Narrowband ISDN (N-ISDN)

- Integrated Services Digital Network (ISDN) was the first *fully digital* WAN technology that integrated voice and non-voice services
  - Caller ID from a database
  - Remote meter readings
  - Online alarms
  - Other data
- Primary application of circuit switching

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N-ISDN Architecture (1/2)

- Digital bit pipe:
  - Connecting the customer with the carrier
  - Bidirectional flow of bits
- Network terminating device: NT1
  - Placed at the customer's side (ISDN ``modem'')
  - Connects to the carrier's network
  - An NT1 Can support up to 8 ISDN devices
- NT2: ISDN PBX (Private Branch eXchange)
  - For supporting larger installations
  - Provides a real-time interface for ISDN devices

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N-ISDN Architecture (2/2)

- Bit pipe supports multiple channels arbitrarily interleaved using time division multiplexing:
  - A: 4 KHz analog telephone channel
  - B: 64 Kbps digital channel (voice or data)
  - C: 8 or 16 Kbps digital channel
  - D: 16 Kbps digital channel for out-of-band signaling
- Standardized combinations:
  - Basic rate: 2B + 1D
  - Primary rate: 23B + 1D (U.S) / 30B + 1D (Europe)
- Focused on 64 Kbps channels, therefore *narrowband*

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N-ISDN Summary

- Massive attempt to replace analog telephone system with a digital one
- Most important shortcoming limited bandwidth
  - LANs: 10 Mbps to 100 Mbps
- Managed to stay alive longer that it deserved
  - Basic rate sold as Internet access method

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Packet Switching

- Based on *message switching*:
  - No physical circuit path is established between sender and receiver; *connectionless*
  - Blocks of data are sent, stored in *switching devices* (routers) then forwarded one hop at a time
  - No limit on block size
- Packet switching:
  - Tight upper limit on block size
  - Blocks buffered in memory
- Packets:
  - Include a destination and sequence number
  - Information about the data stream to which they belong
  - Can follow different routes before being reassembled by the destination
- New paradigm, changed the world

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Circuit vs Packet Switching

Item	Circuit Switching	Packet Switching
Dedicated path	Yes	No
Bandwidth	Fixed	Dynamic
Wasted bandwidth	Yes	No
Store-and-forward	No	Yes
Data follow same path	Yes	No
Call setup in advance	Required	Not required
Congestion	Setup	Every packet
Charging	Time/Distance	Time/Bytes

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Broadband ISDN (B-ISDN)

- Based on ATM (Asynchronous Transfer Mode) technology
  - Packet switching, well yes, but not really
  - Emulates circuit switching using packet switching
- Therefore, backwards compatible with N-ISDN
- Bandwidth increase by a factor of 2500
  - 156 Mbps
- High expectations, thought to be the ``universal telecommunications technology of the future''

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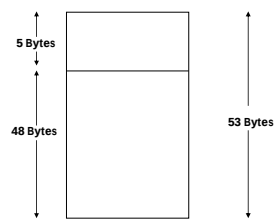
B-ISDN Packets

- All information is carried in fixed size blocks



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B-ISDN: Virtual Circuit Switching (1/3)

- No physical path is established, but a *virtual* one using packet switching
- Route is chosen from source to destination
- Intermediate routers (switches) make table entries so they can route incoming packets along the virtual circuit path
- When a packet arrives, a switch:

- Inspects the packet's header to find the virtual circuit it belongs to
- Looks up that virtual circuit in its table to find which communication line to send it on

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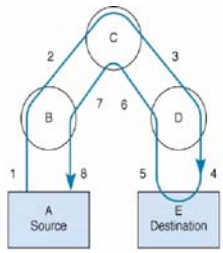
B-ISDN: Virtual Circuit Switching (2/3)

- Connection-oriented service paradigm:



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B-ISDN: Virtual Circuit Switching (3/3)

- Permanent Virtual Circuit (PVC) paths are setup ahead of time after an agreement between a customer and a carrier

- Table entries are hard-coded in switches
- Charged monthly
- May be idle most of time
- No setup time; important in some applications (credit card verifications)

- Switched Virtual Circuit (SVC) paths:

- Like telephone calls
- Path is setup dynamically when needed; torn down afterwards

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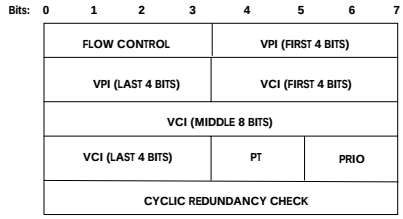
Asynchronous Transfer Mode (ATM)

- The underlying transfer technology of B-ISDN
- Data are divided into fixed size blocks called *cells*

- 53 bytes: 5 header, 48 payload



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ATM: Cell Header

- VPI: Virtual Path Identifier
- VCI: Virtual Channel Identifier
  - Together identify the cell's destination
- PT: Payload type (voice or data)
- PRIO: Cell loss priority bit
  - Can a packet be discarded when the network becomes congested?
- CRC: Used to verify that the cell was not damaged in transit

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ATM: VPI/VCI

- ATM connection: VC
  - Actually stands for *virtual channel*
  - Most people prefer the more descriptive term *virtual circuit*
- Each VC is assigned a 24-bit ID
  - VPI: Specifies the path the VC follows through the network (8 bits)
  - VCI: Specifies a single VC within the path (16 bits)
- The two fields are not interpreted
  - Viewed as a single 24-bit binary value that gives the connection identifier

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ATM: Label Switching

- ATM network formed using ATM switches
  - Attachment points: *ports*
- An ATM switch:
  - Changes the VPI/VCI in each cell it handles
- Forwarding table specifying how incoming cells are forwarded:
  - Each entry corresponds to a possible VPI/VCI for a given port (over which the cell will be sent)
  - Replacement VPI/VCI
- The switch rewrites the VPI/VCI in the cell header with the replacement and forwards the cell

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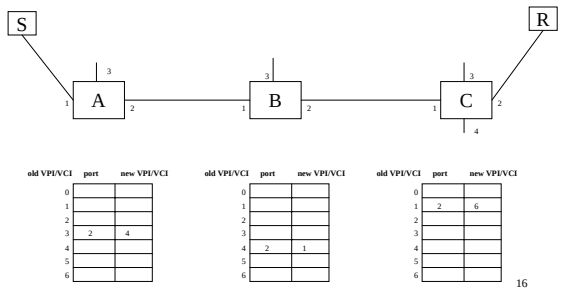
ATM: Label Switching Example



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ATM: Network Setup

- ATM PVCs (*provisioning*):
  - One pair of switches is considered at a time
  - Data-specific VPI/VCI identifiers are not global
  - A VPI/VCI that is not used is selected, a table entry is reserved
  - On the next router the table is filled accordingly
- ATM SVCs:
  - Connection request propagates and table entries are created
  - If a router rejects the VC an error message is sent back
    - * Request and error messages are control traffic
    - * Denoted by global VPI/VCI values

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