Executive Briefing:
ATM and Frame Relay Networks

Distributed Networking Associates

Fall, '99

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Biographical Information - The seminar will be led by Steven Taylor, President of Distributed Networking Associates and columnist for Data Communications magazine. Now in his tenth year as an independent consultant, planner, author, and teacher, Mr. Taylor is frequently quoted in the trade press and is one of the industry's most published authors on high bandwidth networking techniques. Distributed Networking Associates may be contacted at 2707 Lake Forest Drive, Greensboro, NC 27408; Phone: (336) 288-3858; Electronic mail: taylor@distributed-networking.com.

Executive Briefing

- What are ATM & Frame Relay?
- ATM / Frame Relay Networking Advantages
- ATM & Frame Relay: Technologies, Services, and Standards
- What About Multimedia?
- Physical Layer: Dedicated Bandwidth
- Future of the Private Network

Executive Briefing

- What are ATM & Frame Relay?

Telecommunications Trends

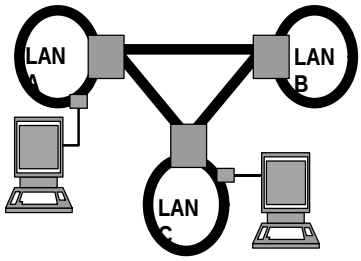
- Evolution from Host-Centric to Distributed (Network-Centric) Computing
  - Fueled by high-performance, low-cost workstations
  - Character-based to file-based traffic evolution
  - Result: Bursty, high-volume traffic

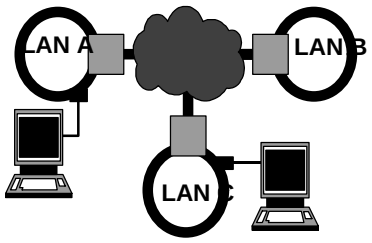
Facility speed	Transfer Time
9.6 kbps	14 minutes
64 kbps	2 minutes
1.544 Mbps	5 seconds
45 Mbps	.2 seconds
150 Mbps	.05 seconds

Based on 1 megabyte of information

Lan Interconnection

- Traditional LAN Internet
  - Dedicated circuits with too much or too little bandwidth
- Packetized LAN Internet
  - Elastic bandwidth provided "on demand"

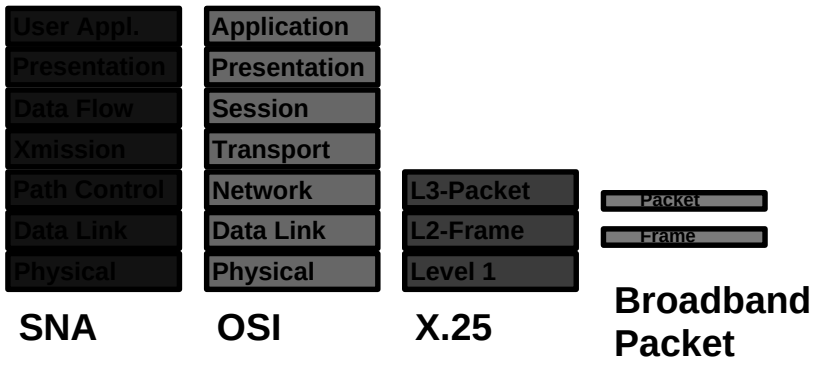




What are ATM & Frame Relay?

- PACKET technologies and services optimized for the transport of protocol oriented data
- Functional competitor for dedicated 56 kbps, Fractional T1 and T1/T3 services
- Not a realistic direct competitor for X.25, SNA, DECNet, TCP/IP, OSI, etc.
- Implementations include Frame Relay, SMDS, and ATM

Positioning Broadband Packet

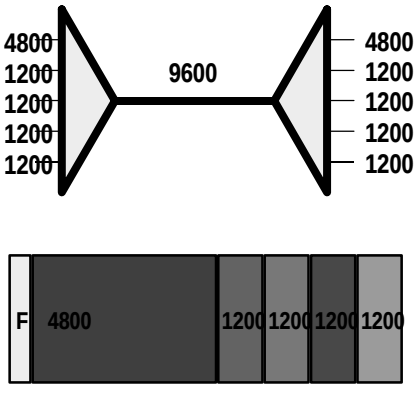


What is “Framing”?

- Framing is the method used by both Time Division Multiplexers, including Circuit Multiplexers (TDMs), and Packet Multiplexers (statistical multiplexers), to determine which data belong(s) to which channels
- This forms the basic difference between circuit (dedicated bandwidth) multiplexing and switching and packet (dynamically allocated) multiplexing and switching

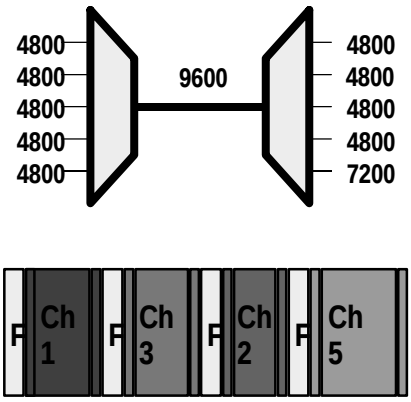
Circuit (TDM) Multiplexing

- Dedicated bandwidth for each channel
- Minimal, fixed delays
- "Transparent" throughput
- Implicit Framing

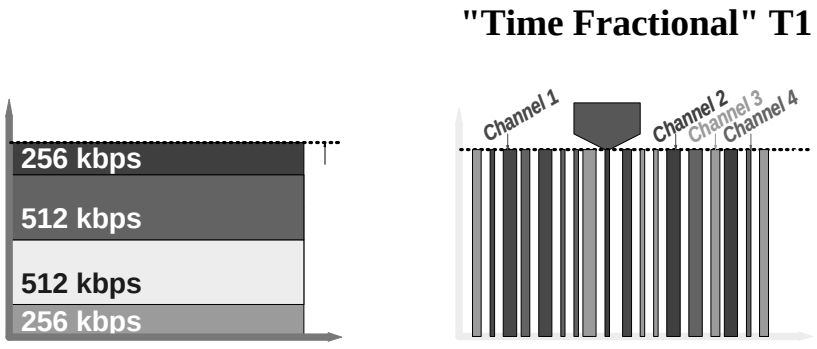


Packet (Statistical) Multiplexing

- True dynamic bandwidth allocation
- Variable delays
- Protocol dependence
- Explicit framing

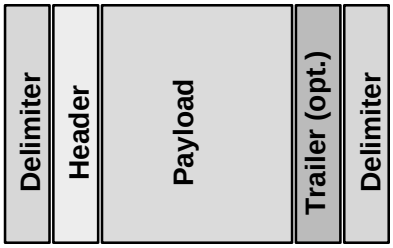


"Fractional" Services



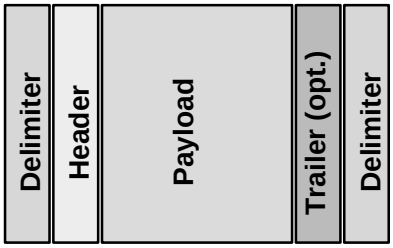
Generic Packet Format

- Protocol Data Unit (PDU) is basic building block
- Key differences:
  - Fixed vs. variable PDU length
  - Connection vs. connectionless



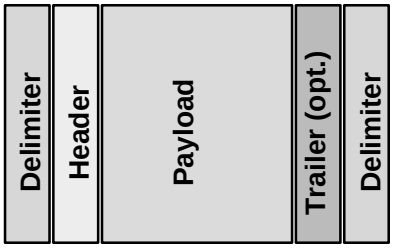
Generic Packet Format: Payload

- **Payload**
  - **Fixed length: Cells**
    - » **Easy to process**
    - » **Predictable delay**
    - » **"ATM"**
  - **Variable: Frames**
    - » **Efficient use of bandwidth**
    - » **"Frame Relay"**



Generic Packet Format: Header

- **Header**
  - Connection oriented
    - » Virtual Circuit number
    - » Conserves address space
  - Connectionless
    - » "Universal," unique address
    - » Needs large address space
      - Is this a problem?
  - More later….

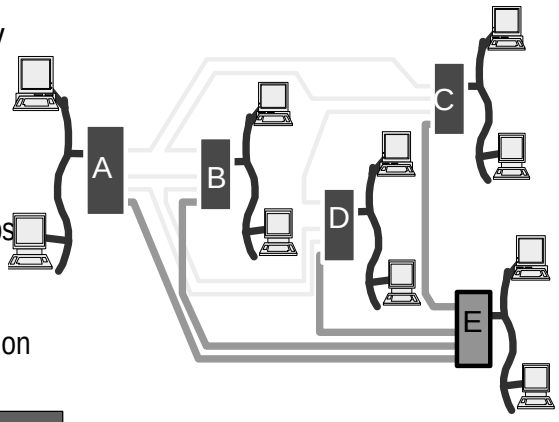


Executive Briefing

- What are ATM & Frame Relay?
- ATM / Frame Relay Networking Advantages

Traditional Network

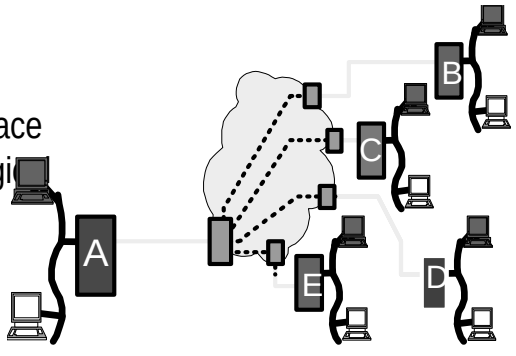
- 1:1 Physical to logical connectivity
- Separate physical interface for each location/link
  - Fractional T1 helps physical interface problem, but not bandwidth allocation



Return

ATM / Frame Relay Network

- Single physical interface with multiple logical terminations
- Higher speed interface handles multiple logical sessions



Return

Public ATM / Frame Relay Advantages

- Dynamic allocation of bandwidth in the network
- Allows carriers to share facilities on a packet-by-packet basis
- Primarily economic advantages

Traditional **ATM / Frame Relay**

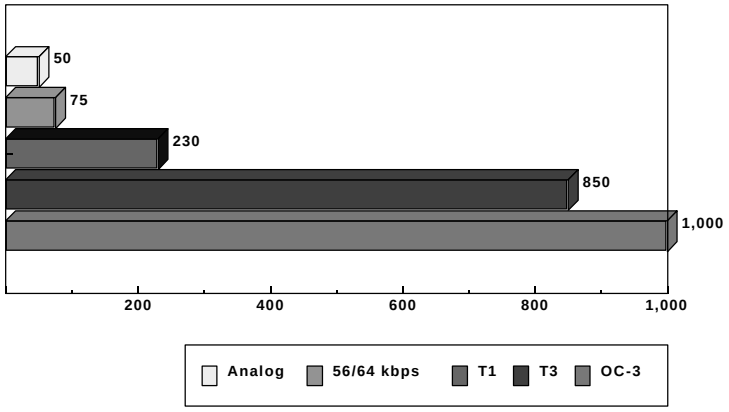
Public ATM / Frame Relay Advantages

- Dynamic allocation of bandwidth in the network
- Reduced local access costs
- Statistical multiplexing on access lines
- Inter-LATA
  - Dedicated local access can be 50% to 70% of total WAN cost
  - 3 or more sites: great savings
- Intra-LATA
  - Similar savings, plus intra-

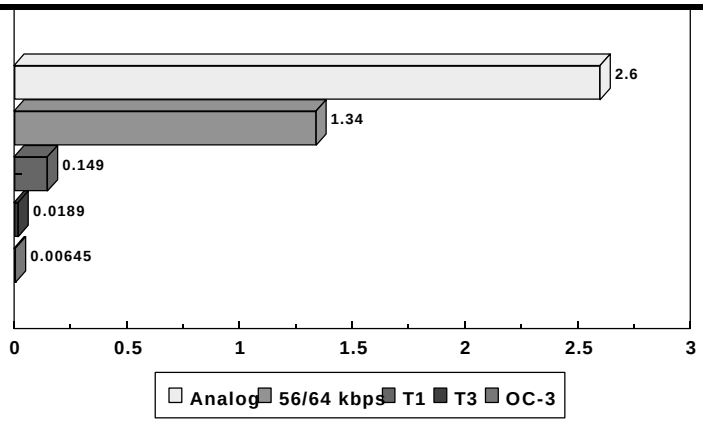
Traditional **ATM / Frame Relay**

Typical Monthly Local Loop Costs

- Estimates - Dollars per month



Dollars per kbps



"Analog" assumes 19.2 kbps modem

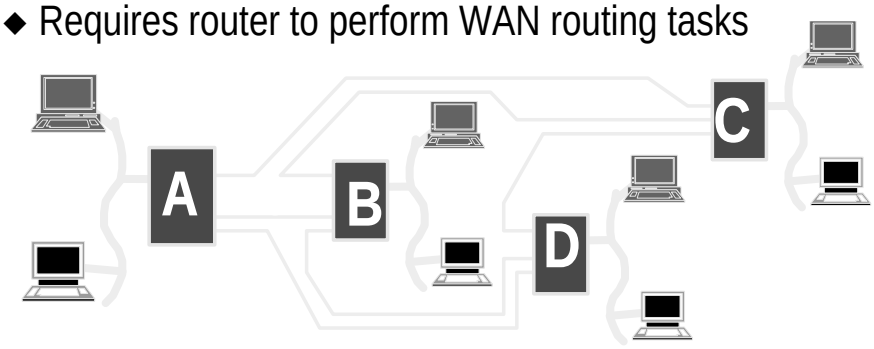
Public ATM / Frame Relay Advantages

- Dynamic allocation of bandwidth in the network
- Reduced local access costs
- Reduced hardware costs and commitment
- Single access port serves multiple connections
- Software upgrade is primary change for various type of broadband packet (plus CSU/DSU for SMDS & ATM)
- Significant reduction in costs

Traditional **ATM / Frame Relay**

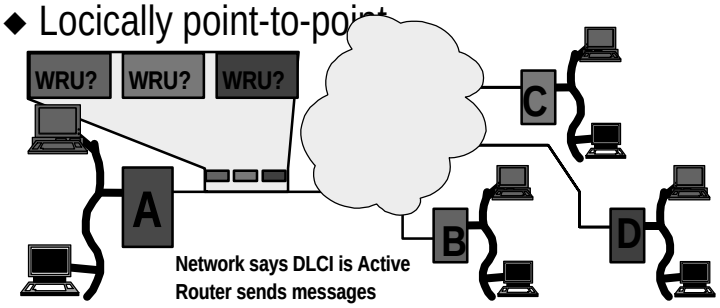
Router Net without ATM / Frame Relay

- Inherent "bypass" capabilities
- "Self-learning" to discover network topology
- Requires router to perform WAN routing tasks



Router Net with ATM / Frame Relay

- One physical interface; multiple logical terminations
- Same "self-learning" discovery process
- Locically point-to-point



Public ATM / Frame Relay Advantages

- Dynamic allocation of bandwidth in the network
- Reduced local access costs
- Reduced hardware costs and commitment
- Simplified network management
- Move from physical to logical management
- Ease of growth and change
- Significant reduction in "Windshield Time" (or "Airplane Time")
- Improved Reliability
- Carrier office based switching

Traditional **ATM / Frame Relay**

Public ATM / Frame Relay Advantages

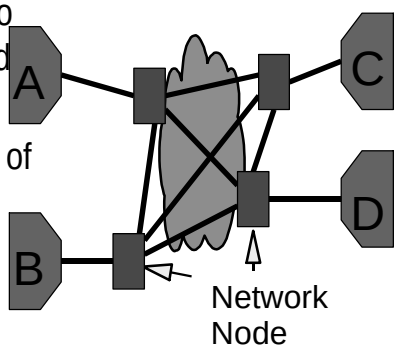
- Dynamic allocation of bandwidth in the network
- Reduced local access costs
- Reduced hardware costs and commitment
- Simplified management
- Support for multimedia?

- Advantages
  - "Seamless & scaleable" network for all applications
  - Eliminates redundant nets
  - Excellent support for "data"
  - Generally attractive pricing
- Cautions
  - Real-time video vs. Image
  - Status of packetized video/voice
  - LAN/WAN issues

Traditional **ATM / Frame Relay**

Private Frame Relay Networks

- Network bandwidth is dynamically allocated to channels, but dedicated internodally
- Key to efficiency is lots of traffic
- Enhanced hardware & management options



Migration from Current T1 Networks

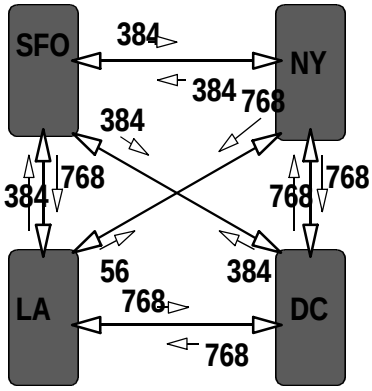
- Advantages
  - Protects current installed based (legacy systems)
  - Add-on to current equipment
  - Integrated TDM/Packet preserves simple voice/data integration
  - Provides interim solution
- Disadvantages
  - Most T1 equipment is based on circuit switching architecture
  - Requires large amount of traffic from each site to gain "good statistical mix"
  - Still must engineer to meet peak traffic over dedicated lines for internodal trunks

Public vs. Private Decision Factors

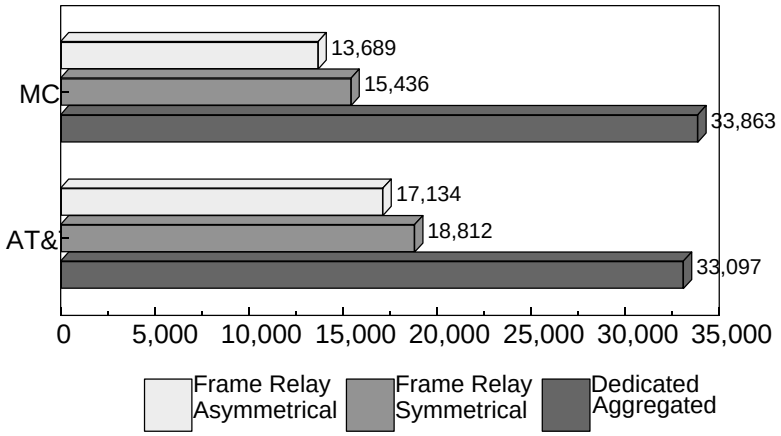
- Price
  - Cost of services - Dedicated leased lines vs. packetized services
  - Cost of equipment
  - Commitment and dedication of capital expenses
  - Commitment of personnel

Case Study Demands

	SFO	LA	DC	NY
SFO to		768	384	384
LA to	384		384	56
DC to	384	768		768
NY to	384	768	768	



Case Study Prices



Case Study Summary

- Dedicated Network
  - IXC Cost: $31k+ per month
  - Minimum of 8 local loops
  - Limited alternate routing
  - Relatively complex upgrade path
- Frame Relay Network
- IXC Cost: $13k to $19k per month
- Minimum of 4 local loops
- Alternate routing within network
- Relatively simple upgrade path

Public vs. Private Decision Criteria

- Price
- Network Topology
  - Private nets tend to excel where there is a high density of traffic among a relatively few sites
  - Public nets for bursty traffic among many sites
  - Does the service availability fit the net topology?

Public vs. Private Decision Criteria

- Price
- Network Topology
- Network "Religion" and views on outsourcing
  - Commitment to a singular type of technology
  - Internal vs. external network responsibility
  - Capital commitment
  - Enslow's Law & Taylor's Corollary

Public vs. Private "Objective" Criteria

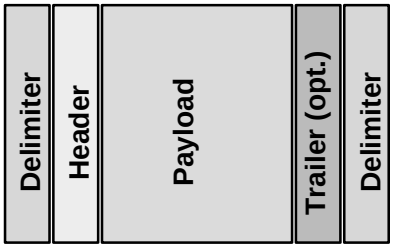
	Public	Private
Network facilities	Stat muxed	Dedicated
Network access	Stat muxed	Dedicated
Net hardware	Not owned	Customer owned
Access hardware	CPE - DTE & DSU	Local Connection
Maintenance Respons.	Network	Customer
Price base	Usage sensitive	Fixed per month
Technology migration	Fairly easy	More difficult
Historical precedent	Voice only (US)	Strong for data
Intracompany comms.	Good	Good
Intercompany comms.	Possible	More difficult
Service ubiquity	Needed	Not needed

Executive Briefing

- What are ATM & Frame Relay?
- ATM / Frame Relay Networking Advantages
- ATM & Frame Relay: Technologies, Services, and Standards

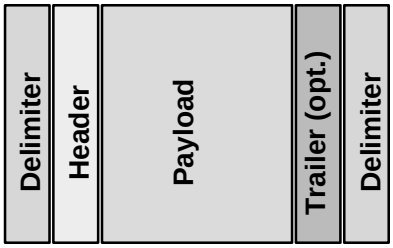
Generic Packet Format

- Protocol Data Unit (PDU) is basic building block
- Key differences:
  - Fixed vs. variable PDU length
  - Connection vs. connectionless



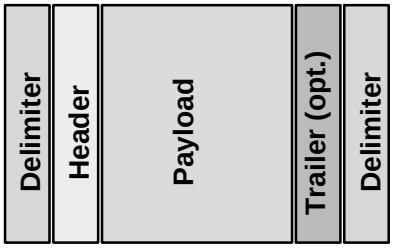
Fixed vs. Variable Length PDUs

- Frames have variable length payloads
  - Efficient bandwidth use
  - Excellent match for data
- Cells have fixed length payloads
  - Simple processing
  - More predictable delay



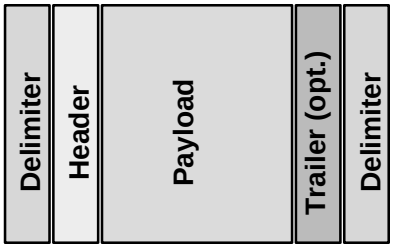
Type of Addressing

- Connection Oriented
  - Based on circuit number
  - Bandwidth efficient
    - » Both PVC and SVC
- Connectionless
  - Contains complete source/destination address



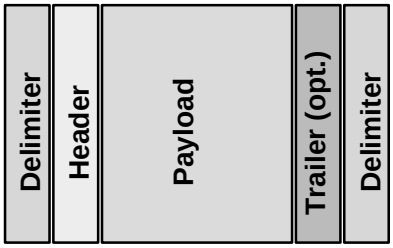
What is ATM?

- Packet Technology
- Cells
  - Easy to process
  - Not particularly efficient
  - Latency can be controlled
- "Fixed-packet-length" Frame Relay



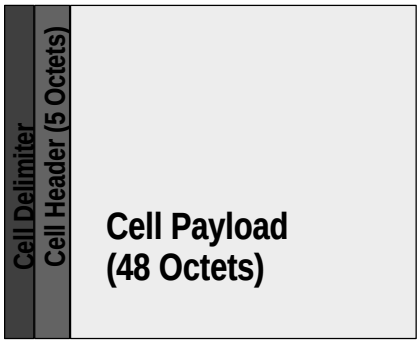
ATM

- Connection-oriented
  - PVC & SVC in current specs
  - Mandated by overhead
  - Many connectionless aspects addressed by SMDS / AAL3/4
- Cells
  - Easy to process
  - Not particularly efficient
  - Latency can be controlled



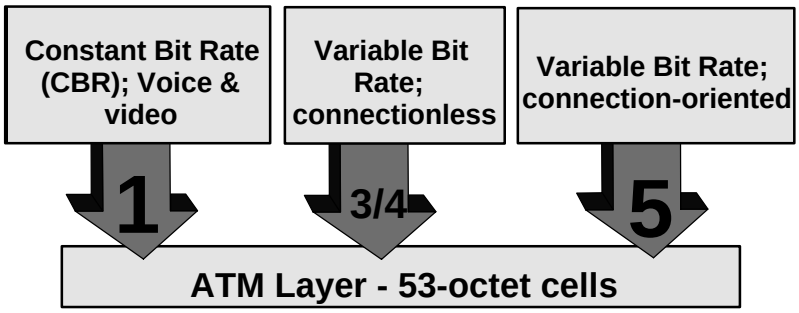
Cell Relay Format

- Standard cell is agreed to be 53 Octets
  - Actual size is compromise
- Long cells
  - Good for bandwidth efficiency re header
- Short cells
  - Good for delay
  - Good for "last cell" efficiency



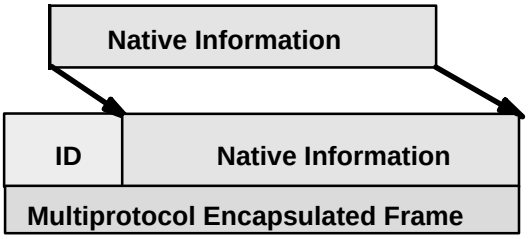
ATM Adaptation Layers

- Different AALs for different types of traffic; Most common: 1, 3/4, 5

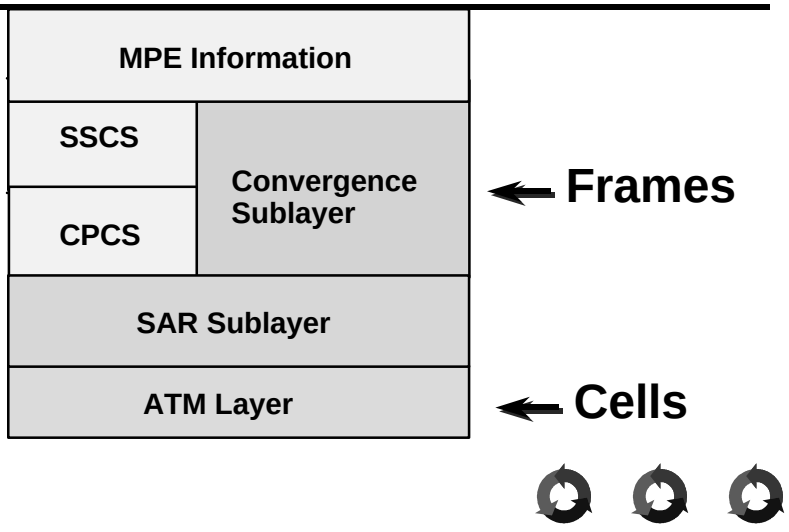


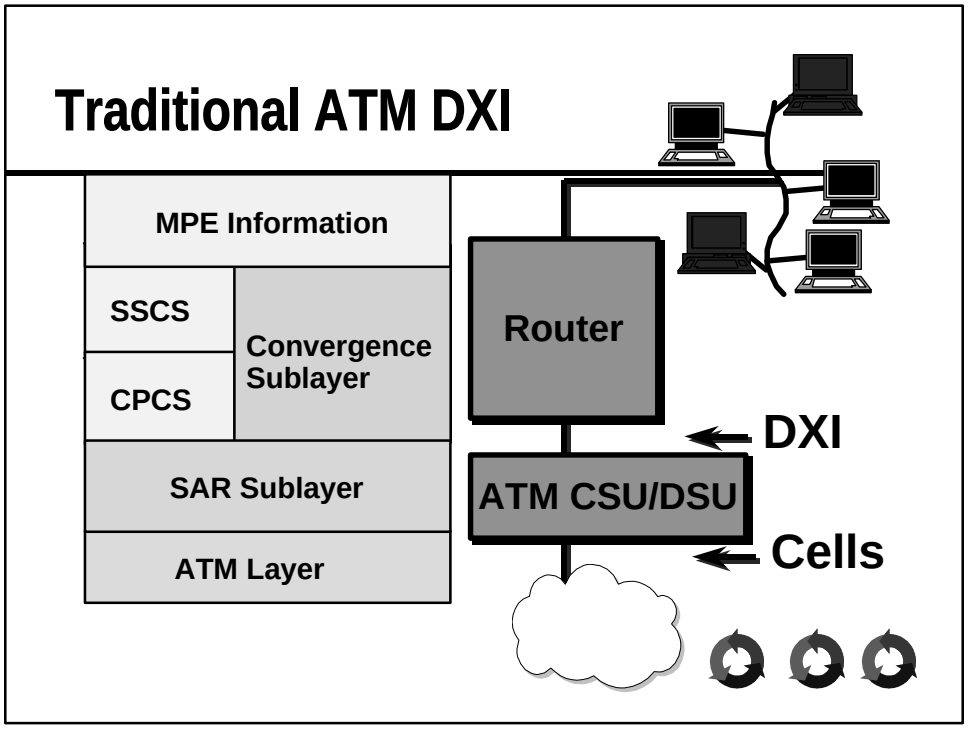
Multiprotocol Encapsulation

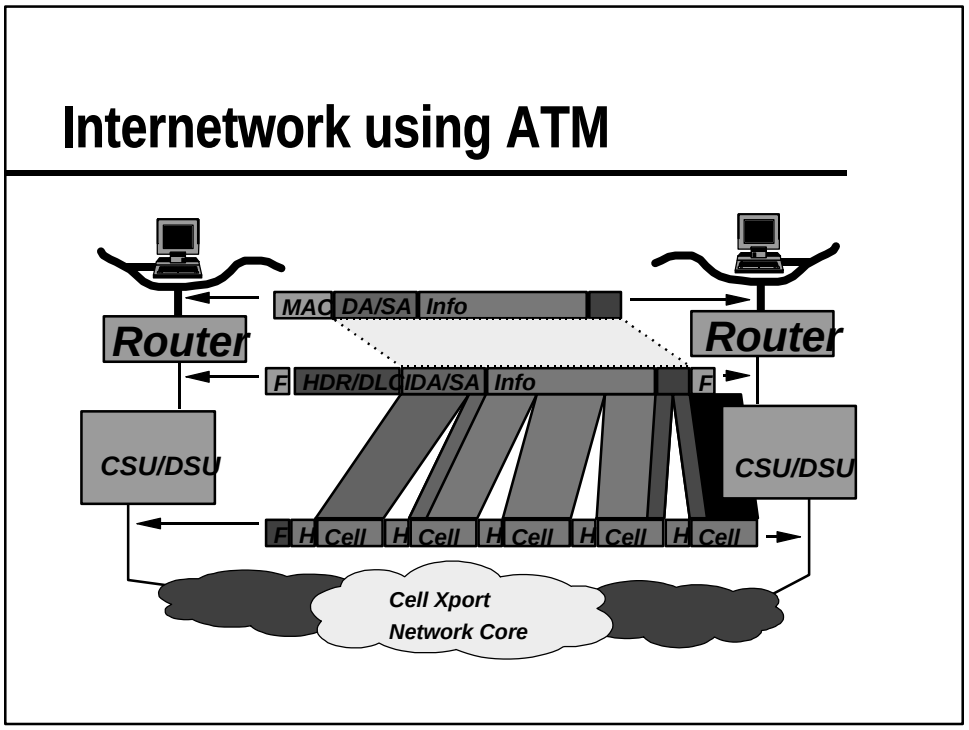
- First step in transporting information
  - ATM uses IETF RFC-1483
  - Frame Relay uses IETF RFC-1490
  - "Equivalent," but not the same



ATM Adpatation Layers

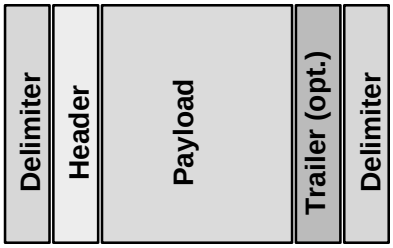






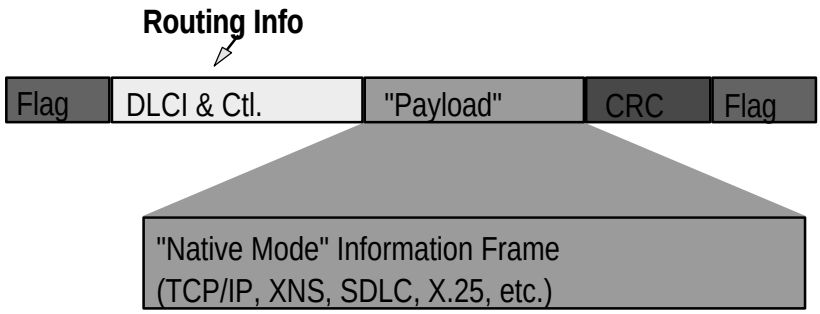
Frame Relay

- Connection-oriented
  - PVC widely available; SVC also in progress
  - Extremely appropriate for limited bandwidth
- Frames
  - Excellent match for data
  - Efficient
  - Challenge for voice/video



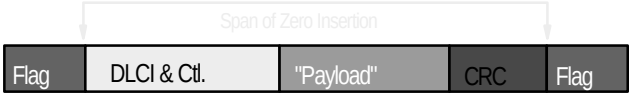
Frame Relay Format

- Simple “wrapper” around native information

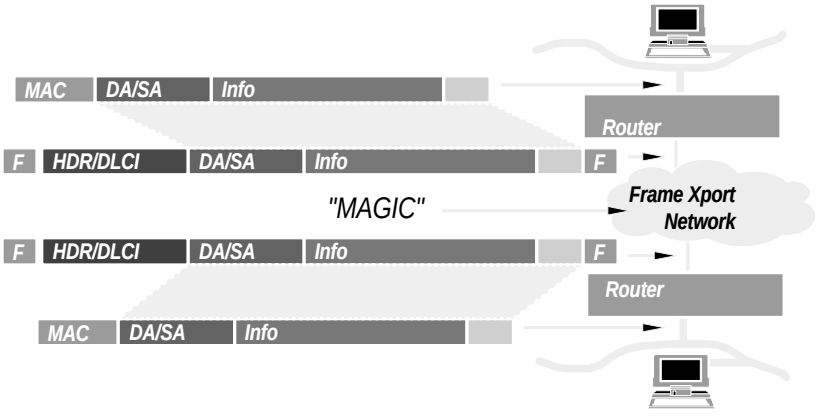


HDLC Framing and Flags

- Like X.25, Frame Relay and DXI use HDLC Framing
- Problem distinguishing the flag (7E or 01111110)
- Solution:
  - Insert "0" after any five consecutive 1's unless really a flag
  - Includes everything except flag
  - Last function before physical line; removed when received
  - Remember for T1 discussion

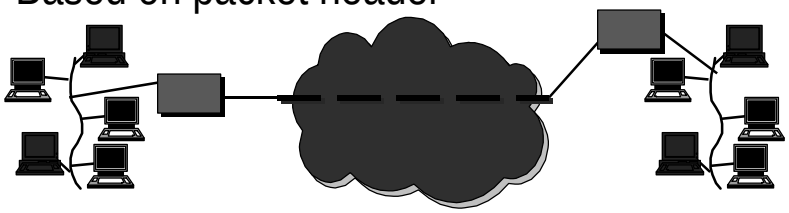


Internetworking using Frame Relay



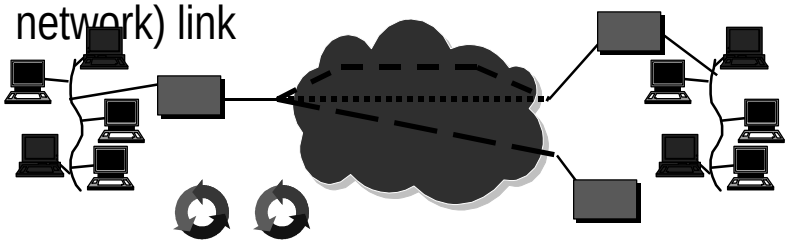
Virtual Circuits

- Define a “path” (endpoints) in the network
- Don’t use resources until needed
  - Other than “address space” in switches
- Based on packet header



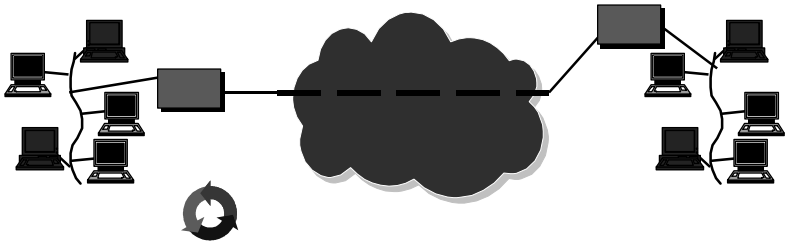
Permanent Virtual Circuits (PVCs)

- Network operator sets endpoints
- Actual path through net may vary
  - PVCs have alternate routing
- Multiple PVCs over a single access (or network) link



Switched Virtual Circuits (SVCs)

- Endpoint(s) set by user (real-time)
  - Well-defined call setup procedures
- May coexist with PVC
  - In fact, this is usually the case at host sites



Current SVC Status

- Standards in place for Frame Relay & ATM
- Equipment
  - ATM: Primarily ATM LAN equipment
  - Frame Relay: Some routers / FRADs, switch support coming
- Services
  - Essentially no availability *today*
    - » Brings immediate need into question…
  - Management & price may be ultimate deciding factors

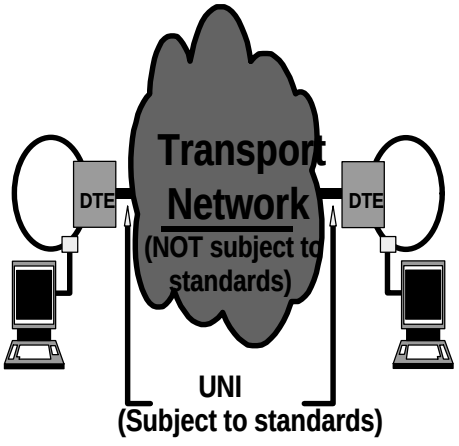
Connection vs. Connectionless Summary

- Primarily a "religious" issue; Both forms "work"
- Histories; LAN vs. WAN
- Some of the issues:
  - Connectivity
  - Overhead
  - Call set-up

Issue	Connection	Con'less
Call setup	Yes	No
Overhead	Lower	Higher
Wide connectivity	Requires SVC	Yes
Best Traffic Pattern	Fairly constant	Sporadic
Complexity	Lower	Higher
Heritage	WAN	LAN
Technology/ Service	ATM, Fr Relay	SMDS

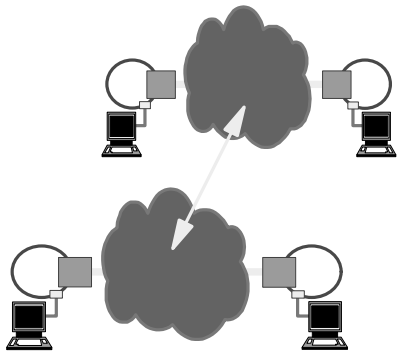
User-to-Network Interfaces

- Most standards are some form of UNI (aka SNI)
- Intra-network transport is still largely proprietary
  - ATM evolving Network Node Interface (ATM NNI)



Network-to-Network Interface

- Standards are in place; work generally based on expanded UNI with higher speeds & more addresses
- Also called ISSI, ICI, B-ICI
- Important both for multiple carriers and for LEC access to IXC



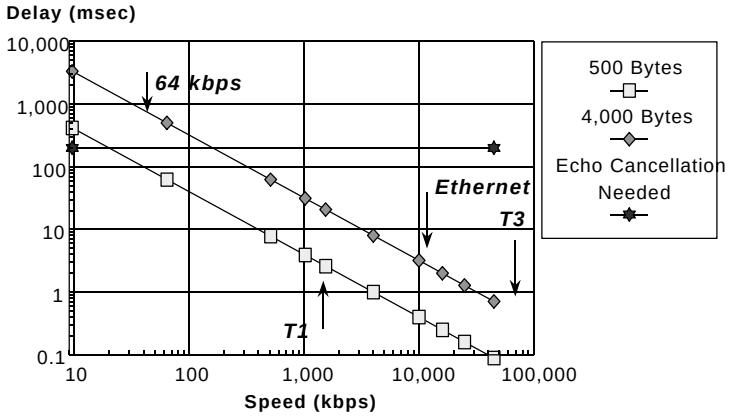
Executive Briefing

- What are ATM & Frame Relay?
- ATM / Frame Relay Networking Advantages
- ATM & Frame Relay: Technologies, Services, and Standards
- What About Multimedia?

Voice and Video

- "Interactive" vs. "File" Multimedia
- Some conversations may need cell-based ATM for latency control
- "Files" may need cells for speed, but not for delay characteristics

Freeze-out: Myth & Reality

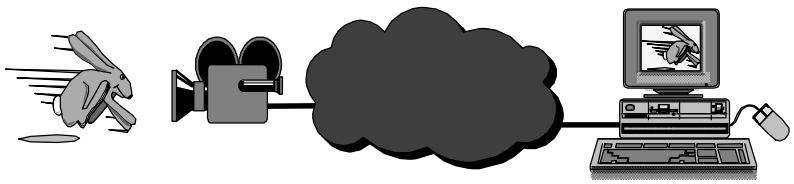


Voice and Video

- Packet Voice & Video
- "Stat muxing" is the real power of Frame Relay and ATM
- Voice is half duplex

Frame-based Multimedia

- Products, mostly proprietary, are currently available for both voice and video
- Caveat: Need for enhanced products and standard algorithms for both voice and video



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Physical Layer: Dedicated Bandwidth

- Switched Dedicated Bandwidth

Switched Dedicated Bandwidth Services

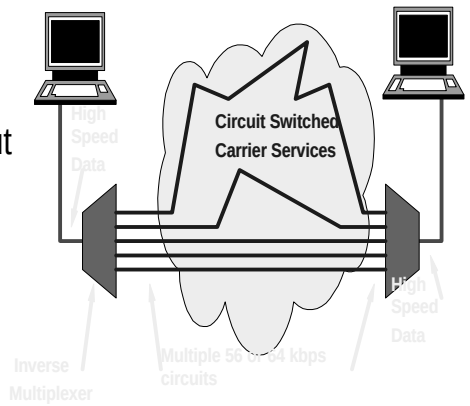
- Provides high bandwidth as a metered service
  - Though often viewed as competitor with broadband services, SDBS can be complementary where appropriate.
- ISDN, plus Switched 384, T1, T3
- Requires call set-up procedure
  - Questionable set-up time for "instantaneous" on-demand needs

Switched Dedicated Bandwidth Services

- (Continued…)
- Excellent for short-term, predictable needs
  - Time-of-day reconfiguration; disastery recovery (dial back-up); Video conferencing; Other voice-like traffic
- May use inverse multiplexing to combine multiple slower streams into a single high-speed stream

Inverse Muxing

- Typically multiple 56 / 64 kbps to a sub-T1 speed
- Emerging needs for speeds greater than T1 but less than T3
- "BONDING" coalition setting ad-hoc standards
  - Bandwidth on Demand Interoperability Group



Switched Services vs ATM/Frame Relay

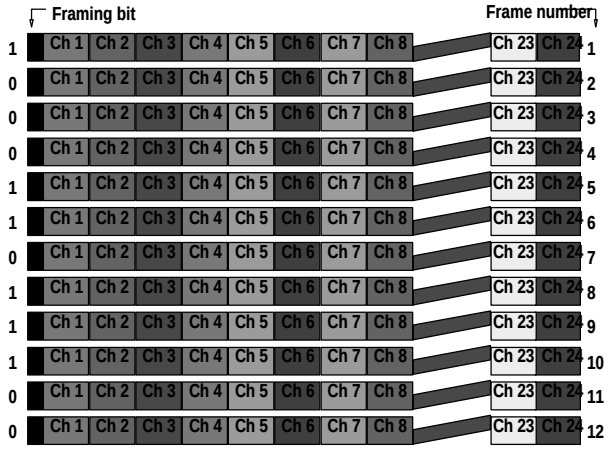
	Switched Services	Broadband Packet
Multiplexing Mode	Circuit	Packet
Typical Speed	Up to T1, some T3	64 kbps to T3
Billing Increment	Circuit/Time	Packet Load
Error Detection	No	No
Optimal Traffic	Any; Transparent	Protocol Oriented
OSI Layer(s)	1	"MAC"
Common Conn. Type	Dedicated BW circuit	PVC/SVC
Internat. Standard	ISDN only	Yes
Typ. Data Efficiency	Difficult to define	High
Set-up speed	Few seconds?	N/A for PVCs
Technology	Conceptually simple	Sophisticated

Physical Layer: Dedicated Bandwidth

- Switched Dedicated Bandwidth
- Transport Facility Issues
  - Clocking: Packet vs. Circuit switching
  - Bit density
  - T3 & SONET

T1 Transport with SF

- Most services today will use T1 as a transport medium
- SF or ESF still must be used with 193rd bit reserved for carriers
- Note "matrix" format for framing



Bit Density

- T1 circuits require roughly 1/8 of the bits to be 1's due to clock recovery method
- Fundamental reason behind 56 kbps services
- B8ZS (ZBTSI, etc.) needed for "clear channel"
- Compare bit density for T1 with flag problem for HDLC
- Possible mechanism for bit density without B8ZS: Data Inversion
- What about framing bits?

T3 and SONET Compatibility

- For discussion here, assume essentially a "fast T1"
- T3, provides about 45 Mbps, equivalent of 28 T1s
  - Higher bandwidth provides challenge in local loop
  - "Fractional T3" for an intermediate speed circuit is a challenge - but possible if needed - since the components are "asynchronous" to each other.

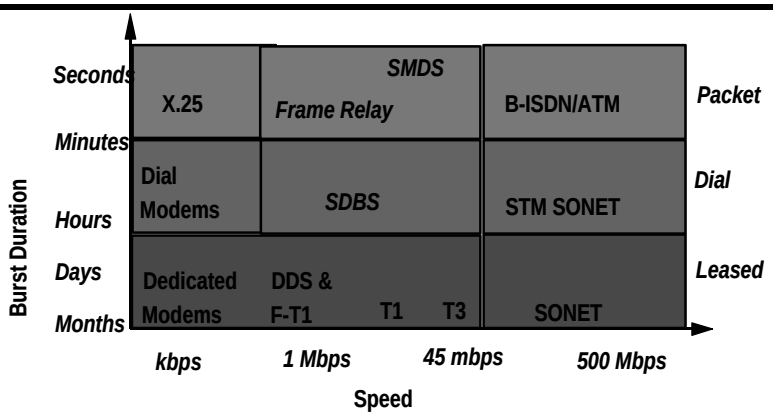
T3 and SONET Compatibility

- For discussion here, assume essentially a "fast T1"
- T3, provides about 45 Mbps, equivalent of 28 T1s
- SONET provides bandwidth at ~50 Mbps & above
  - Framing structure is much like ESF
  - Basically a TDM structure with lots of management hooks built in
  - International standards (Synchronous Digital Hierarchy - SDH) starts at 150 Mbps.

Physical Layer: Dedicated Bandwidth

- Switched Dedicated Bandwidth
- Transport Facility Issues
- Mixing Dedicated and Packet Technologies/Services
  - Often viewed as an "either-or" (mutually exclusive) decision
  - Most realistic solutions are a combination

Possible Technology Choices



"SDBS" = Switched Dedicated Bandwidth Services, or Dial-up "Bandwidth on Demand" in N x 56/64 kbps to N x T1 increments

Physical/Packet Layer Combinations

	Frame Relay	SMDS	ATM
56/64 kbps	Yes	SMDS DXI	ATM DXI
F-T1	Yes	SMDS DXI	ATM DXI
T1	Yes	Yes	YEs
T3	Yes (demo)	Yes	Yes
SONET	No	No	Yes
N-ISDN	Yes	??	??
Sw. 56	Yes	Maybe	No
Sw. T1	Yes	Maybe	Maybe
Sw. T3	Maybe	Maybe	Maybe

Switched Services

- Switched dedicated bandwidth, SVC, and connectionless all provide "switched services"
- Switched dedicated services allow "per minute" connections, especially for access to the local service point
- SVC & PVC services assume some form of dedicated bandwidth at the physical layer
- Possible to mix and match to provide best possible mix of services

Switched Service Combinations

Packet Type	Physical	Characteristics
PVC	Dedicated	Typical installation today for Frame Relay and ATM
PVC	Switched	Provides "virtual modem pool" and/or reduced access costs
SVC	Dedicated	Traditional SVC arrangement with dedicated access but changeable endpoints and wide connectivity
SVC	Switched	Behaves like traditional "Public Data Network"
Connectionless	Dedicated	SMDS today
Connectionless	Switched	Technically feasible if needed

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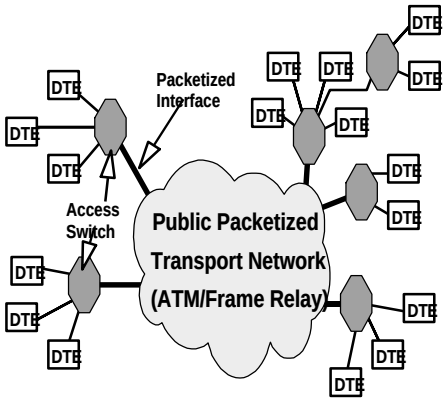
Future of the “Private” Network

- Private networks will continue to exist in some form. Remember:
  - Economics
  - Failure of the Carriers to Respond to Users' Data Networking Needs
  - Network Flexibility and Competitive Advantages
- Move to tighter "hybrid" integration
  - Broadband packet services will lead to new transport mechanism for "private networks"
  - Requires shift in philosophy by vendors, users, and carriers
  - New network component: Access Switches

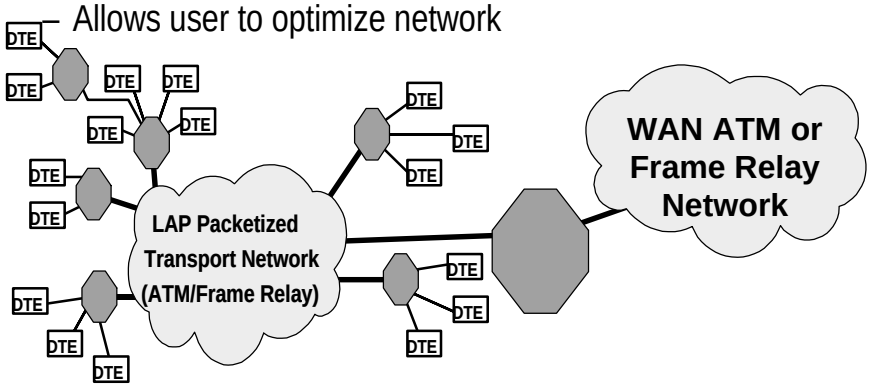
Access Switches

- Look like a single DTE to the network
- Look and feel of a private network to the private network operator
- Take advantage of emerging broadband packet public network offerings



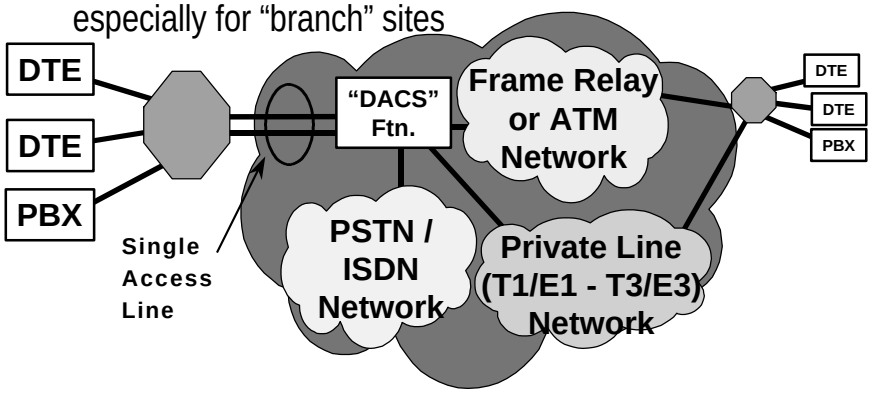
"Private" Network-Network Interface

- Private solution to address lack of carrier NNI
  - Allows user to optimize network



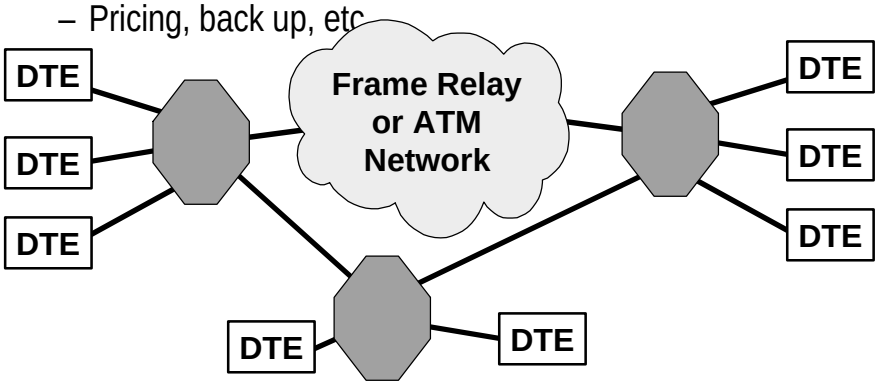
Hybrid Trunking

- Hybrid access transport
  - Can be an enormous help with access line costs, especially for “branch” sites



Hybrid Access Switches

- Access switch for Frame Relay/ATM services
- ➡Private line transport when more advantageous
  - Pricing, back up, etc.



Frame Relay, ATM, or IP?

- IP
  - May offer excellent pricing
  - Limited Quality of Service
  - Needs encryption and authentication
  - "Politically" very popular

Frame Relay, ATM, or IP?

- Frame Relay
  - Available today, Excellent pricing
  - Inter-LATA & intra-LATA
  - PVC today; SVC coming
  - Limited voice support
  - Sub-T1 to T1; T3 emerging
  - Easy upgrade; compatible with "legacy" networks
  - Network or access method

Frame Relay, ATM, or IP?

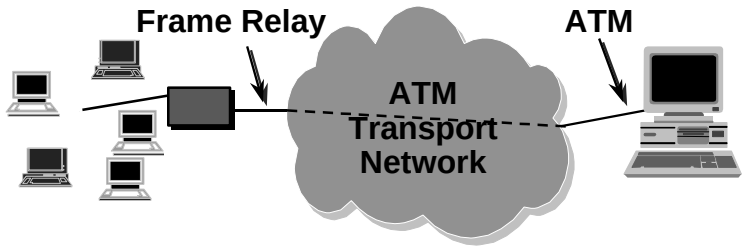
- ATM
  - Excels at T3 and above
  - Real-time multimedia
    - » Technology is capable
    - » Not defined available for single-line voice
    - » Real-time video / "imaging"
  - Available today for high-end applications
  - LAN/WAN issues

Frame Relay, ATM, or IP?

- Combination
  - "Mix and Match" eventually according to applications and prices
  - Frame Relay & IP as access technologies
  - Start gaining benefits
  - Migration paths to ATM when (or if) needed

Frame Relay / ATM Interoperability

- "Network Interworking"
  - Specification already in place
    - » Frame Relay transport over ATM
    - ➡**Limited Frame Relay <> ATM (SSCS)**

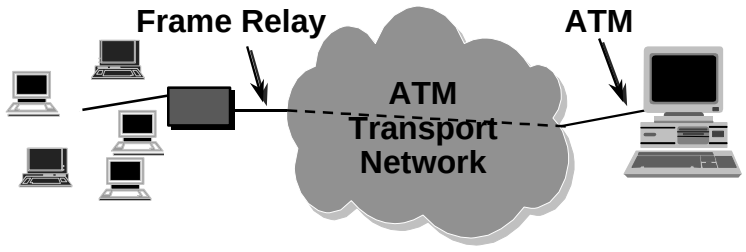


Network Interworking

- Advantages
  - It "works"
  - Not bad for frame relay transport
- Disadvantages
  - Requires FR-SSCS
    - » Not otherwise necessary in ATM device
    - » ATM device must "know" frame relay
  - PVCs only

Frame Relay / ATM Interoperability

- "Network Interworking"
- "Service Interworking"
  - Specifications ratified
  - "Complete" translation



Service Interworking

- Advantages
  - Provides needed translation
  - Transparent to users
- Disadvantages
  - Still must translate Multiprotocol Encapsulation
    - » RFC 1490 vs. RFC 1483 (reminder)
  - PVCs only

Network and Service Interworking

- Provide necessary functions
- ATM and Frame Relay stay "separate"
  - Well defined frame/cell boundaries
- Should "work" for Frame Relay to/from F-UNI translation
  - Even though translation *shouldn't* be needed
- Widespread adoption planned

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