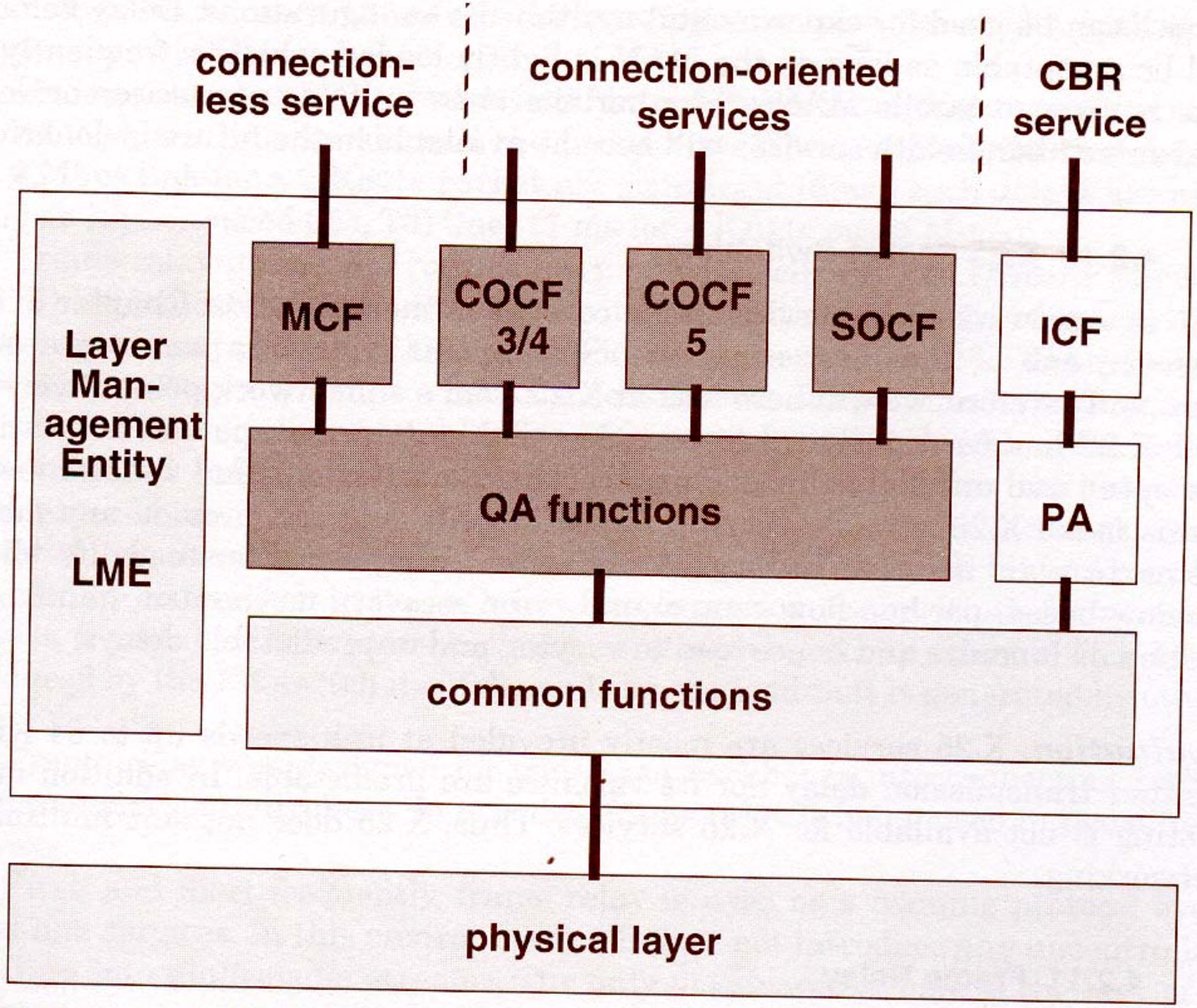



**Figure 4–3** FDDI Synchronous Traffic Class




| | |
|---|---|
| **MCF:** | MAC Convergence function |
| **COCF 3/4:** | Connection-Oriented Convergence Function using AAL 3/4 |
| **COCF 5:** | Connection-Oriented Convergence Function using AAL 5 |
| **SOCF:** | Stream-Oriented Convergence Function |
| **ICF:** | Isochronous Service Convergence Function |
| **QA:** | Queue-Arbitrated Access Function |
| **PA:** | Prearbitrated Access Function |

**Figure 4–4** DQDB Functional Blocks

| Bandwidth | | | | |
|---|---|---|---|---|
| **Packet Size** | **64 kbps** | **128 kbps** | **384 kbps** | **1920 kbps** |
| **256 byte** | 32 ms | 16 ms | 5 ms | 1 ms |
| **1 Kbyte** | 128 ms | 64 ms | 21 ms | 4.3 ms |
| **4 Kbyte** | 500 ms | 250 ms | 85 ms | 17 ms |

**Table 4–1** ISDN Packetization Delays

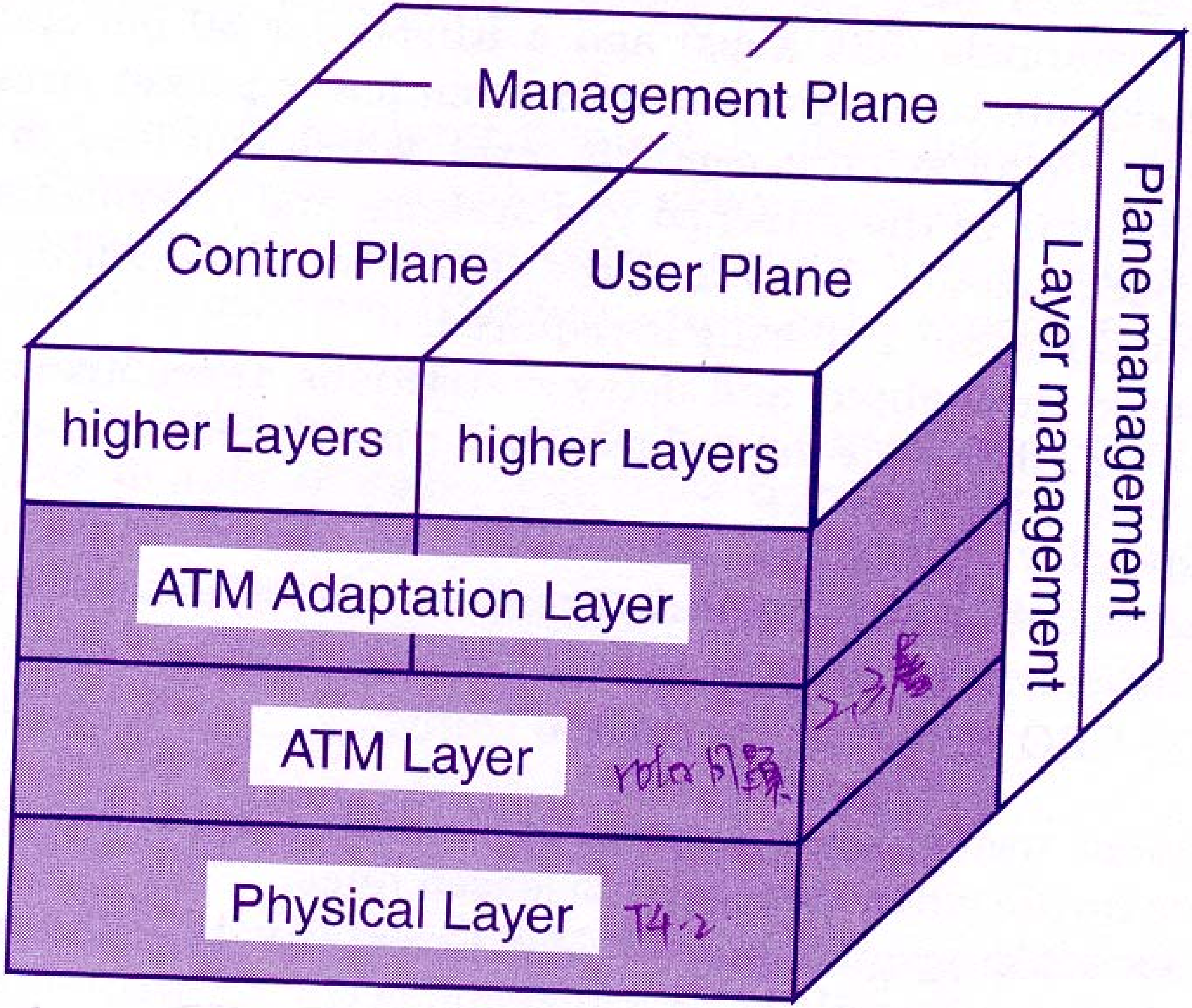



**Figure 4–5** B-ISDN: Protocol Reference Model

| rate | name and framing | defined by |
| --- | --- | --- |
| 622 Mbit/s | SDH STM4/SONET STS-12 over SMF | ITU |
| 155 Mbit/s | SDH STM-1/SONET STS-3C over SMF, MMF, STP, UTP-5 | ITU, ATM Forum |
| 155 Mbit/s | cell based over MMF, STP, UTP-5 | ATM Forum |
| 100 Mbit/s | cell based MMF (TAXI) | ATM Forum |
| 51 Mbit/s | UTP-3, MMF, SMF | ATM Forum |
| 45 Mbit/s | G.804/T3 | ATM Forum/ANSI |
| 34 Mbit/s | G.804/E3 | ATM Forum/ETSI |
| 25.6 Mbit/s | STP, UTP-3, UTP-5 | ATM Forum |
| 2 Mbit/s | E1 | ATM Forum/ETSI |
| 1.5 Mbit/s | T1 | ATM Forum/ANSI |

SDH: synchronous digital hierarchy (ITU)
STM: synchronous transfer module (ITU)
SONET: synchronous optical network (ANSI)
SMF: single-mode Fiber
MMF: multi-mode Fiber
TAXI: transmitter/receiver interface- physical FDDI interface
STP: shielded twisted pair
UTP: unshielded twisted pair

**Table 4–2** ATM Physical Layer Options

| | Class A | Class B | Class C | Class D |
|---|---|---|---|---|
| **Timing Relation Between Source and Destination** | required | | not required | |
| **Bit Rate** | constant | variable | | |
| **Connection Mode** | Connection-oriented | | | Connection-less |

**Table 4–3** ATM Service Classes

| | CBR | rt-/nrt-VBR | ABR | UBR |
|---|---|---|---|---|
| CLR | specified | | specified | unspecified |
| CTD | specified | | unspecified | |
| CDV | specified | optional | n.a. | |
| PCR | specified | | | |
| SCR/BT | n.a. | specified | n.a. | |
| MCR | n.a | | specified | n.a. |

**Table 4–4** ATM Traffic Classes

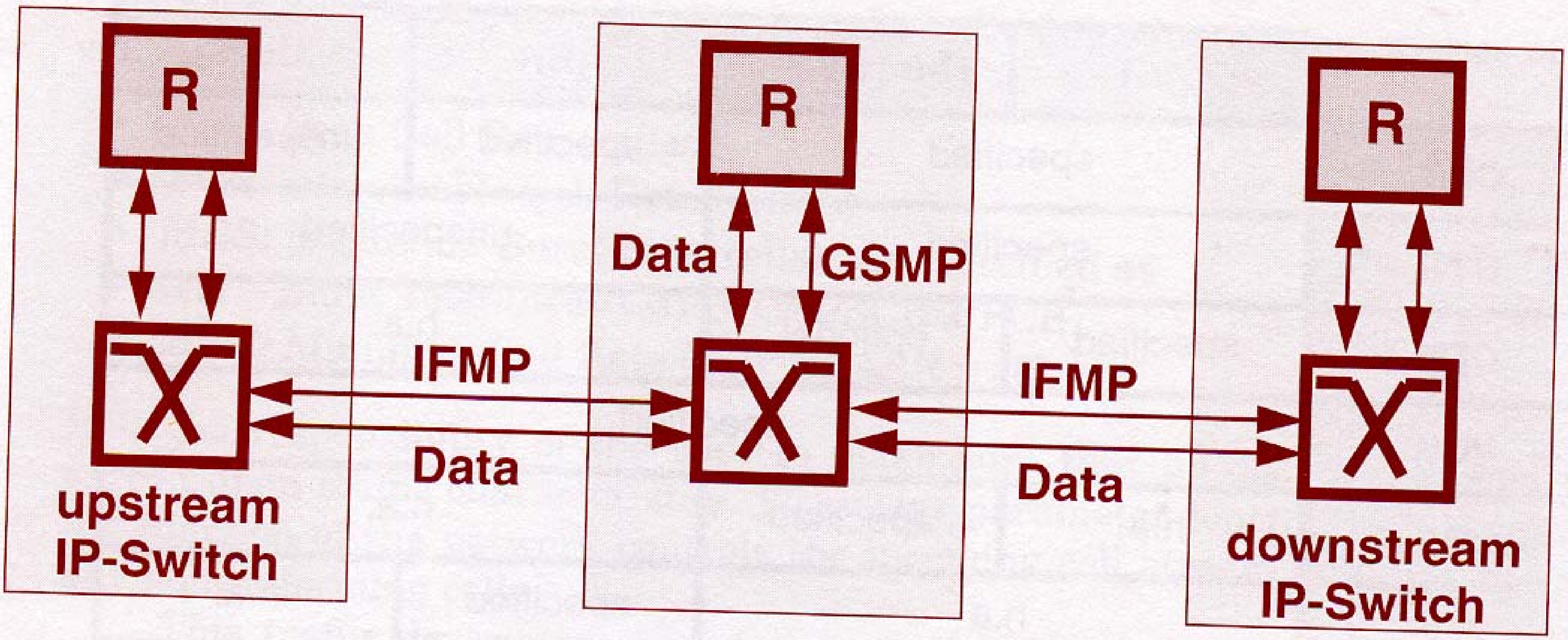



Figure 4–6 Ipsilon's IP-switching

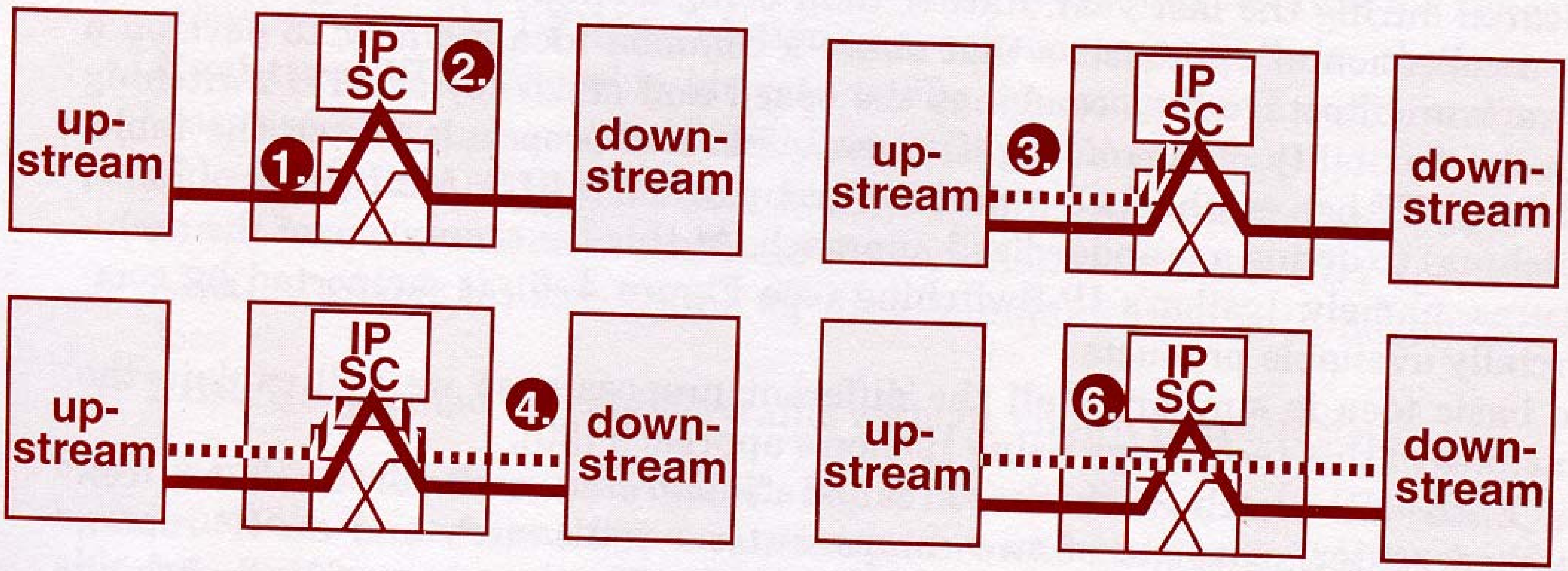



**Figure 4–7** IP Switch Operation

| Network | Band-width (Mbit/s) | Dedicated vs. Shared | Transmission Delay | Delay Variance | Broad-cast | Avail-able |
|---|---|---|---|---|---|---|
| Ethernet | 10 | shared | random | • | + | + |
| Iso-Ethernet (isochr.part) | 10+6 | shared | fixed < 1 ms | 0 | - | + |
| Token Ring | 4/16 | shared | configuration dependent < 20 ms | max. | + | + |
| 100 Base-T | 100 | shared | random | • | + | + |
| Demand Priority | 100 | | configuration dependent < 10 ms | max. | + | + |
| FDDI | 2*100 | shared | configuration dependent < 20 ms | max. | + | + |
| FDDI II (isochr. part)) | n*6 | shared | fixed < 1 ms | 0 | + | - |
| DQDB QA Acc. | 2...155 | shared | random | • | + | + |
| DQDB PA Acc. | 2...155 | shared | fixed | 0 | - | - |
| X.25 | < 2 | dedicated | random | • | - | + |
| Frame Relay | < 50 | dedicated | random | • | (+) | + |
| IP | unlim. | dedicated | random | • | + | + |
| ISDN | n*0.064 | dedicated | fixed < 10 ms | 0 | - | + |
| ATM | 25..2048 | dedicated | bounded < 10 ms | max. | (-) | + |
| IP Switching | ...2048 | dedicated | bounded < 10 ms | max. | (-) | + |

delay variance:
•= asynchronous network without delay jitter control
max.= synchronous network with delay variance between 0 and max. delay
0 = isochronous network with constant delay

**Table 4–5** Survey of Network Characteristics

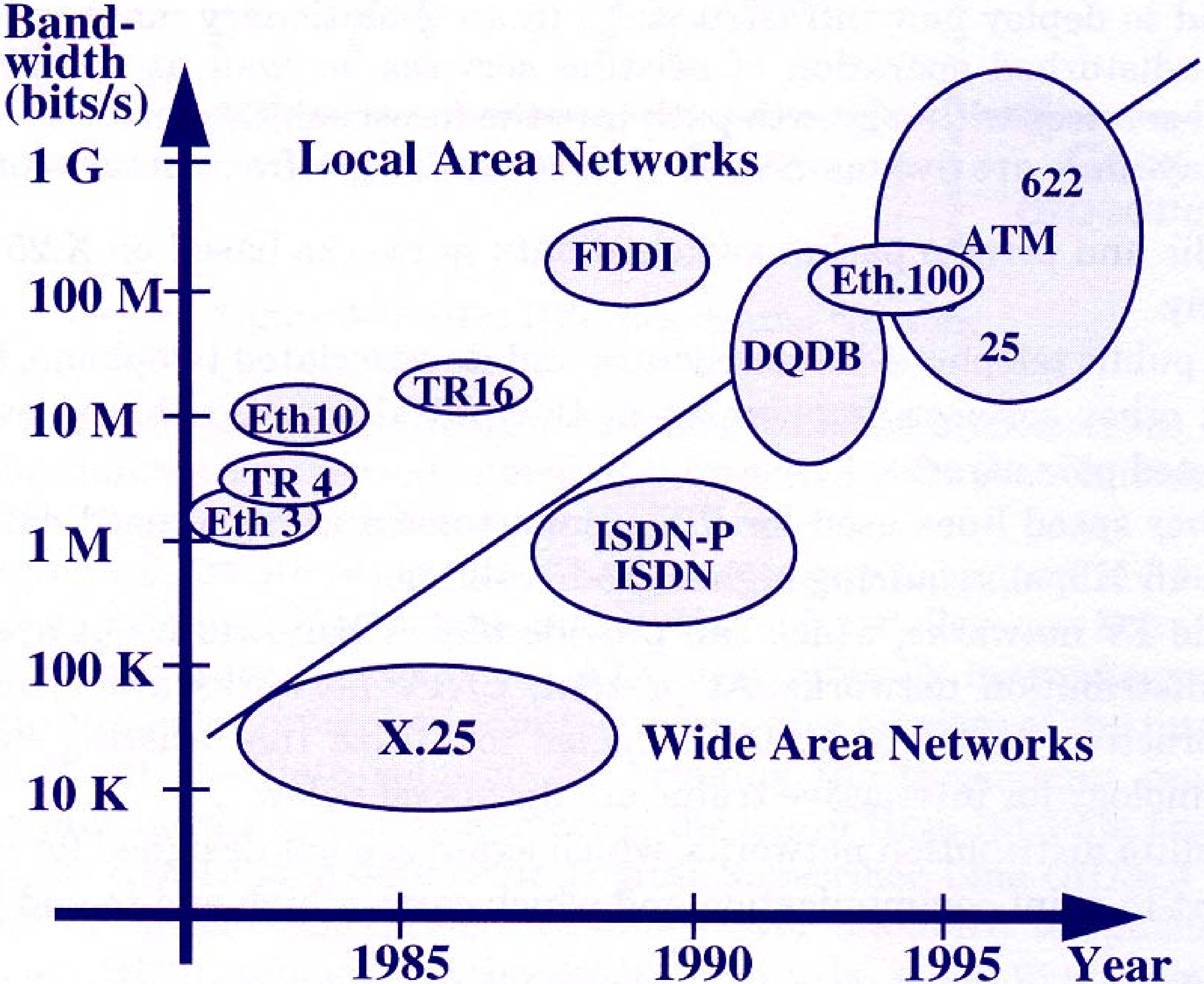



**Figure 4–8** Network Bandwidth Evolution

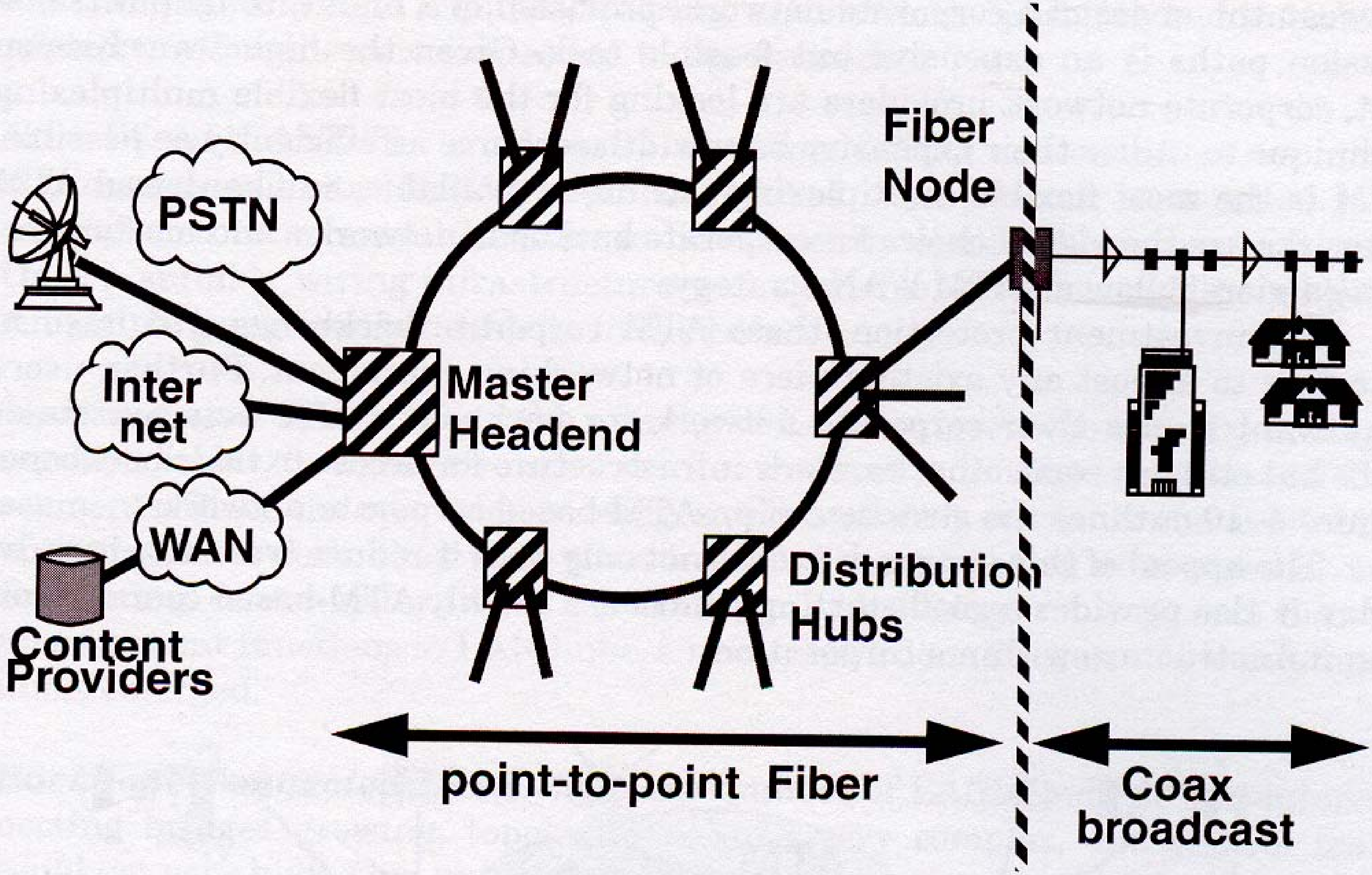



**Figure 4–9** ATM HFC Residential Network

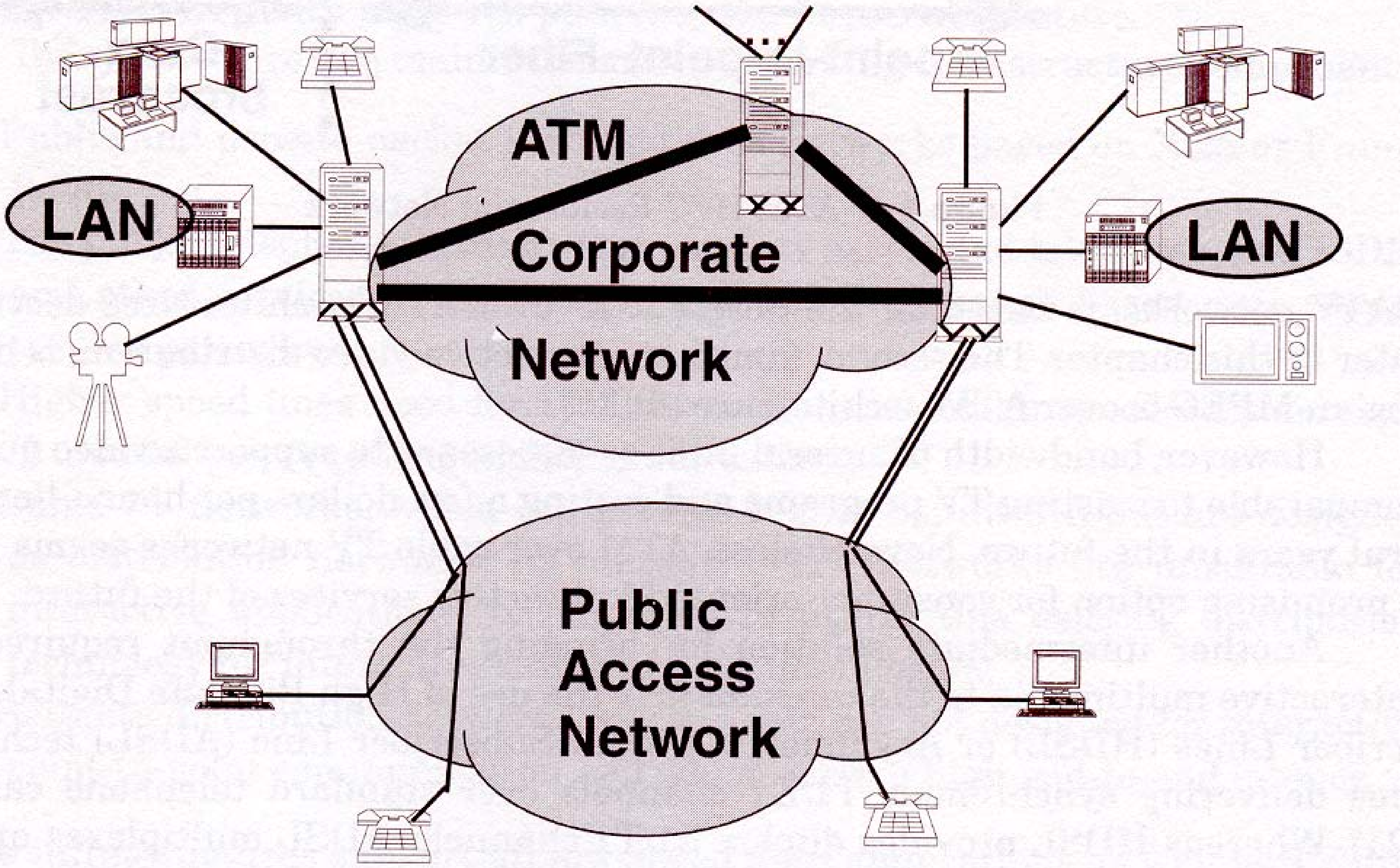



**Figure 4–10** ATM-Based Corporate Network

| LAN type | max. packet size [byte] | number of ports | delay [ms] |
|---|---|---|---|
| 10 Mbit/s Ethernet | 1518 | 8 | 1 ... 2.5 |
| 100 Mbit/s Ethernet | 1518 | 8 | < 1 |
| 16 Mbit/s Token Ring | 4096 | 8 | 2 ... 5 |

**Table 4–6** Store-and-Forward Delay in LAN Switches

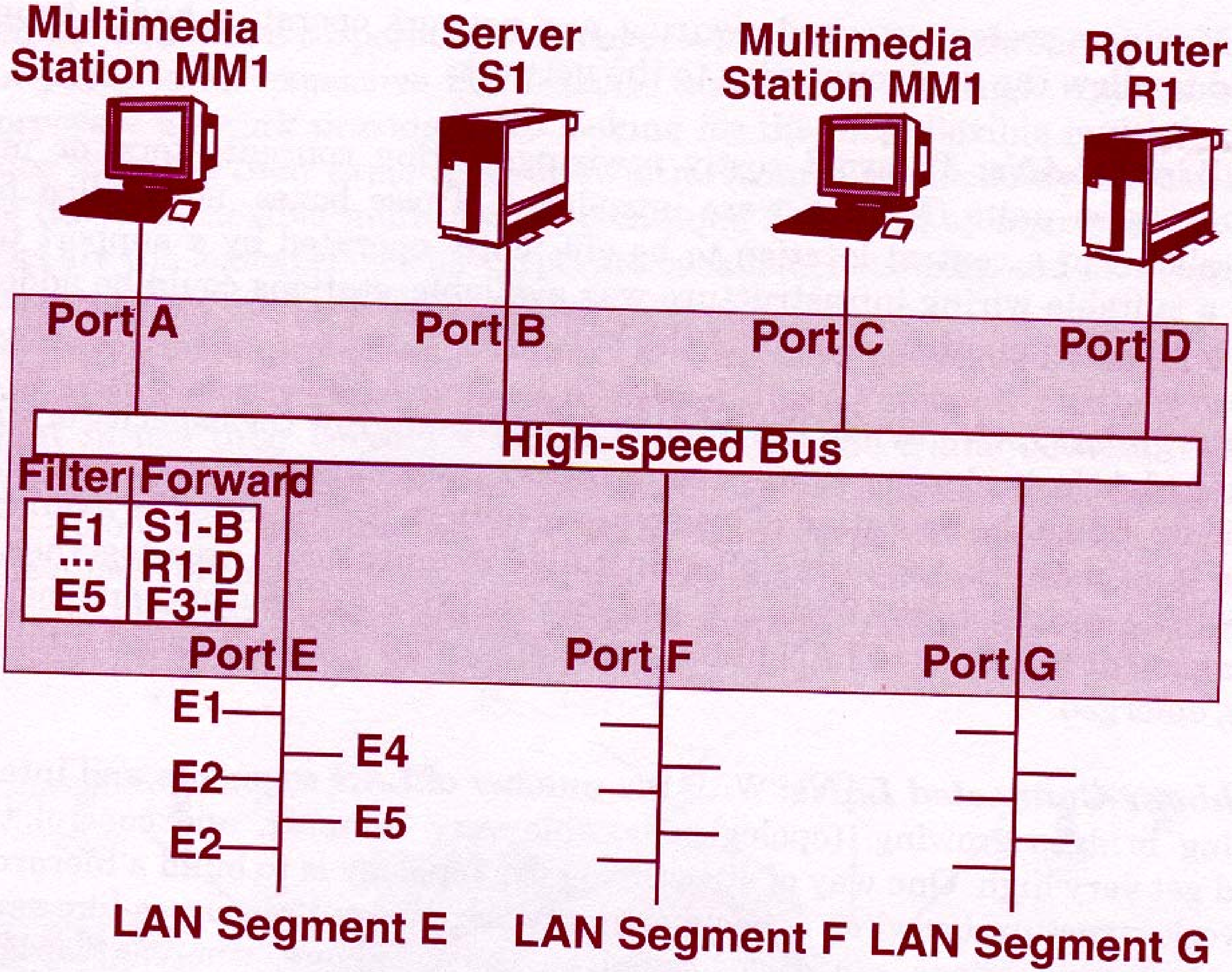



**Figure 4–11** LAN Switch Configuration

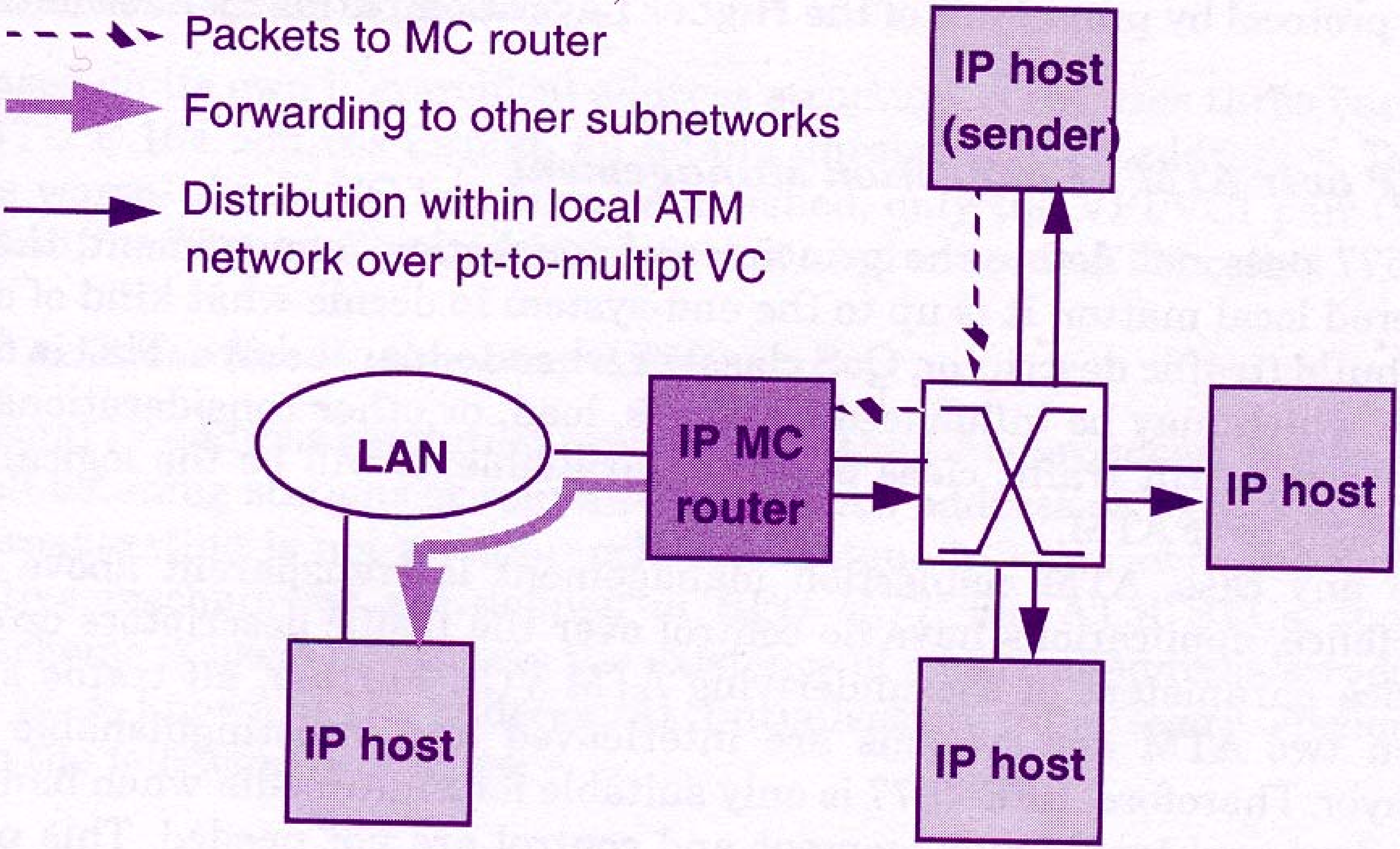



**Figure 4–12** Multicast IP Server Configuration

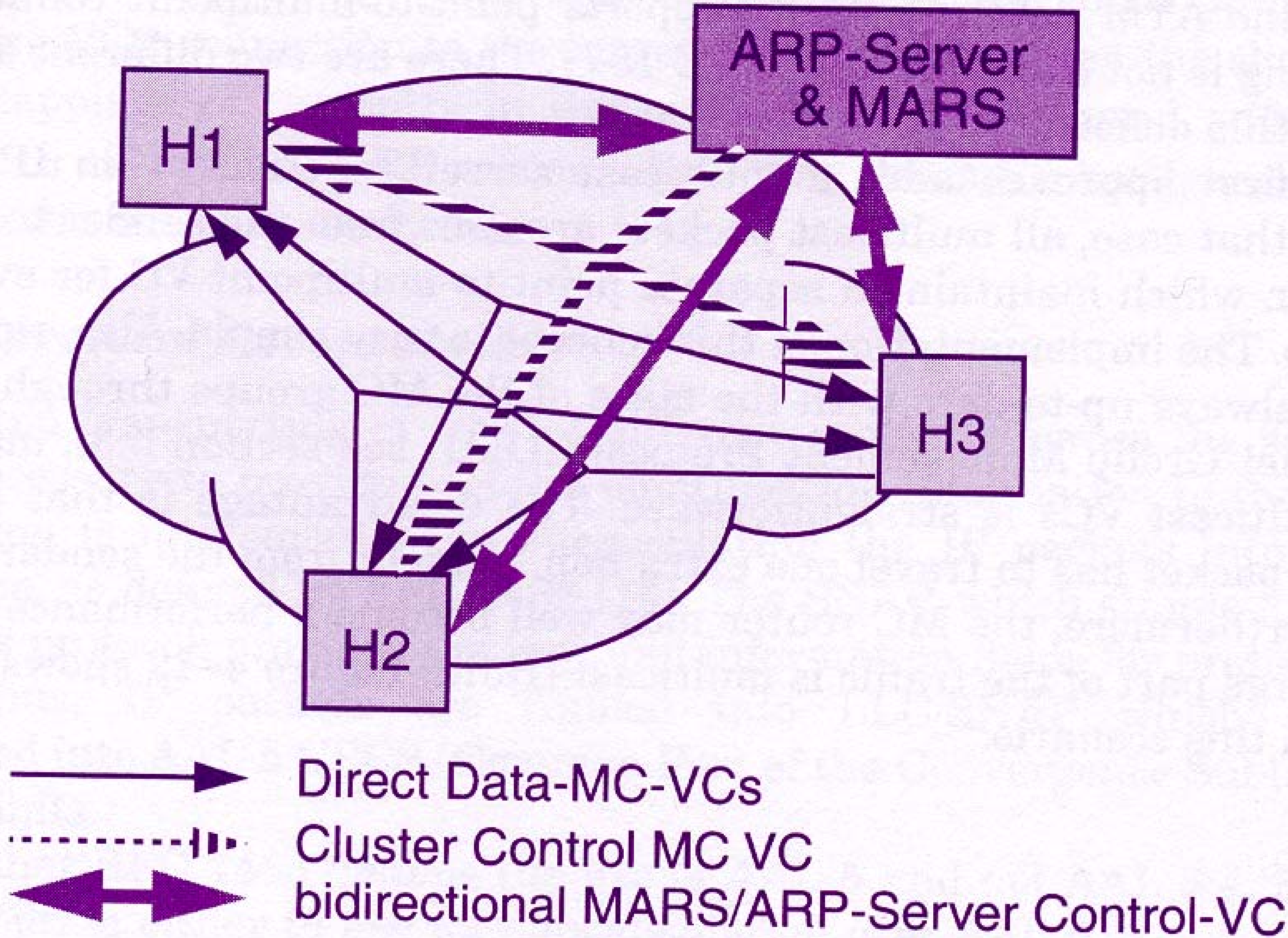



**Figure 4–13** MARS Direct Mesh Configuration

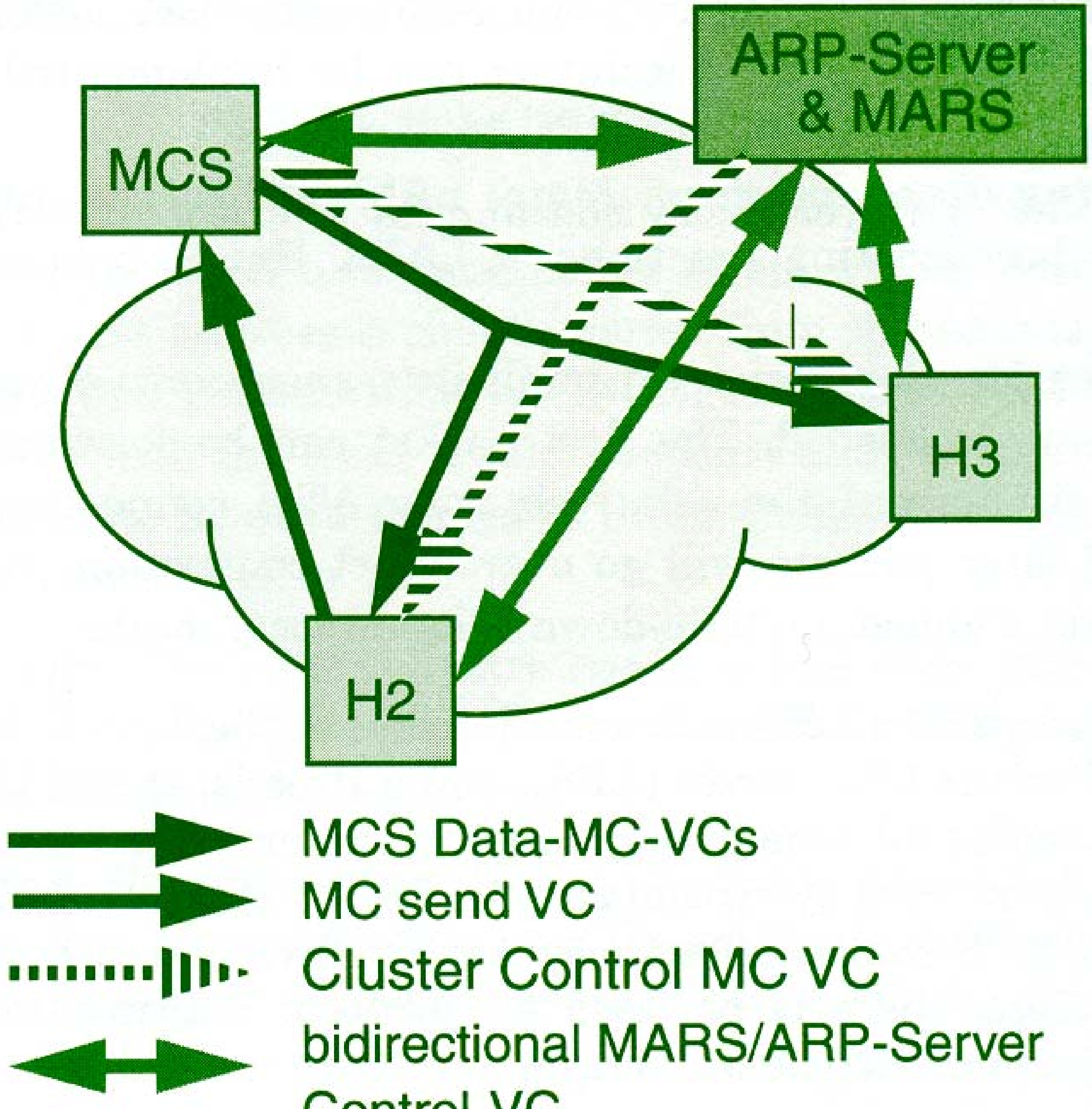



**Figure 4–14** MARS Multicast Server Configuration

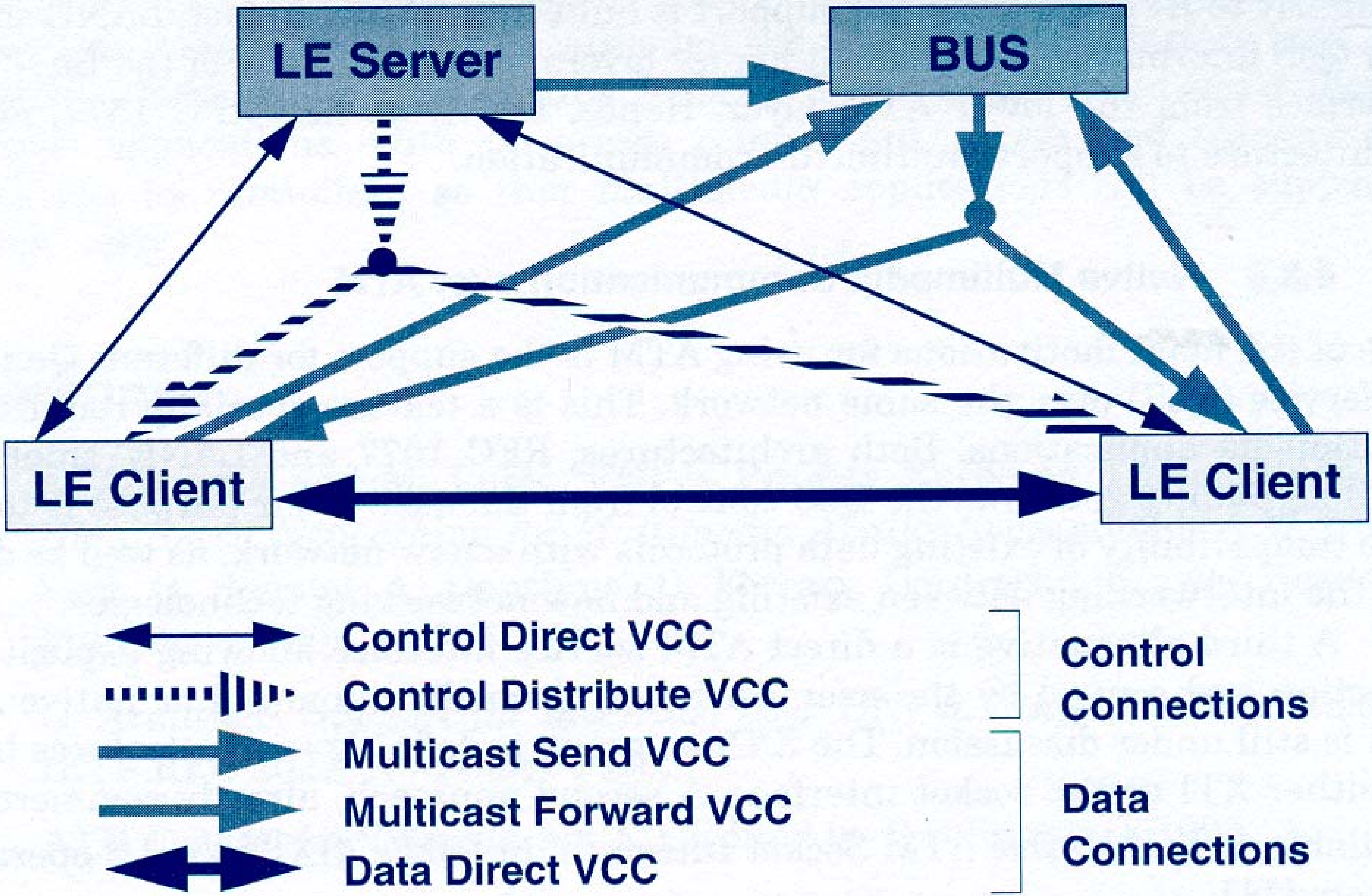
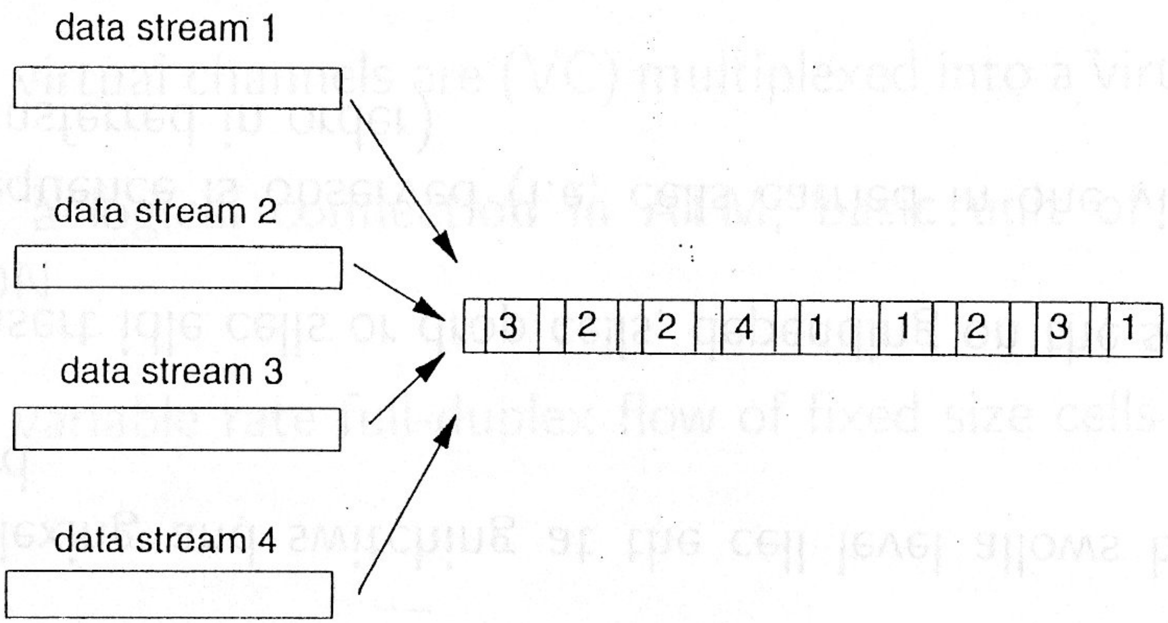



**Figure 4–15** LANE Configuration

# Advantages of ATM

- Exploiting the benefit of B-ISDN
- ATM is a connection-oriented packet-switching network and contains the advantages of
  - circuit switching (low overhead)
  - packet switching (flexibility)
- Virtual channels in ATM are implemented by small fixed size cells (i.e., each cell is of 53 bytes)
  - Sequence of cells from a particular user with the same headers constitute a virtual channel

# ATM Multiplexing Mechanism

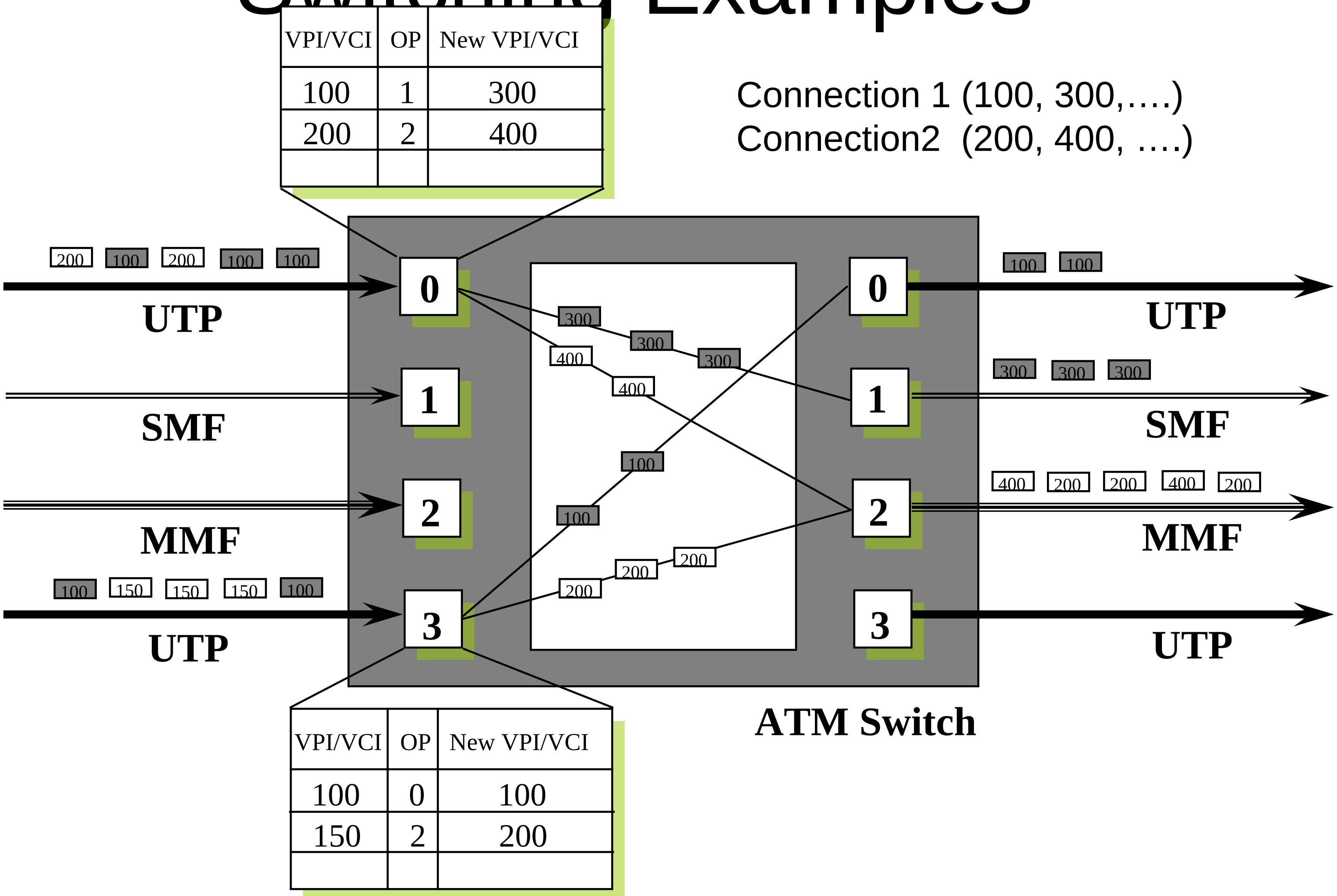


## Advantages of ATM (cont'd)

- Small cell size in ATM allows small transfer delay variations, thus making ATM suitable for carrying various media (audio, video, text)
- Multiplexing and switching at the cell level allows bandwidth on demand
- May insert idle cells or drop cells, depending on the source activity
- Cell sequence is observed (i.e, cells carried in one virtual channel are transferred in order)

# Cell Multiplexing and Cell Switching Examples

Connection 1 (100, 300,….)
Connection2  (200, 400, ….)



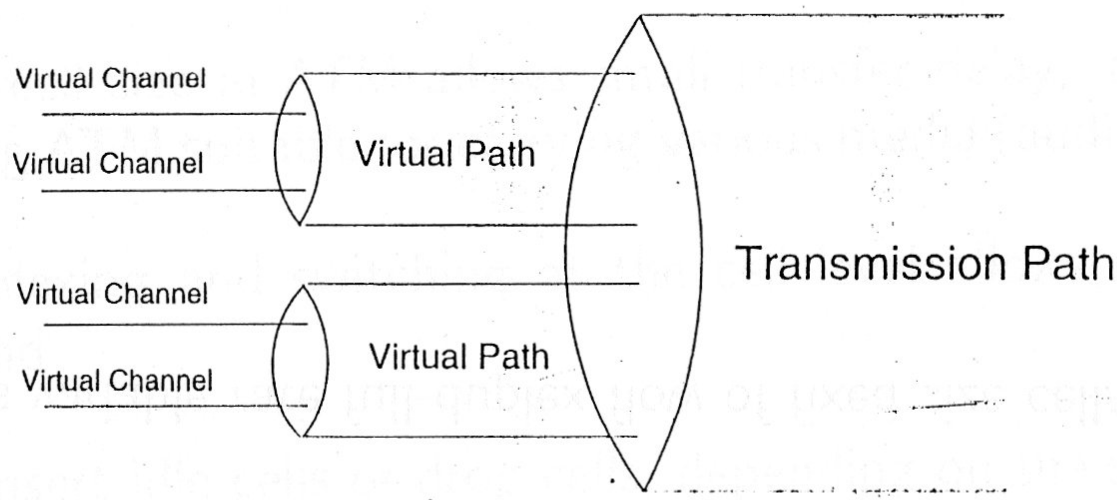

| VPI/VCI | OP | New VPI/VCI |
|---|---|---|
| 100 | 1 | 300 |
| 200 | 2 | 400 |
| | | |

| VPI/VCI | OP | New VPI/VCI |
|---|---|---|
| 100 | 0 | 100 |
| 150 | 2 | 200 |
| | | |

## Virtual Channels

- Many virtual channels are (VC) multiplexed into a virtual path (VP)
- VC is a logical connection in ATM; basic unit of networking in B-ISDN
- VC is variable rate full-duplex flow of fixed size cells

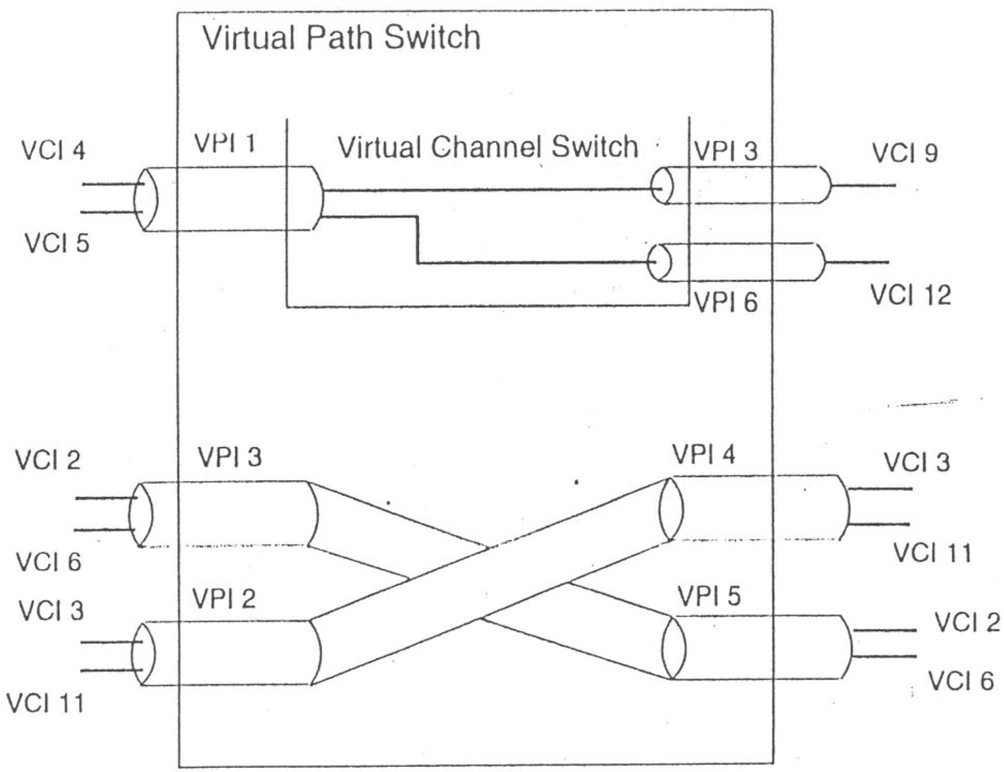
# ATM Connection Relationships



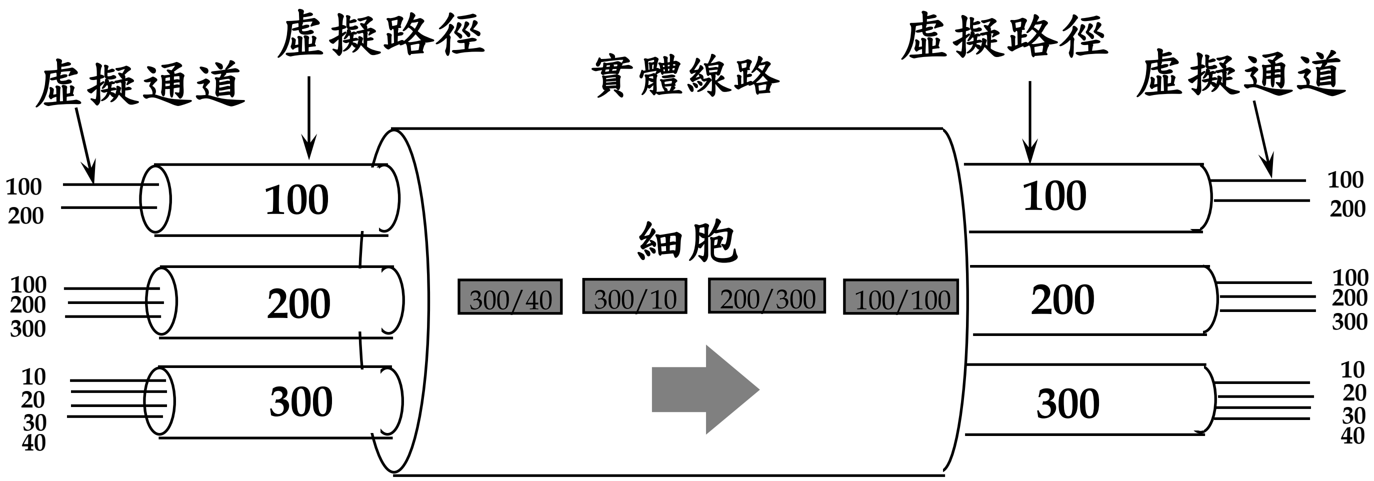
## Virtual Paths

- Many virtual paths are multiplexed into a physical link
- VP is a group of VC's with the same endpoints
- All cells in virtual circuits in a VP are switched together

# Virtual Path/Channel Switches



# Virtual Channels, Virtual Paths, and the Physical Channel




- 連線 (VPI/VCI) = (100,100),(100,200),(200,100),(200,200),(200,300),(300,10),(300,20),(300,30),(300,40)

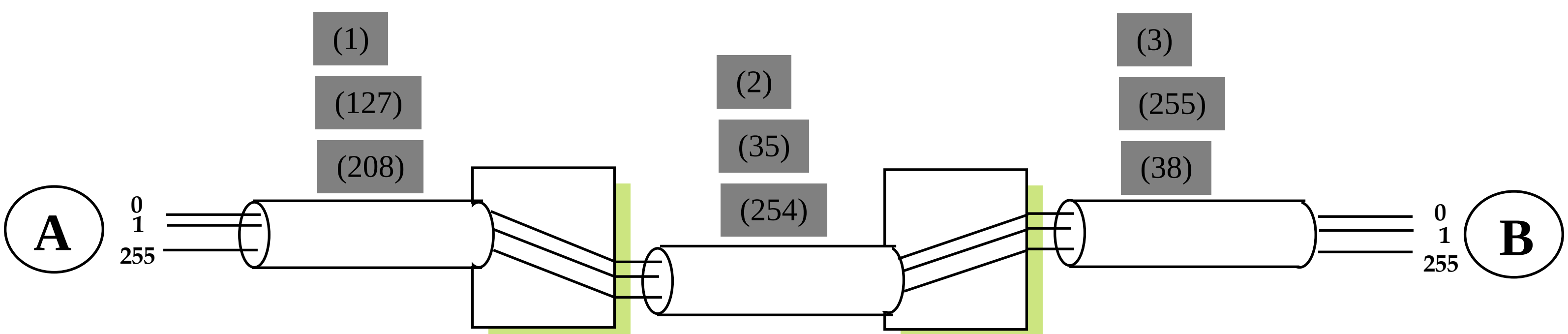
Connection Path (VPI1,VCI1), SW1, (VPI2, VCI2), SW2, (VPI3, VCI3),……..

# Why Virtual Paths and Virtual Channel ?

- **Assume the identification field contains 8 bits. All used as VCI. Then the size of the mapping table is 256.**

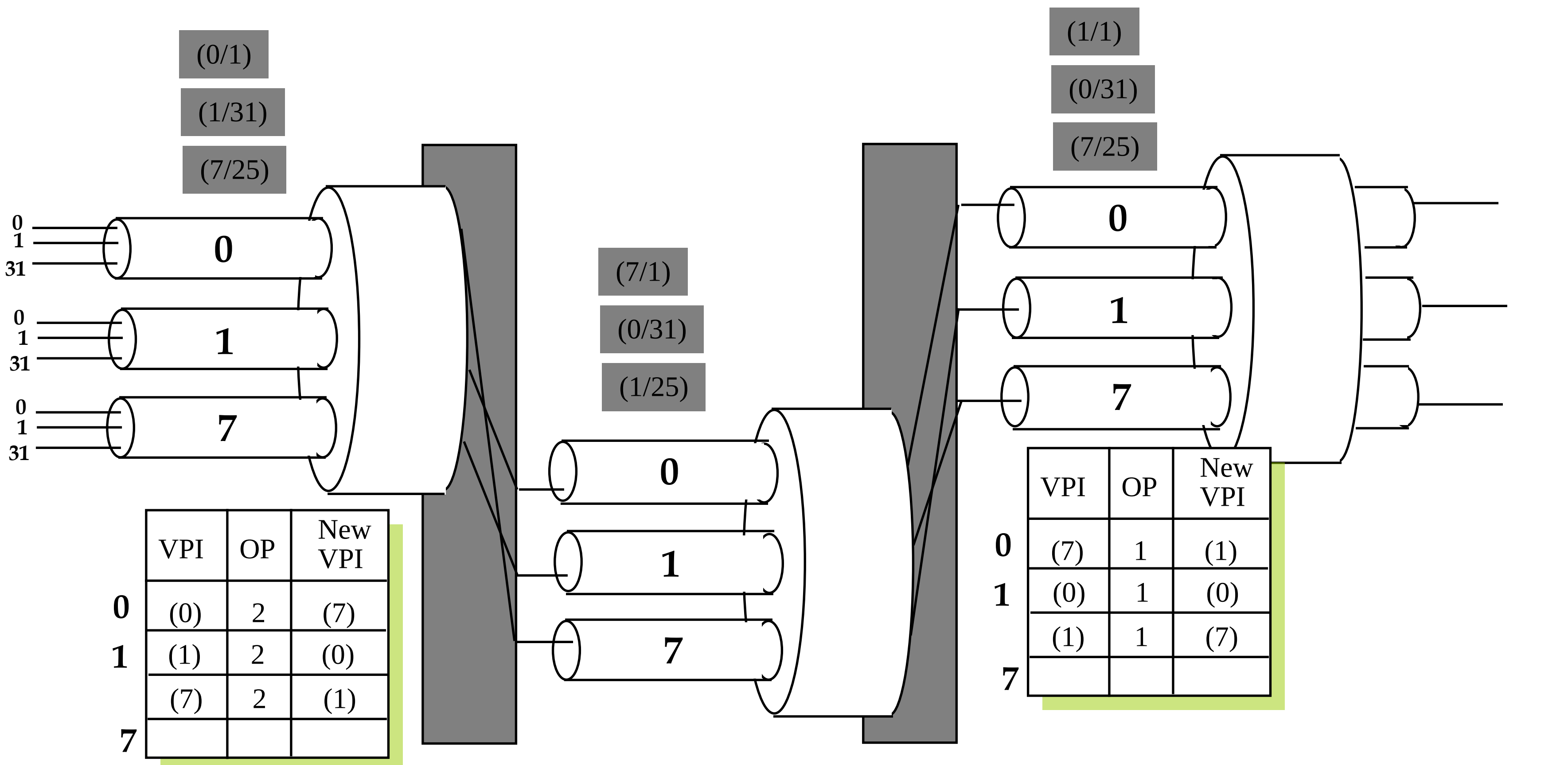
| | VCI | OP | New VCI |
|---|---|---|---|
| **0** | (1) | 2 | (2) |
| **1** | (127) | 2 | (35) |
| | (208) | 2 | (254) |
| | | | |
| **255** | | | |

| | VCI | OP | New VCI |
|---|---|---|---|
| **0** | (2) | 1 | (3) |
| **1** | (35) | 1 | (255) |
| | (254) | 1 | (38) |
| | | | |
| **255** | | | |



# Why Virtual Paths and Virtual Channels ?

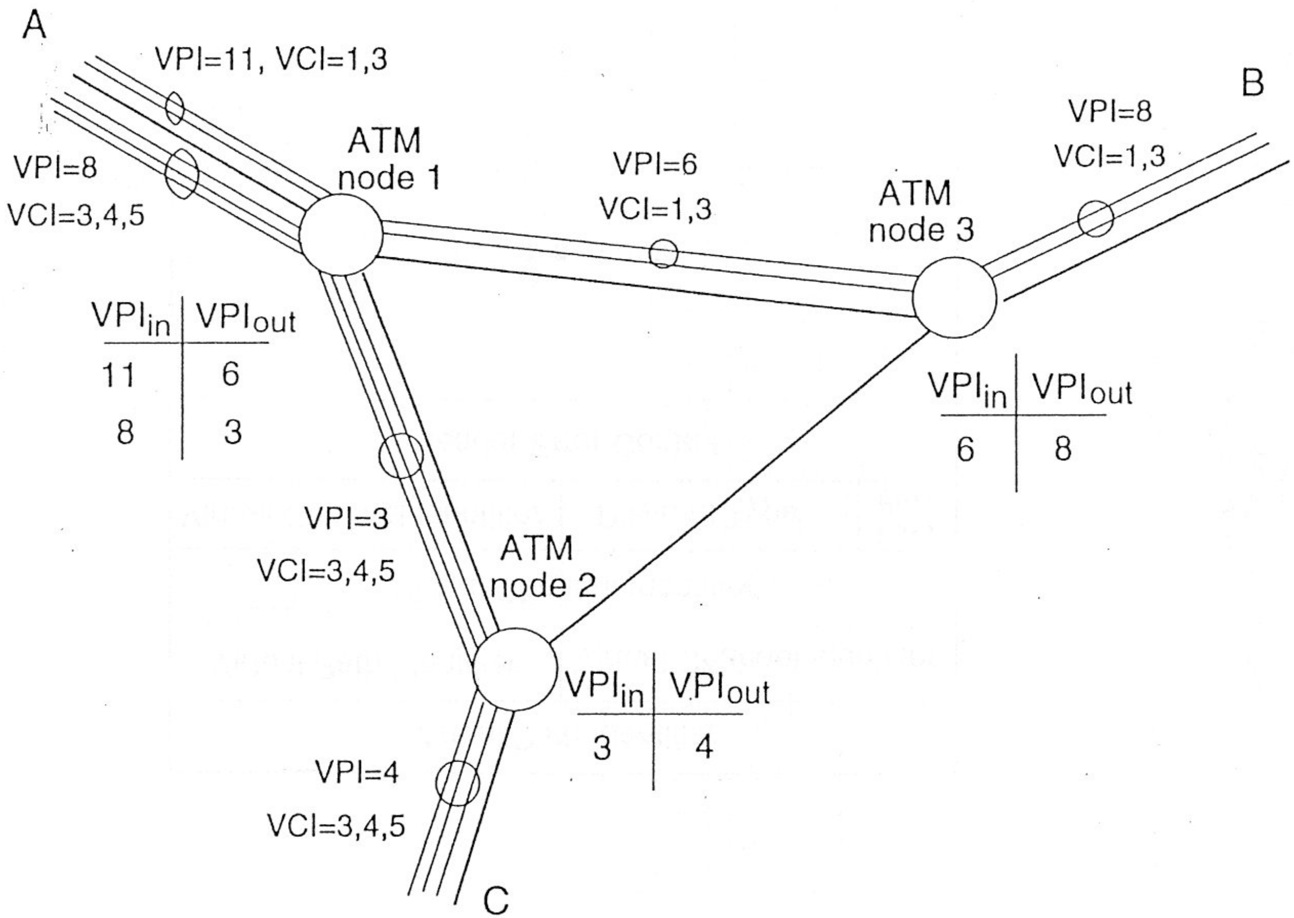
- **Assume the identification field contains 8 bits. VPI takes 3 bits and VCI takes 5 bits. Then the size of the mapping table is 8.**




| | VPI | OP | New VPI |
|---|---|---|---|
| 0 | (0) | 2 | (7) |
| 1 | (1) | 2 | (0) |
| | (7) | 2 | (1) |
| 7 | | | |

| | VPI | OP | New VPI |
|---|---|---|---|
| 0 | (7) | 1 | (1) |
| 1 | (0) | 1 | (0) |
| | (1) | 1 | (7) |
| 7 | | | |

# Use of VPI


A
VPI=11, VCI=1,3
VPI=8
VCI=3,4,5
ATM node 1
VPI=6
VCI=1,3
ATM node 3
B
VPI=8
VCI=1,3
VPIin | VPIout
11 | 6
8 | 3
VPIin | VPIout
6 | 8
VPI=3
VCI=3,4,5
ATM node 2
VPIin | VPIout
3 | 4
VPI=4
VCI=3,4,5
C

# Virtual Channels Examples

Port (a,1)

| VPI/VCI | OP | New VPI/VCI |
|---|---|---|
| (100,10) | 2 | (200,10) |
| (100,20) | 2 | (200,20) |

Port (c,2)

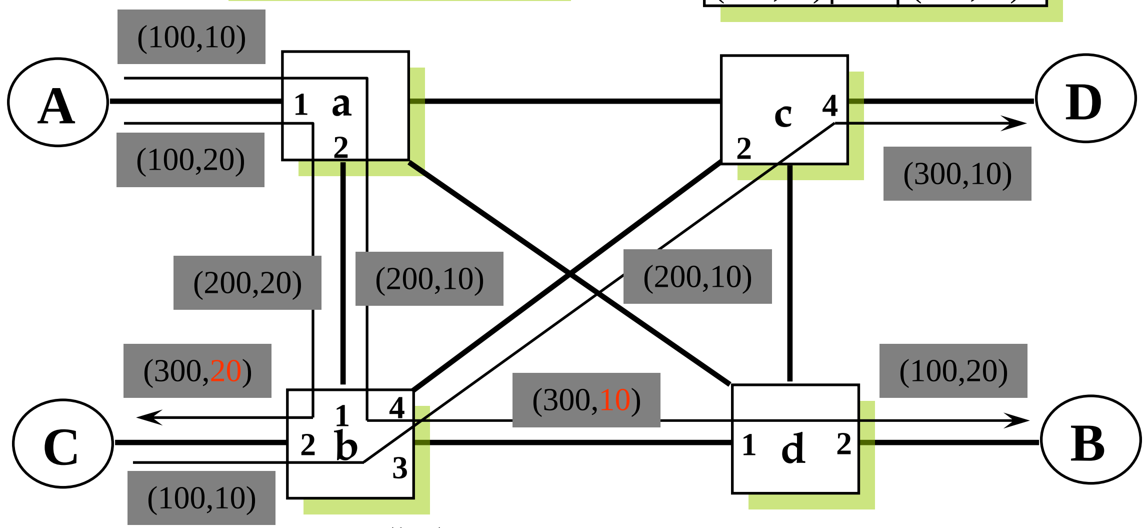
| VPI/VCI | OP | New VPI/VCI |
|---|---|---|
| (200,10) | 4 | (300,10) |

輸出連線

| 連線 | VPI/VCI |
|---|---|
| 1 | (100,10) |
| 2 | (100,20) |

輸入連線

| 連線 | VPI/VCI |
|---|---|
| 1 | (300,10) |




輸入連線

| 連線 | VPI/VCI |
|---|---|
| 1 | (300,10) |

輸入連線

| 連線 | VPI/VCI |
|---|---|
| 1 | (100,20) |

輸出連線

| 連線 | VPI/VCI |
|---|---|
| 1 | (100,10) |

Port (b,1)

| VPI/VCI | OP | New VPI/VCI |
|---|---|---|
| (200,10) | 3 | (300,10) |
| (200,20) | 2 | (300,20) |

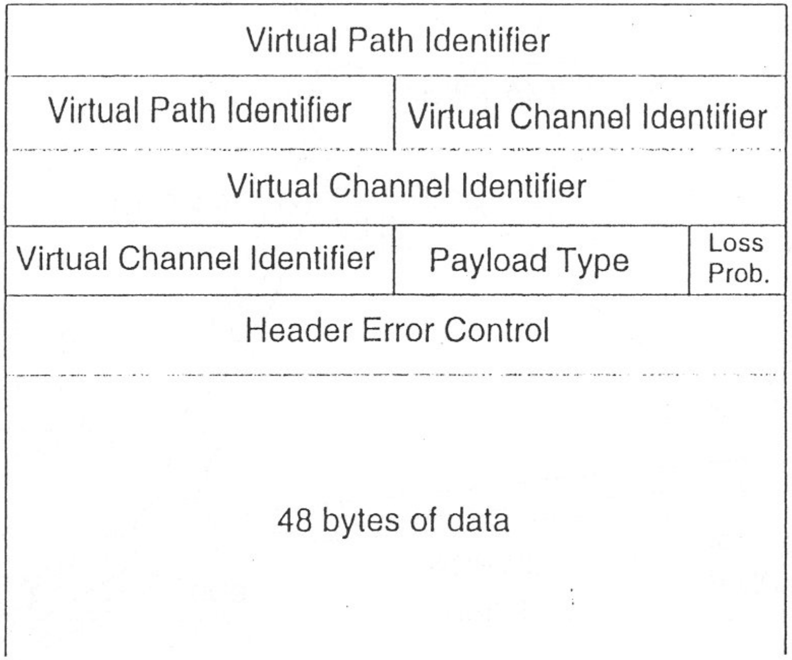
Port (d,1)

| VPI/VCI | OP | New VPI/VCI |
|---|---|---|
| (300,20) | 2 | (100,20) |

Port (b,2)

| VPI/VCI | OP | New VPI/VCI |
|---|---|---|
| (100,10) | 4 | (200,10) |

# ATM Cell Header Format



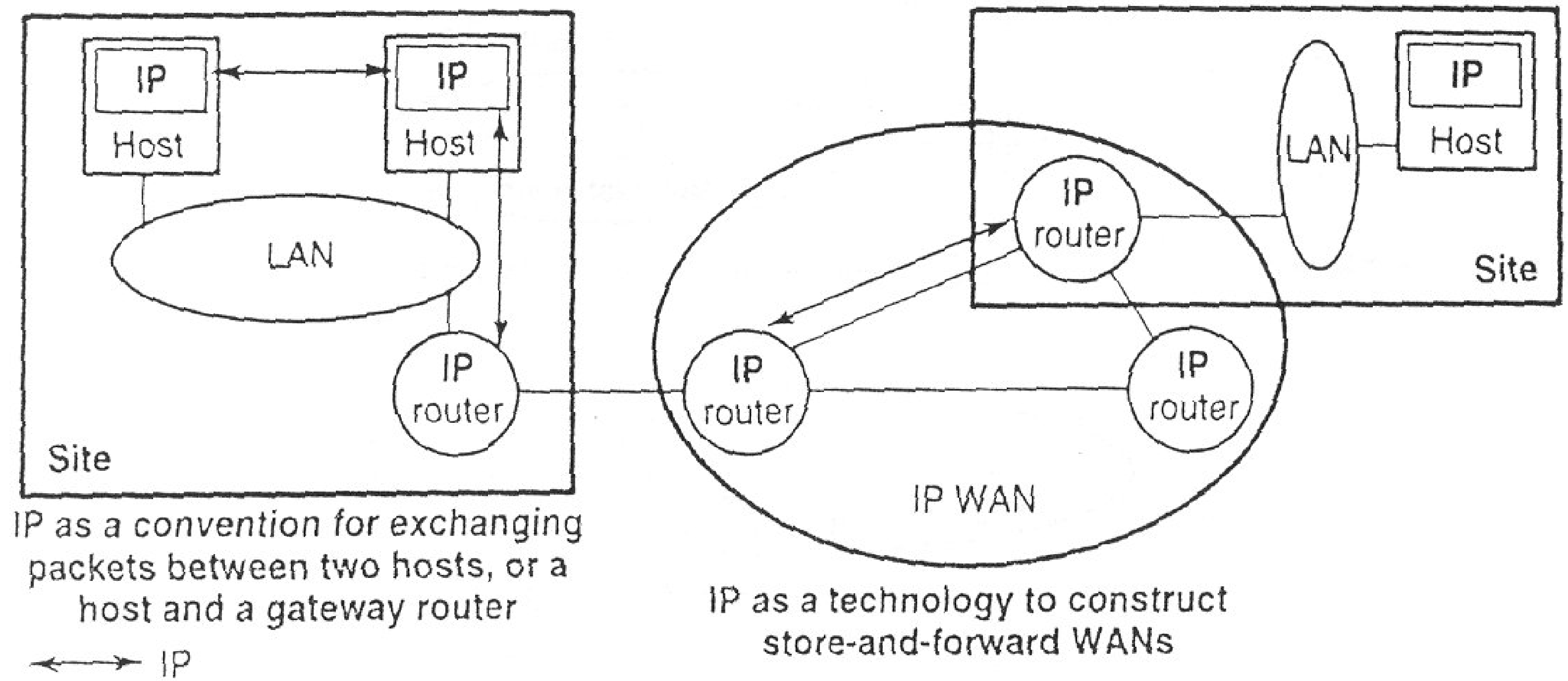



Figure 22.1 IP for host communication over LANs and for store-and-forward WANs

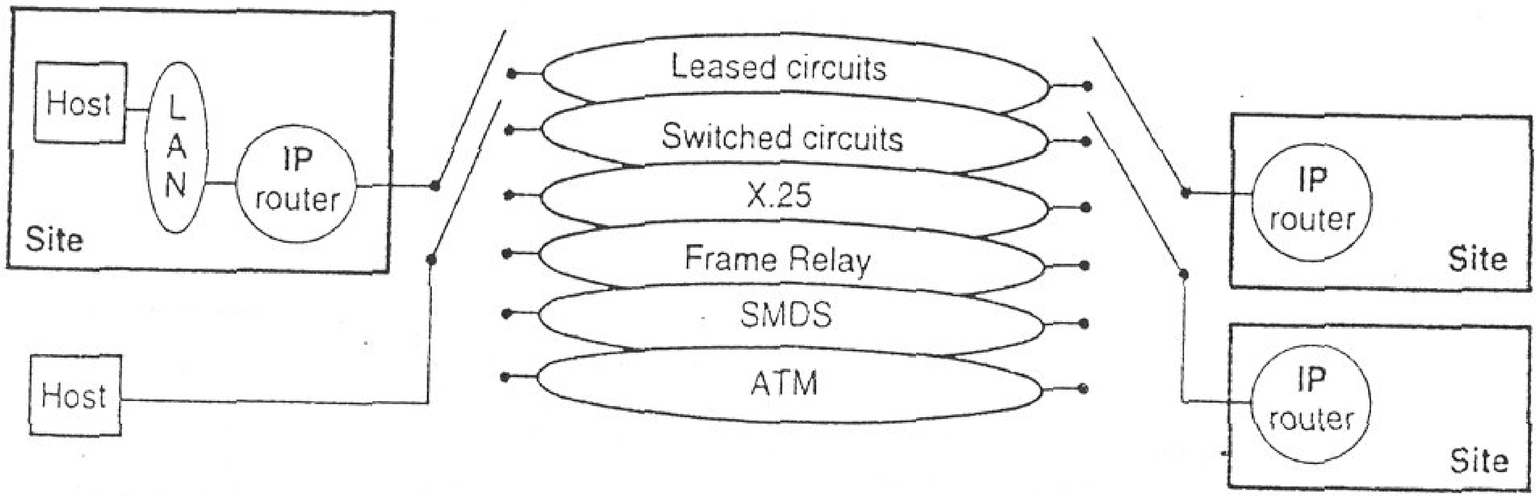



Figure 22.2 Wide-area IP networks. Any low- or high-speed transport technology may be used to interconnect IP routers or hosts to routers

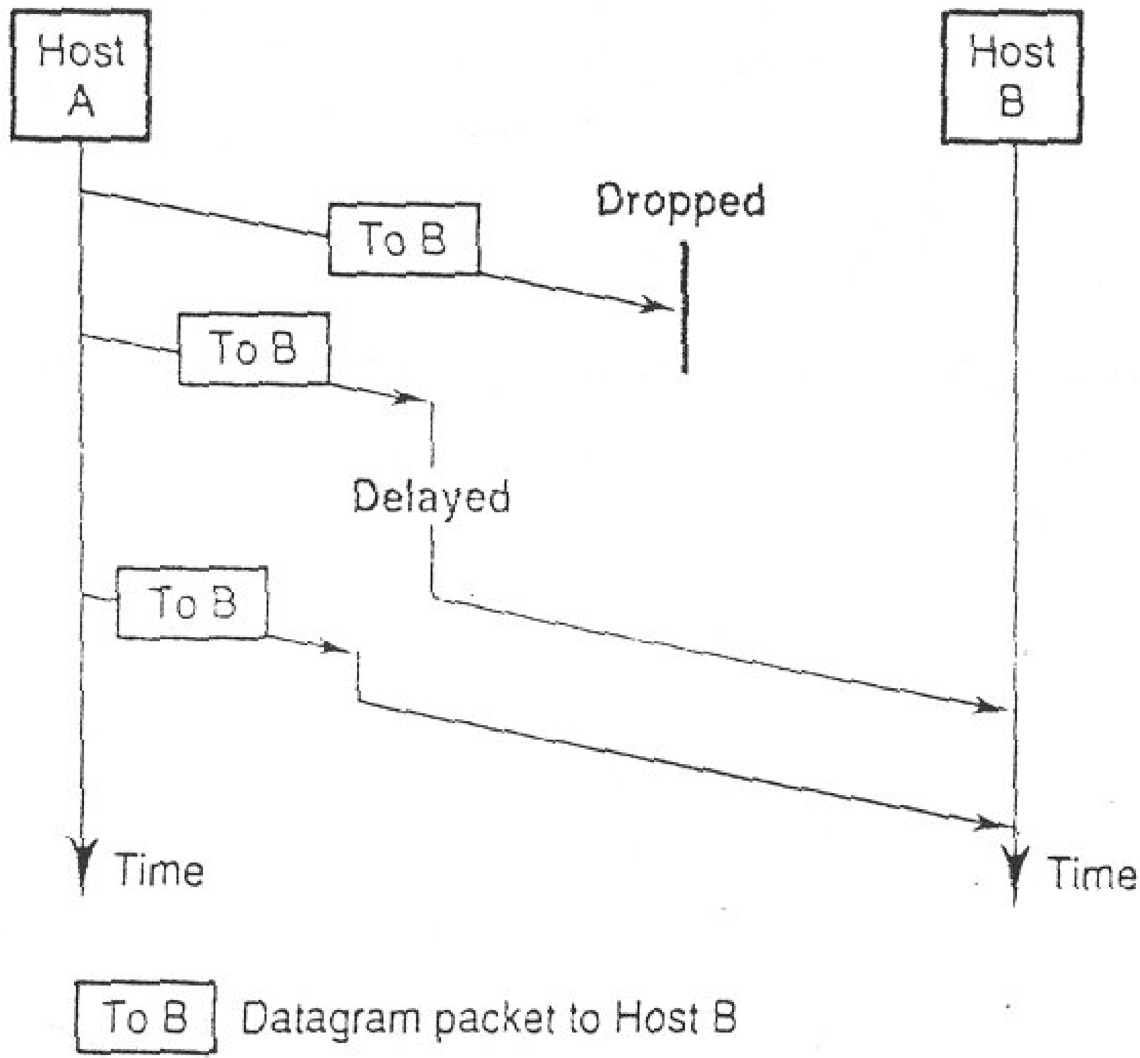



Figure 22.3 IP WAN service: best-effort delivery of datagrams

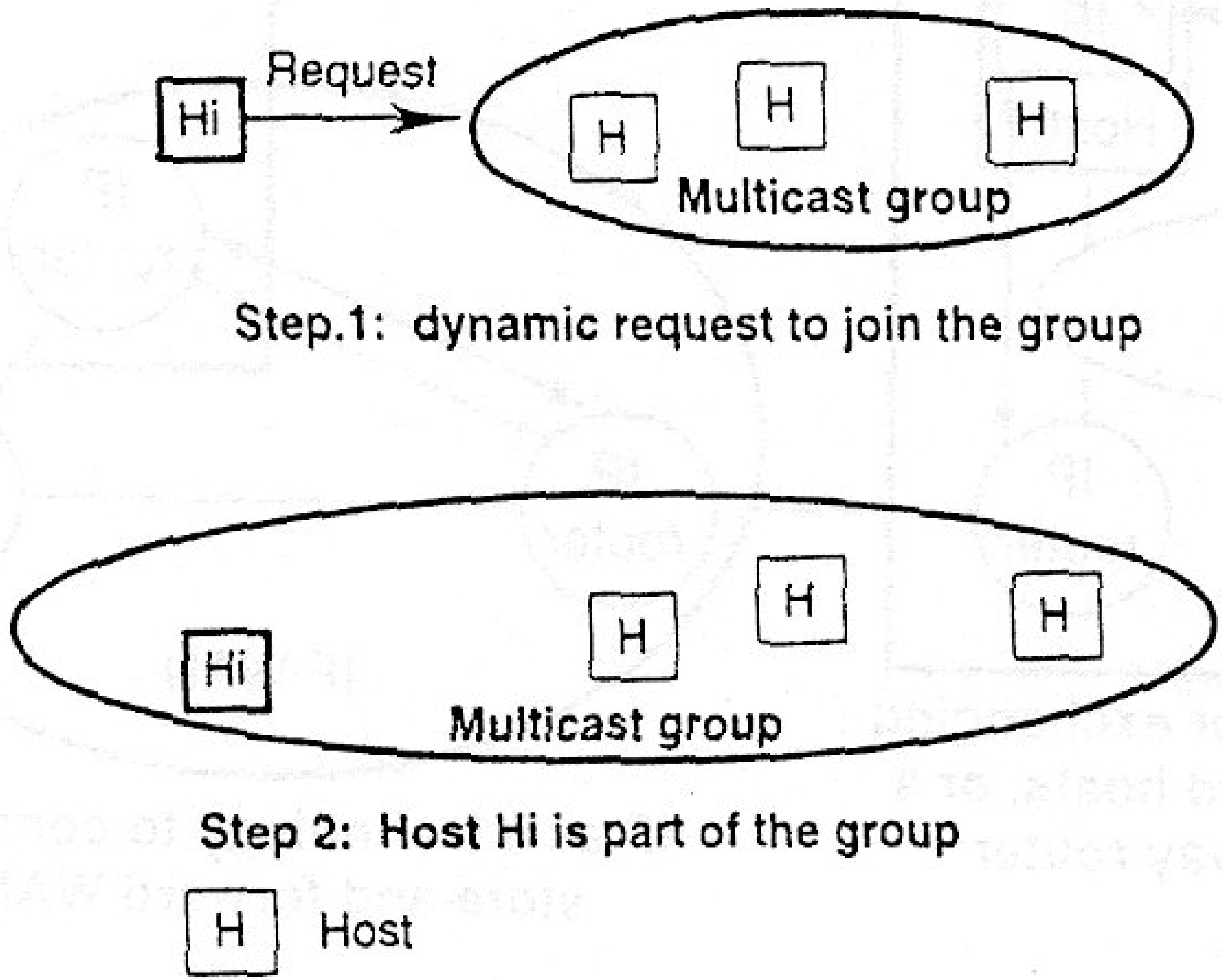



Figure 22.4 Joining IP multicast groups is dynamic

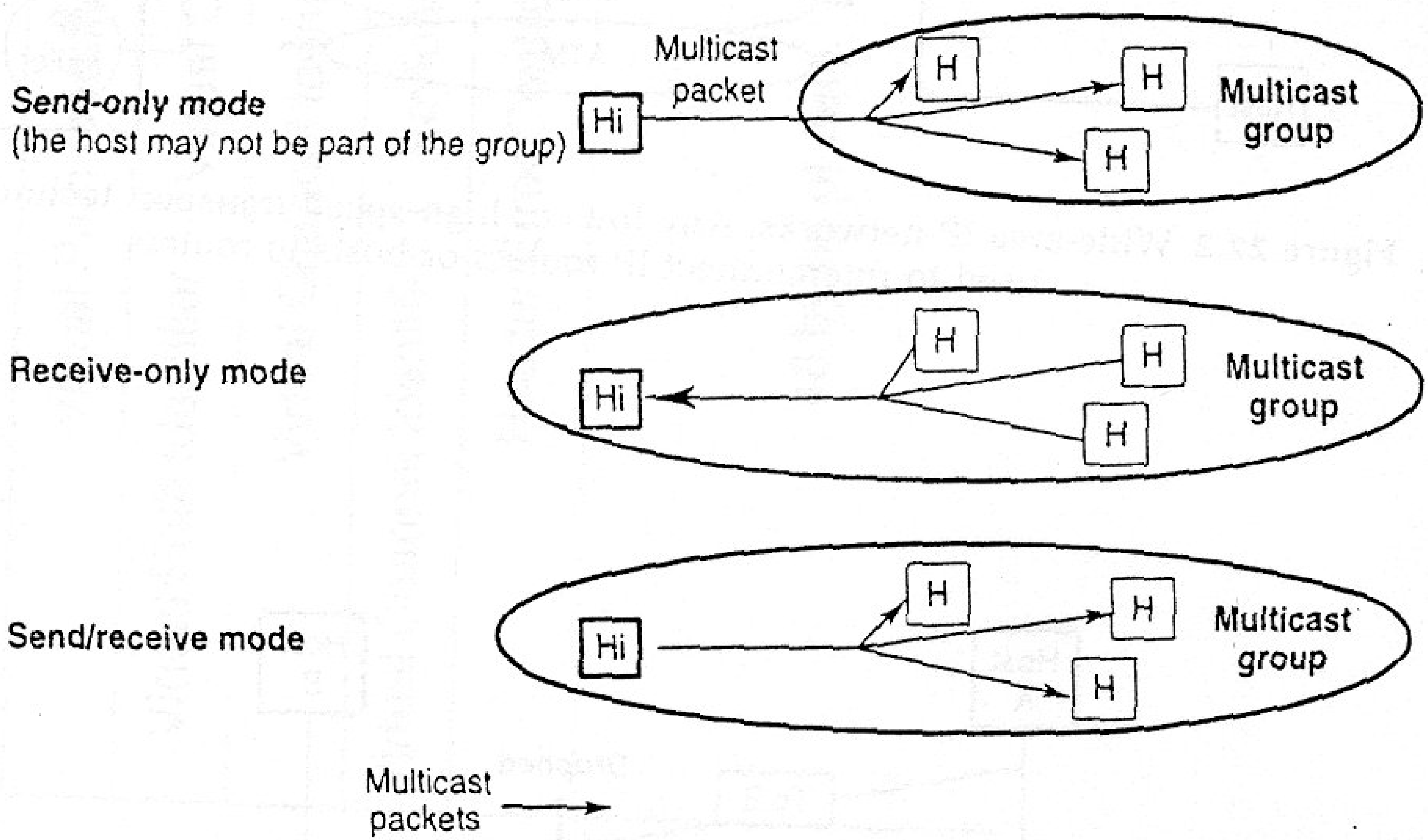



Figure 22.5 Three types of membership of IP multicast group

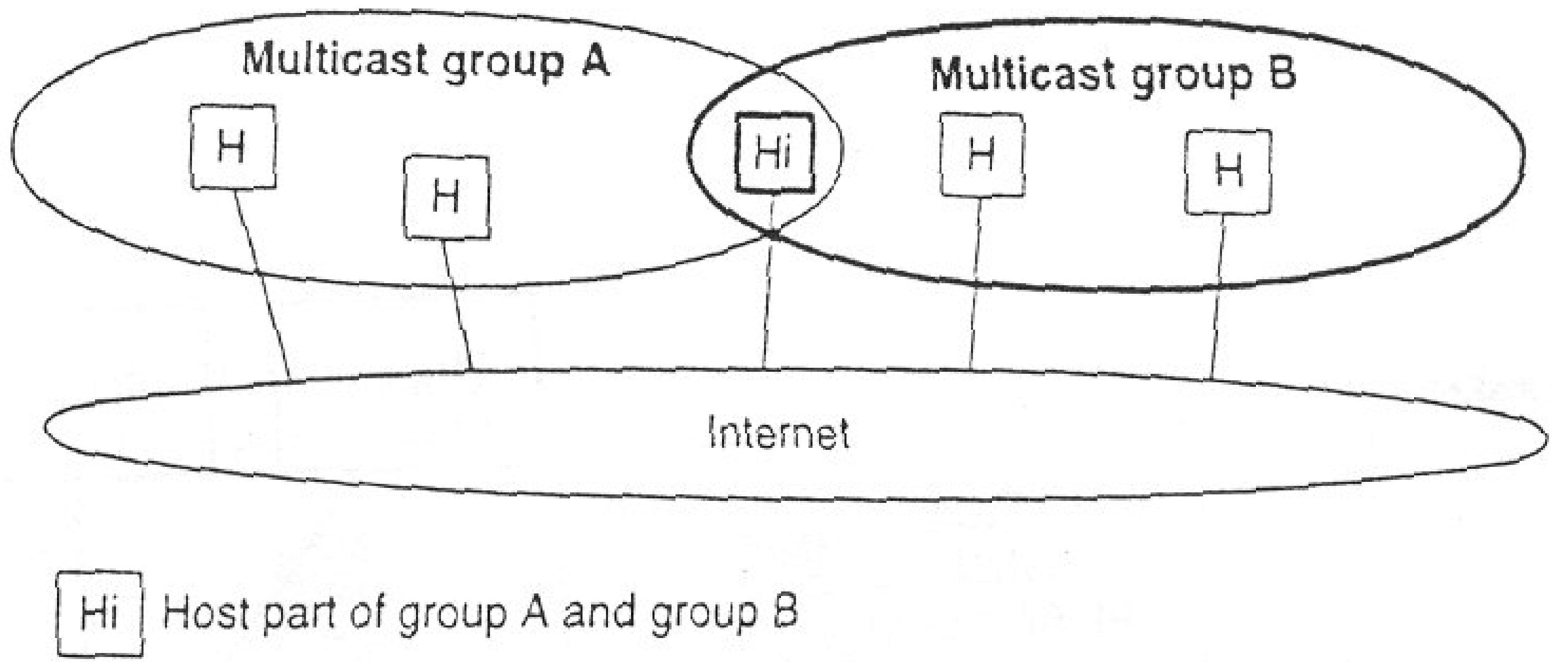



Figure 22.6 Example of a host member of several multicast groups

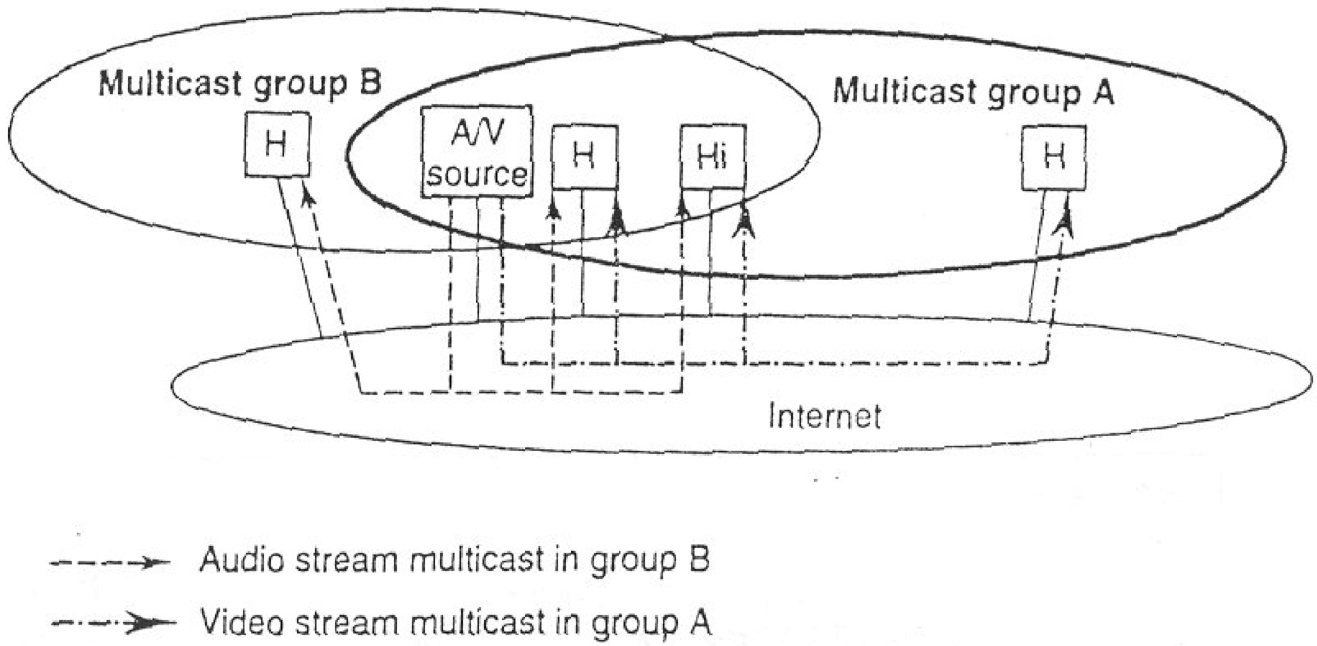



**Figure 22.7** Example of use of multiple group membership. Hosts electing to receive the audio stream join group B exclusively

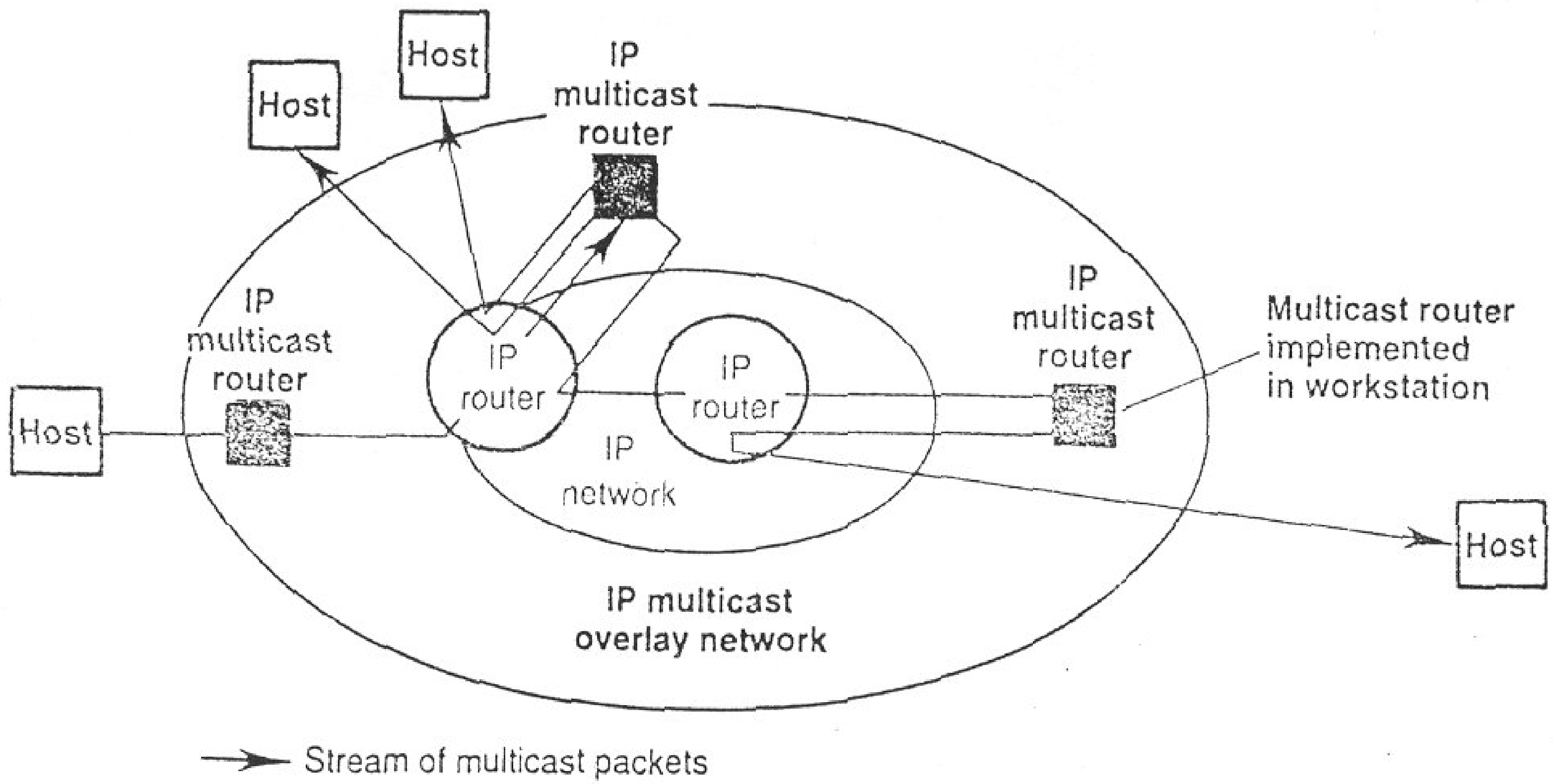



Figure 22.8 Initial implementation of the MBone network: overlay consisting of IP multicast routers implemented in workstations

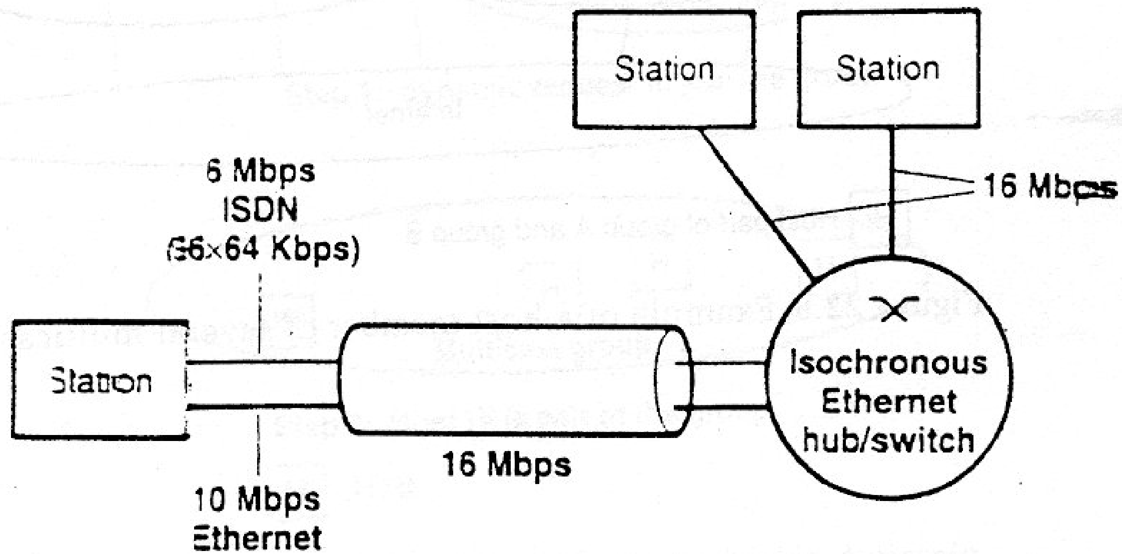



Figure 21.11 Isochronous Ethernet. Mixes conventional shared-medium Ethernet with circuit-switched ISDN-like channels

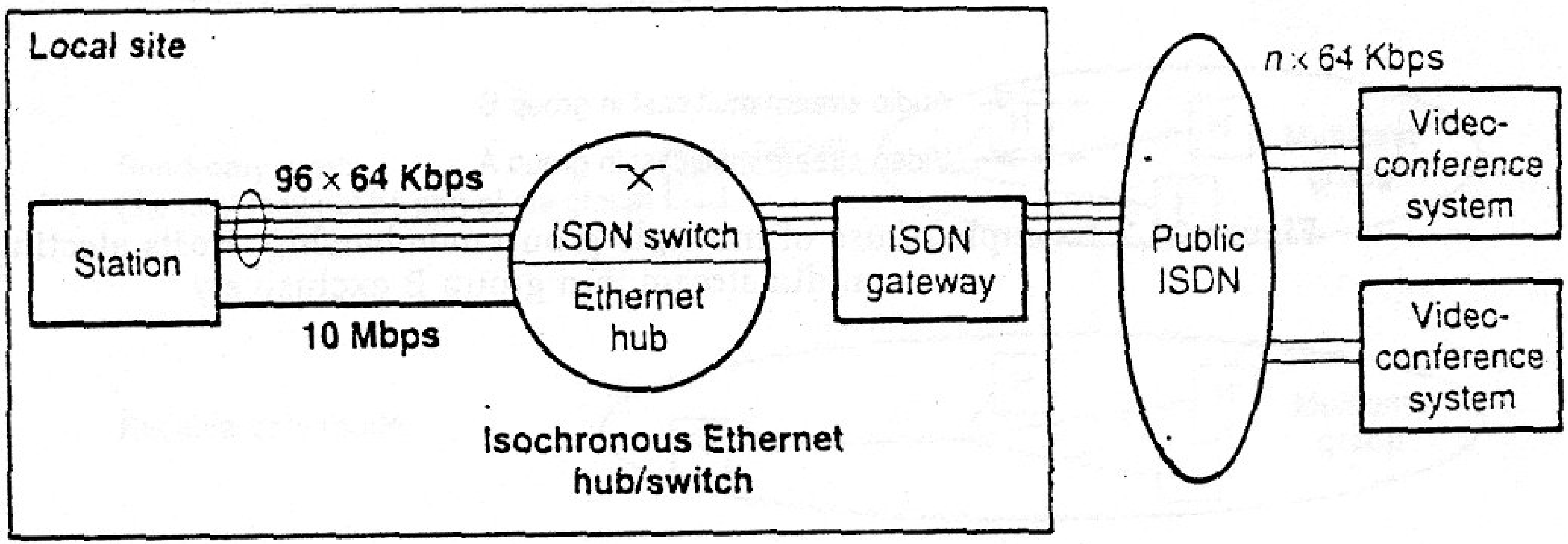



**Figure 21.12** Use of isochronous Ethernet for accessing the external public ISDN network

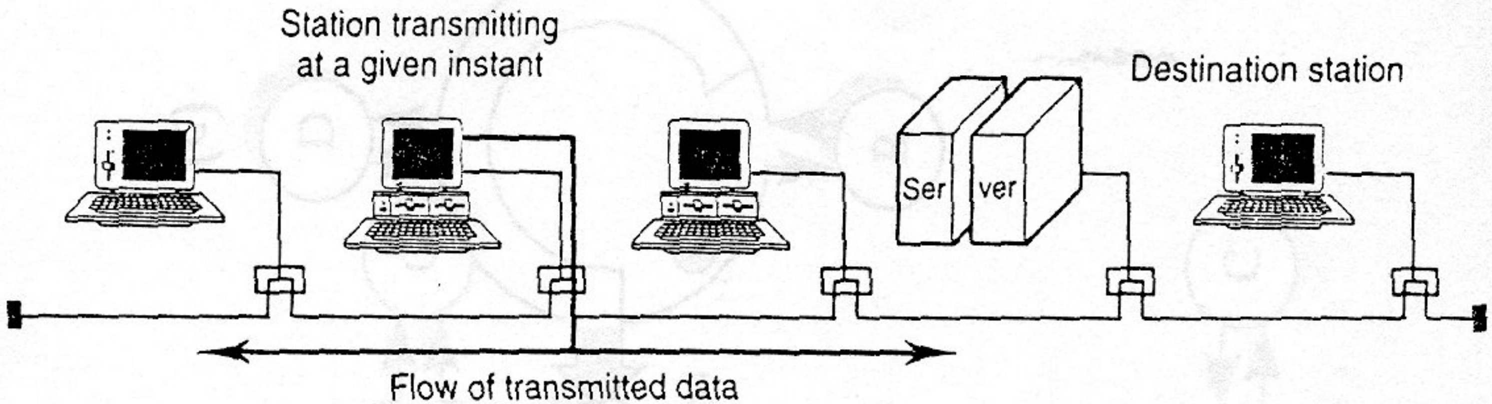



**Figure 4.5** Bus topology used in shared-medium LANs such as Ethernet. The signal is propagated in both directions and visits all the station attachments

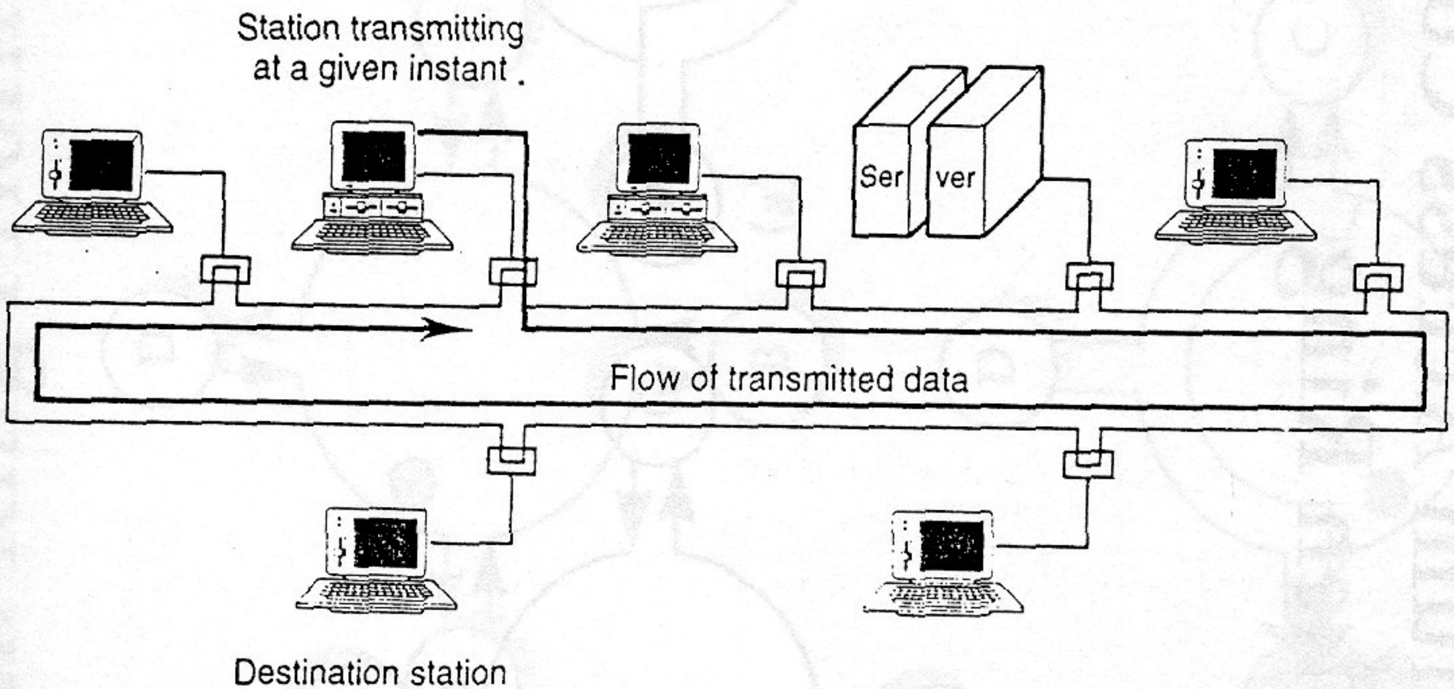
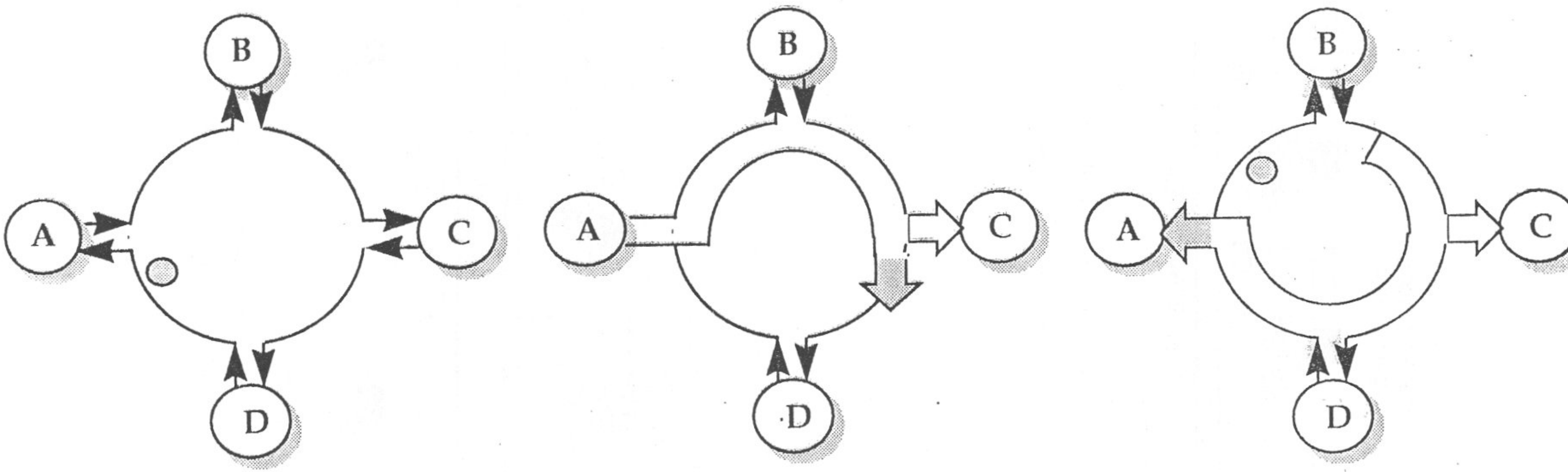


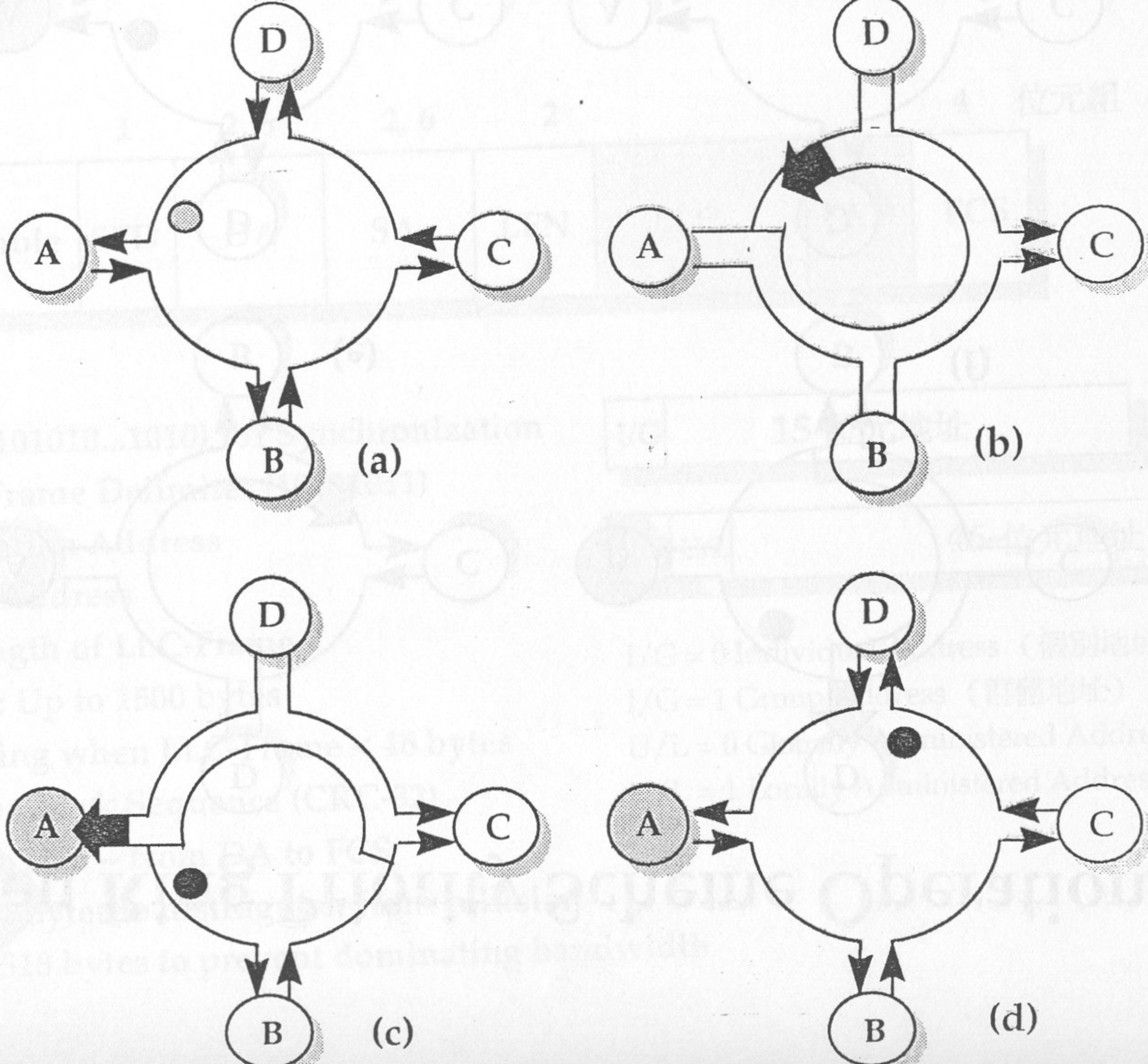

**Figure 4.6** Ring topology used in shared-medium LANs such as the Token Ring or FDDI The signal is propagated in one direction only and visits all station attachments

# Medium Access Control Method -- Token Ring

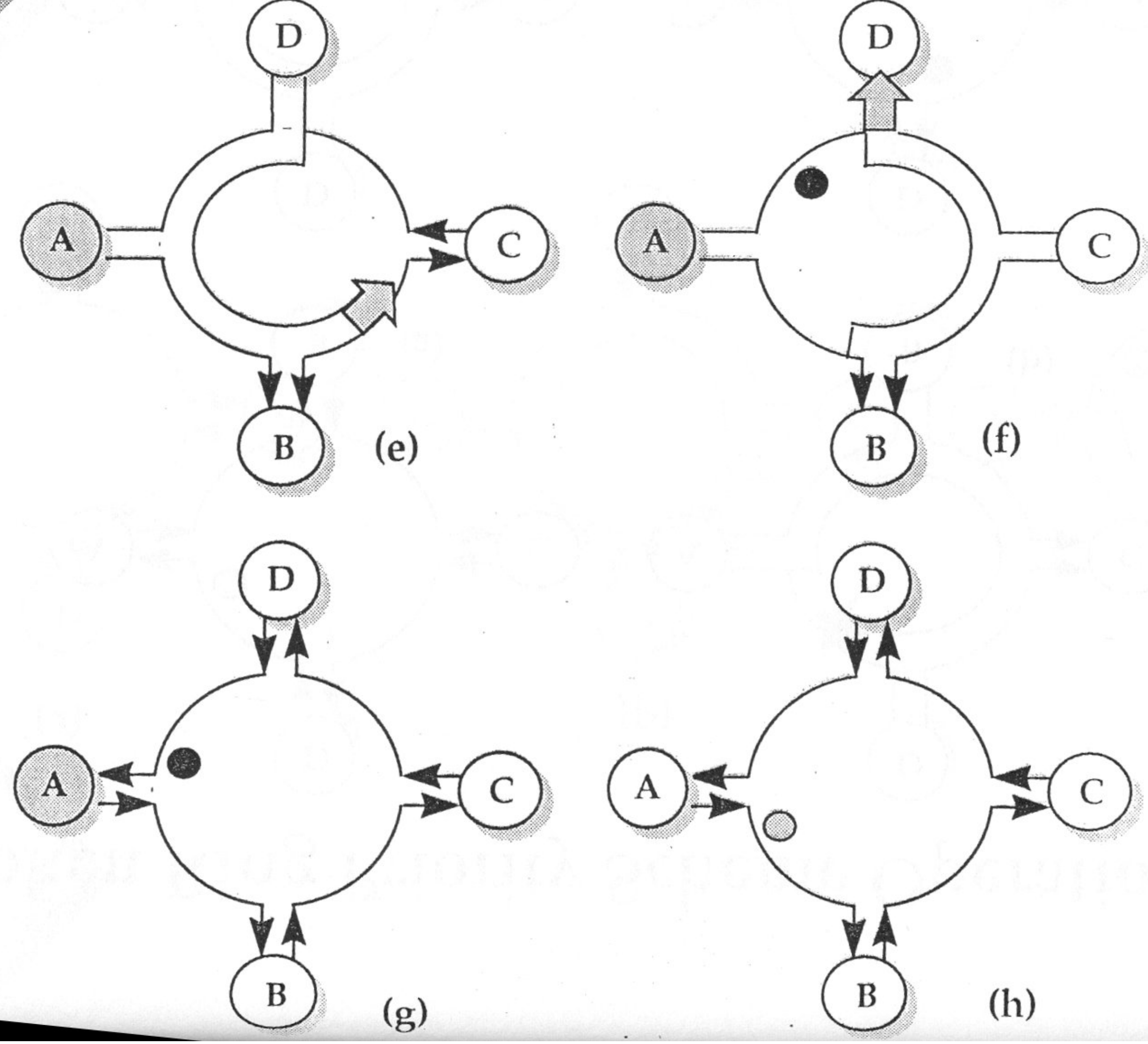



(a) (b) (c)

# Token Ring Priority Scheme Operation

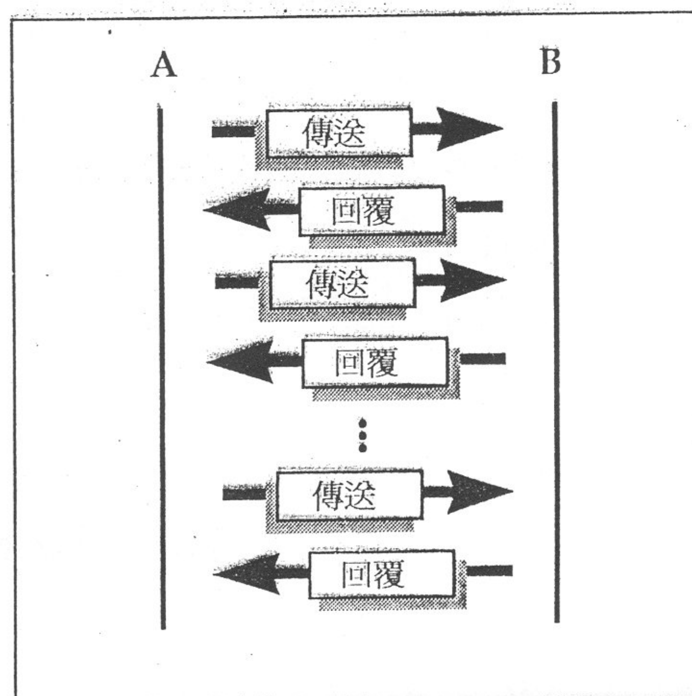


# Token Ring Priority Scheme Operation

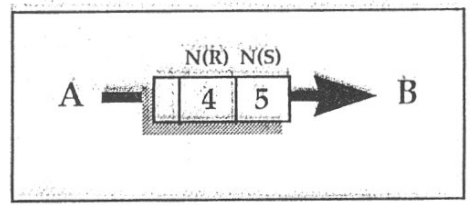


# Type 2 Services -- Flow Control

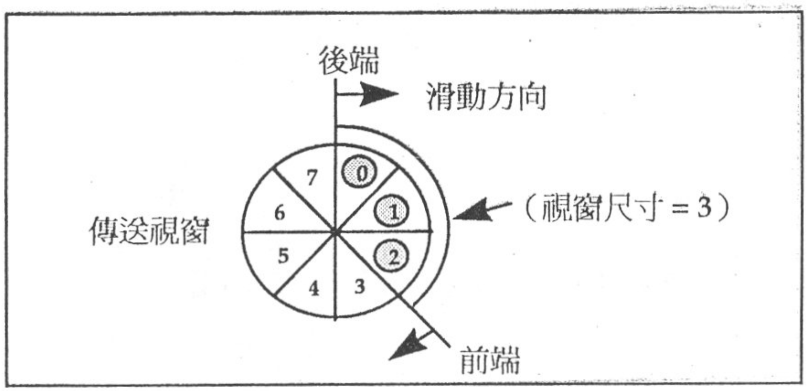
- Flow Control Methods
  - Stop-and-Wait : Simple but not efficient enough
  - Sliding Window
    - Send Window
    - Receive Window
    - Window Size

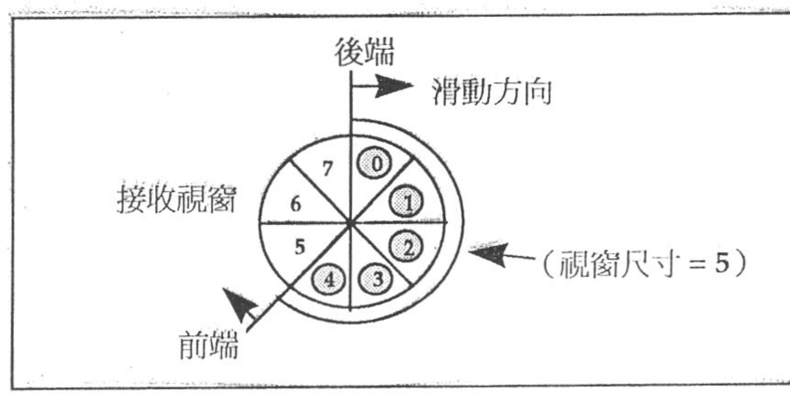


# Sliding Window Flow Control



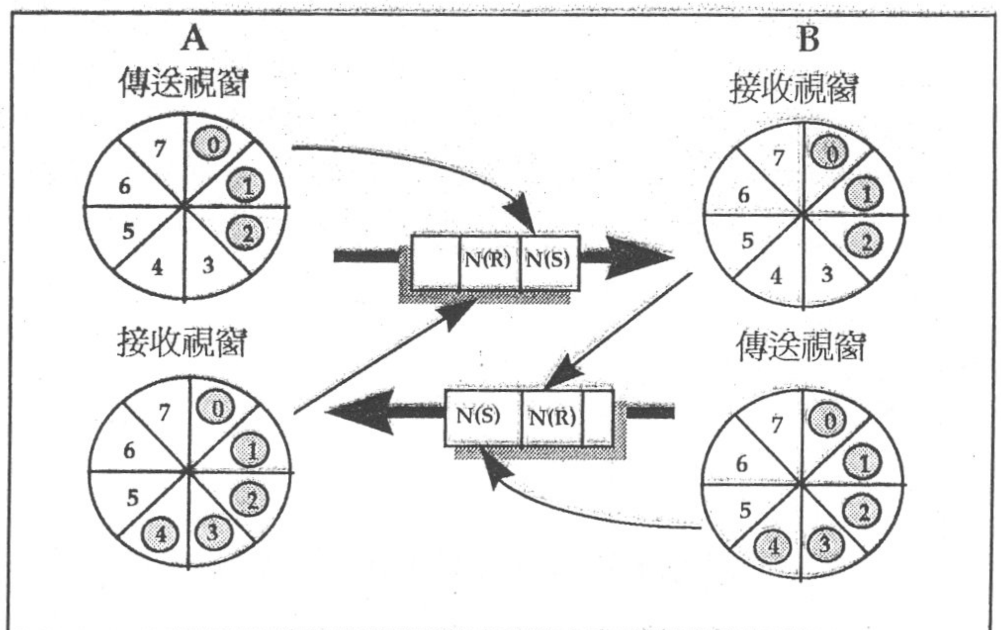

- Sequence Number
- N(S): The sequence number of this PDU
- N(R): The sequence number the LLC sublayer entity expects to find in the next LLC-PDU it receives. This means that the PDUs with sequence number < N(R) have been received.
- Send Window
- Receive Window
- Window Size



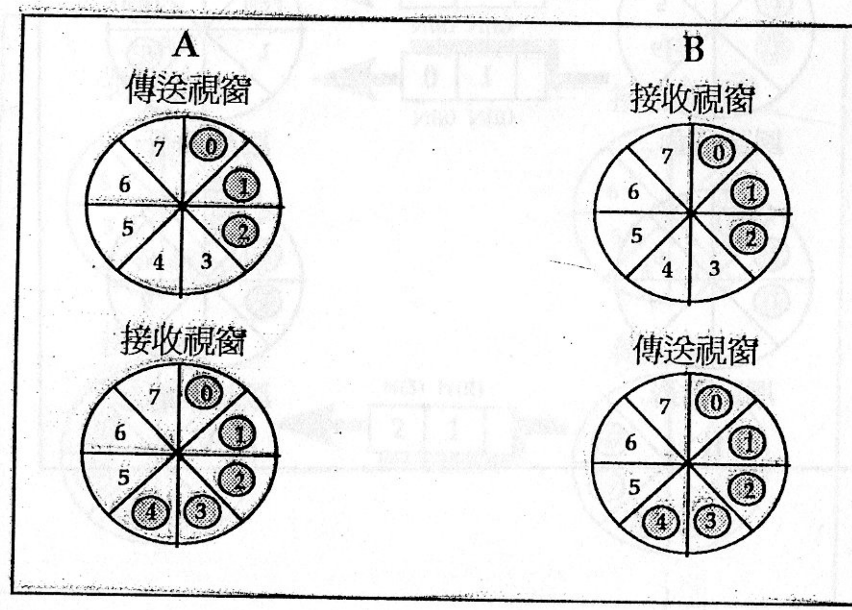
# Sliding Window

- Put N(S) and N(R) into the transmitted frames
- Sliding of Send Window
- Sliding of Receive Window

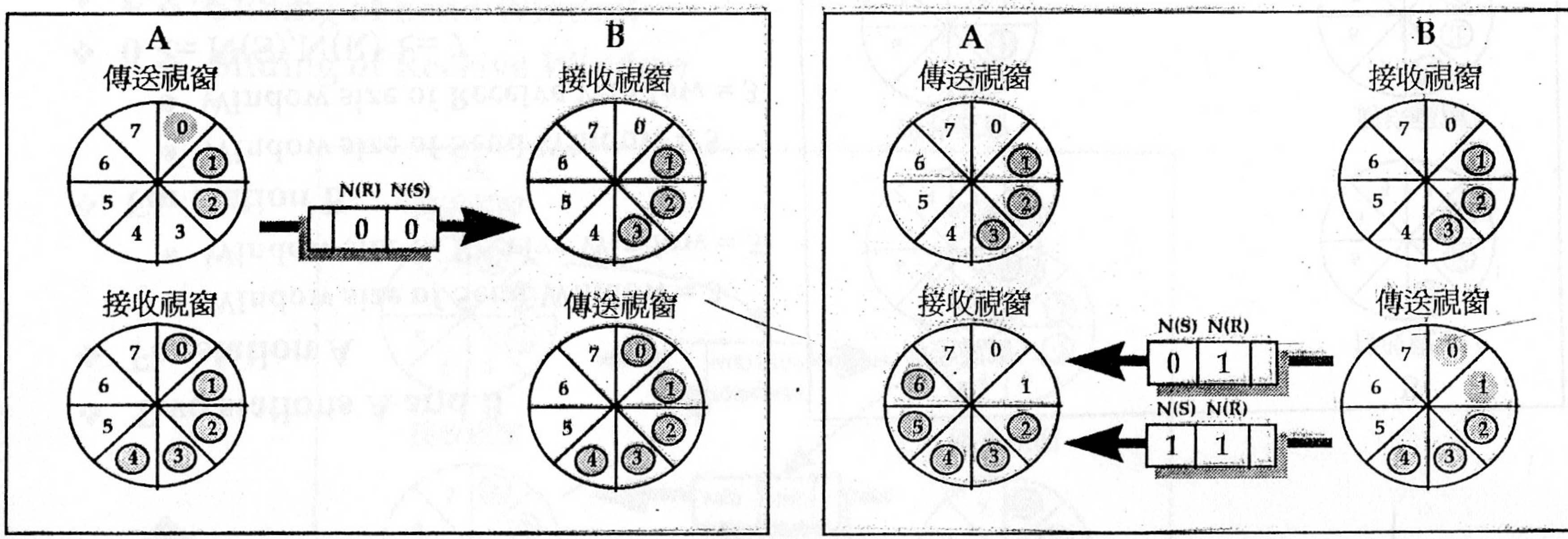


# Sliding Window Operation Example

- Two stations A and B
- For station A
  - Window size of Send Window = 3
  - Window size of Receive Window = 5
- For station B
  - Window size of Send Window = 5
  - Window size of Receive Window = 3
- 0 <= N(S),N(R) <= 7
- For the following events:
  - A sends a frame to B
  - B sends two frames to A
  - A sends three frames to B, the first one is lost
  - B sends a frame to A
  - A retransmits a the lost frame to B
  - B sends five frames to A



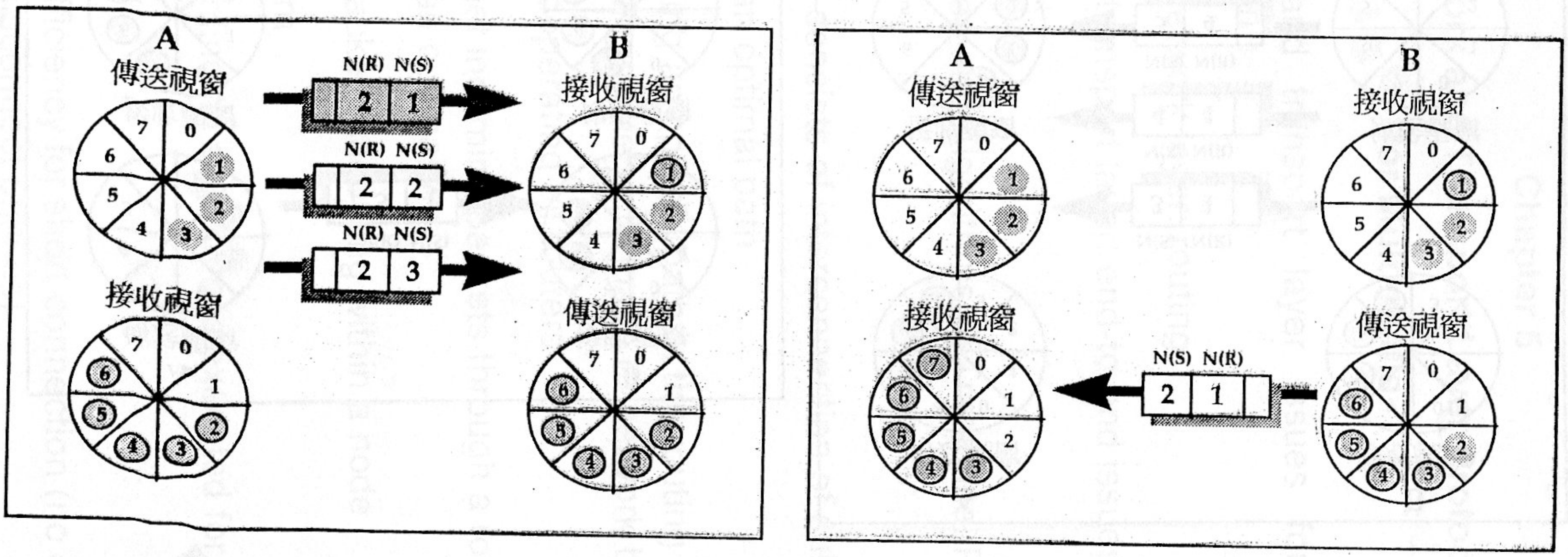
# Sliding Window Operation Example




(a) A sends a frame to B

(b) B sends two frames to A

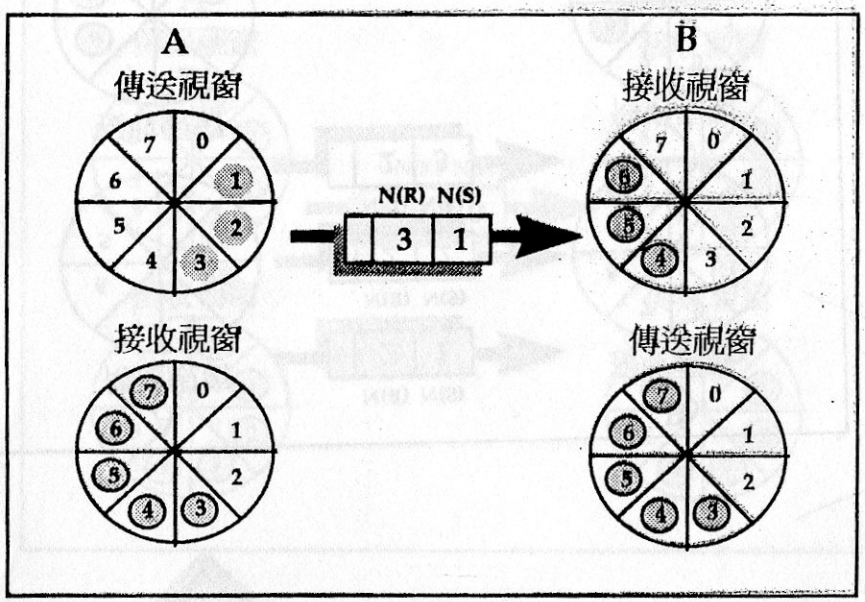
# Sliding Window Operation Example



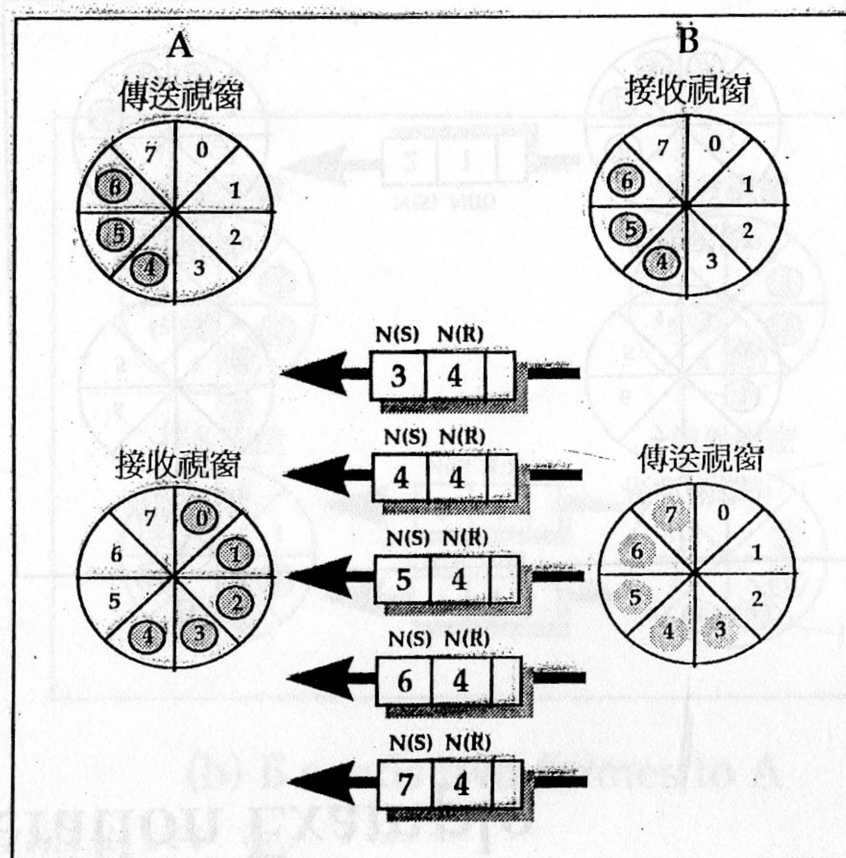

(c) A sends three frames to B, the first one is lost

(d) B sends a frame to A

# Sliding Window Operation Example




(e) A retransmits the lost frame to B




(b) B sends five frames to A