Voice Over IP, Frame Relay, & ATM: Getting Ready for Prime Time

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Distributed Networking
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Convergence Timeline

Getting Ready For Prime Time

- Introduction & Technology Background
- Reference Architectures and Implementation Models
- Does Packet Voice "Work"?
- Does Packet Voice Make Business Sense?
  - For the Enterprise?
  - For the Service Provider?
- Summary

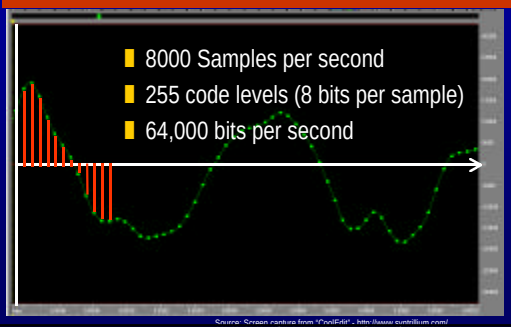
Convergence Timeline

- Pre-Broadband converged network infrastructure
  - One network
  - Data over the voice network
    - It "works," and the data voice network was in place
    - Based on circuit switching, and inefficient for data
  - Voice network as the building block for data networks
    - 64 kbps data circuits, for example...

Getting Ready For Prime Time

- Introduction & Technology Background
  - Network convergence
  - Service types
  - Why packet voice?
  - Compressed voice

Digital Voice Example (PCM)

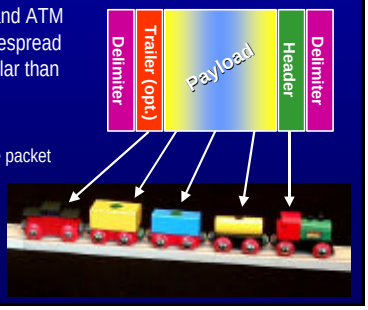


Traditional Digital Hierarchy

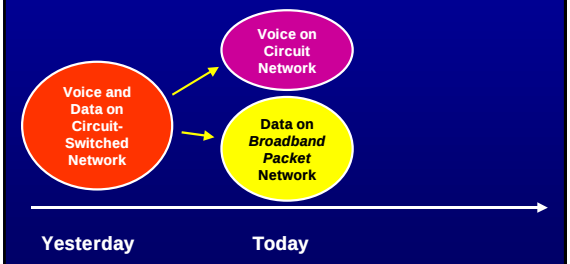
- 64 kbps (DS0) is the fundamental building block
  - DS1 (T1) carries 24 DS0s in 1.544 Mbps
  - DS3 (T3) carries 28 T1s in ~45 Mbps
  - OC1 carries 3 T3s on ~150 Mbps
- Data speeds have been adapted to fit into this hierarchy
  - "Low speed" data at 56 kbps due to timing considerations
    - Can only use seven bits per "voice sample" timeslot

Broadband Packet Service Types

- Frame Relay, IP and ATM are becoming widespread and are more similar than different
- Key differences:
  - Fixed vs. variable packet length
  - Connection vs. connectionless



Convergence Timeline



Generic Packet Format: Payload

- Variable: Frames
  - Efficient use of bandwidth
  - "Frame Relay" & IP

What is "Broadband Packet"

- Packet switching for bandwidth efficiency
  - Data is "bursty"
- High transmission speeds
  - Fast throughput, with guaranteed transmission (if desired) left to higher layers
  - Multimedia-enabled infrastructure
- Currently in three "flavors"
  - IP, Frame Relay, and ATM

Generic Packet Format: Payload

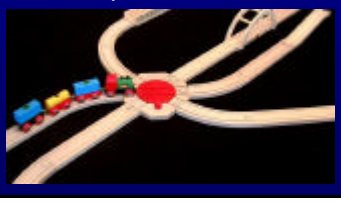
- Variable: Frames
  - Efficient use of bandwidth
  - "Frame Relay" & IP
- Fixed length: Cells (ATM)
  - Easy to process with Predictable delay

Generic Packet Format: Payload

- Variable: Frames
  - Efficient use of bandwidth
  - "Frame Relay" & IP
- Fixed length: Cells (ATM)
  - Easy to process with Predictable delay
  - ***Always*** the same size

Generic Packet Format: Header

- Connection oriented
  - Virtual Circuit number
  - Conserves address space
  - ATM and Frame Relay
- Connectionless (IP)
  - "Universal," unique address
  - Needs large address space
    - Is this a problem?



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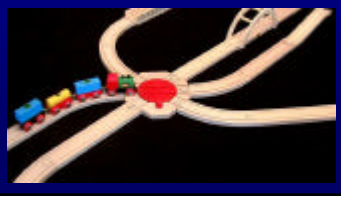
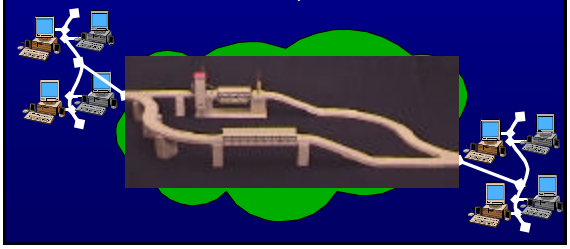


Connection-oriented vs. Connectionless Architectures

- Common misconception: Connection-oriented architectures are "nailed-up" within the network.



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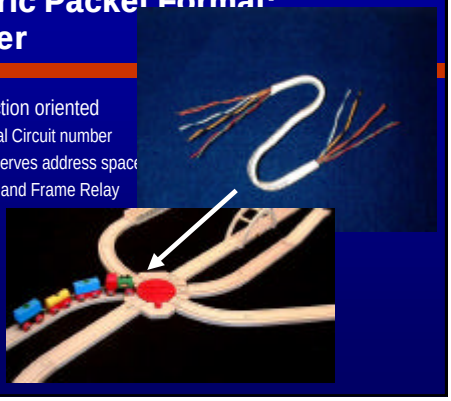
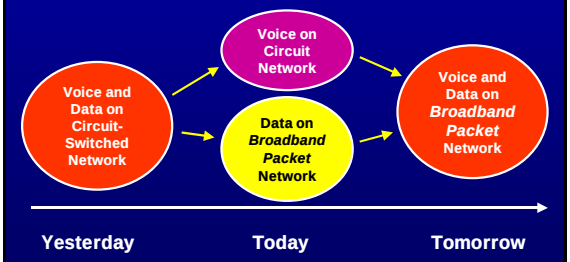


Broadband Packet Types

- Bottom Line: All three "work"
  - Single-technology world view misses the big picture
    - Great for marketing, selling magazines, and creating editorial content and controversy
    - Promotes the "Technology of the Month Club"
  - "Broadband Packet" looks at the bigger picture

	Fixed length	Variable length
Connection	ATM	Frame Relay
Connectionless	N/A	IP

Convergence Timeline



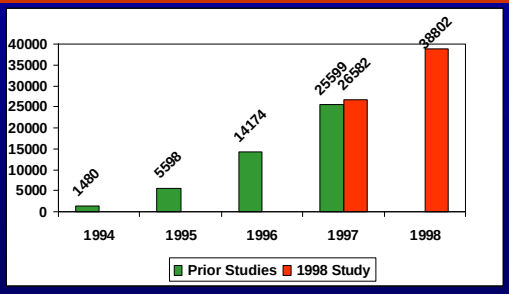
Why packet voice?

- Effective bandwidth utilization and control
- ➡ Available services
  - Frame Relay, IP, and ATM are reaching ubiquitous coverage
  - For instance...

Converged Broadband Networks

- Voice is added to the "data network"
- Implies:
  - Voice over IP (VoIP)
  - Voice over Frame Relay (VoFR)
  - Voice over ATM (VoATM)
- Voice over IP, Frame Relay and ATM implies:
  - Packet voice
  - Compressed voice

Worldwide Companies Using Frame Relay Services



Source: www.webtorials.com; Based on responses from 24 carriers

Why packet voice?

- ➡ Effective bandwidth utilization and control
  - Only send info that is actually needed
  - Voice Activity Detection (VAD)
    - No "clipping" as in prior Digital Speech Interpolation (DSI) mechanisms

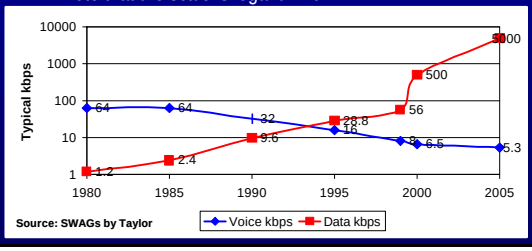
Source: Screen capture from "CoolEdit" - http://www.syntrillium.com/

Why packet voice?

- Effective bandwidth utilization and control
- Available services
- ➡ Unified network infrastructure
  - Evolution from circuit switched / TDM hierarchy to packet hierarchy
  - "Broadband Packet" infrastructure required for data
  - Eventually voice will pale in comparison to data
    - Again, for instance...

Voice vs. Data Bandwidth

- Typical speeds for a single "conversation"
  - Note that the scale is logarithmic



Getting Ready For Prime Time

- Introduction & Technology Background
- **Reference Architectures and Implementation Models**
  - Four Reference Architectures
  - Packet Voice Implementations
  - Which Implementations Fit Which Architectures?
  - Equipment Challenges

Today's Compressed Voice

- 5 - 8 kbps "CELP" Algorithms reproduce "sounds"
- Less than 10% of traditional bandwidth
- Excellent quality
  - Lots of processing, but processing is cheap

Application Models

- Packet Telephony Service Providers
  - Carriers who provide standard telephony services over a "Broadband Packet" infrastructure
  - ITSP (IP Telephony Service Providers)
    - Usually an ISP offering VoIP
  - Could be a Frame Relay or ATM service provider
    - The exact type of "packet" is relatively unimportant

When is Compressed Voice Important?

- ✓ If you pay a lot for facilities
- ✓ If you have a high density of calls
- ✓ If facilities are scarce or don't exist
- ✓ Key Trade-off: Processing and reduced bandwidth versus simplicity and compatibility

Carrier Infrastructure (ITSP)

- "Normal" telephony interfaces to customers
  - 1+ or 1010xxx+ service; direct access, or 800 access
- POTS, plus normal enhanced telephony features

Application Models

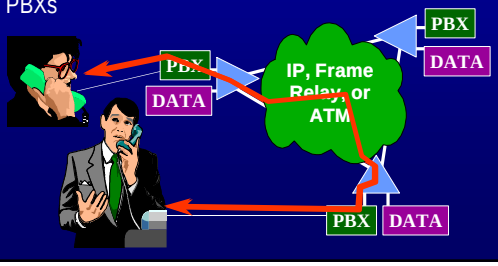
- Packet Telephony Service Providers
- ➡Integrated Voice/Data Service
  - Corporate "Enterprise WAN" Architecture
  - Primary carrier service is IP, Frame Relay, or ATM

Reference Architectures

- Packet Telephony Service Providers
- Integrated Voice/Data Service
- ➡Workstation-to-Workstation
  - "PC-to-PC" communications
  - Always works on the LAN; Plenty of bandwidth
  - May be creeping into the WAN

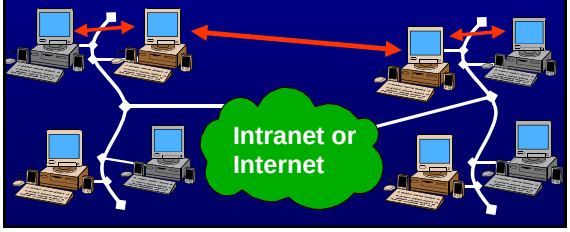
Integrated Voice/Data Infrastructure

- Corporate intranetwork transport of voice from PBXs

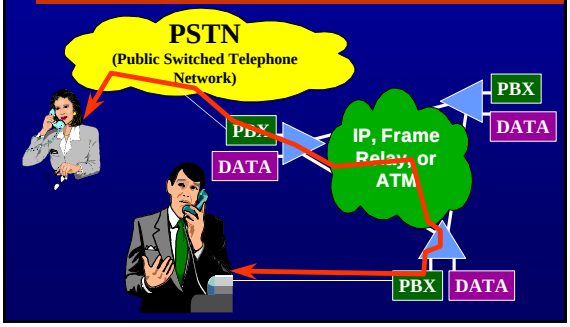


Workstation-to-Workstation

- Primarily IP
  - Provides the feature set originally envisioned for ATM



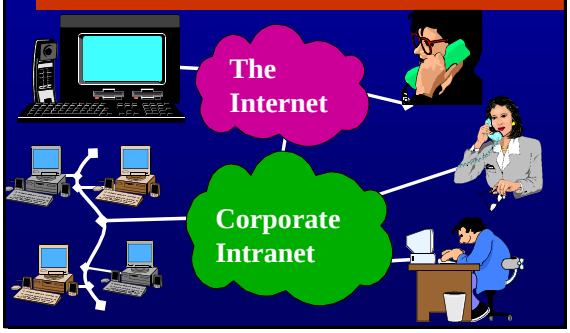
Also for Remote Off-Net



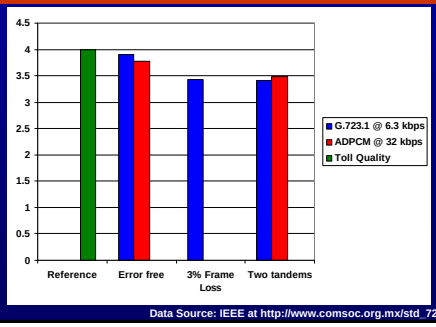
Reference Architectures

- Packet Telephony Service Providers
- Integrated Voice/Data Service
- Workstation-to-Workstation
- ➡Any-to-Any
  - Workstation to PSTN is particularly key (and difficult)
  - "Gateway Services" will provide interworking

Hybrid Applications



"Mean Opinion Score" Values



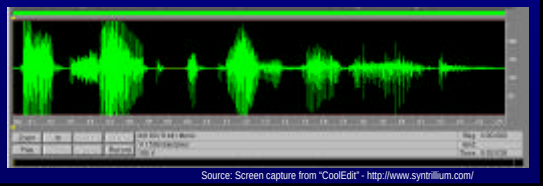
Data Source: IEEE at http://www.comsoc.org.mx/std_7231.htm

Getting Ready For Prime Time

- Introduction & Technology Background
- Reference Architectures and Implementation Models
- **Does Packet Voice "Work"?**
  - Does it sound good?
  - Delay
  - Signaling
  - Fax
  - Status of standards and interoperability

How do you think it sounds?

- Actual samples of phonetically balanced sentence at various bit rates
  - "Add salt before you fry the egg."



Source: Screen capture from "CoolEdit" - http://www.syntrillium.com/

Packet Voice Sound Quality

- Primary algorithms are "CELP" based
  - VoIP uses G.723.1 at 5.3 and 6.3 kbps (default)
  - VoFR uses G.729 at 8 kbps (default)
- Quantitative measurements show "near toll quality"
- Mean Opinion Scores (MOS) measurements
  - 4.0 is "toll quality"

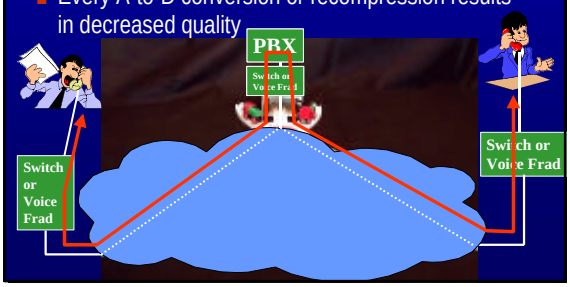
Voice Samples

- Prepared by Sipro Lab Telecom Inc.
- For more information, visit http://www.sipro.com.
- Reference Samples
  - 44 khz
  - 8khz
  - 64 kbps PCM

Algorithm	No Errors	1% Bit Errors	3% Bit Errors	1% Frame Loss	3% Frame Loss
ITU G723.1 at 5.3 kbps (ACELP)					
ITU G723.1 at 6.3 kbps (MP-MLQ)					
ITU G729A at 8 kbps (CS-ACELP)					

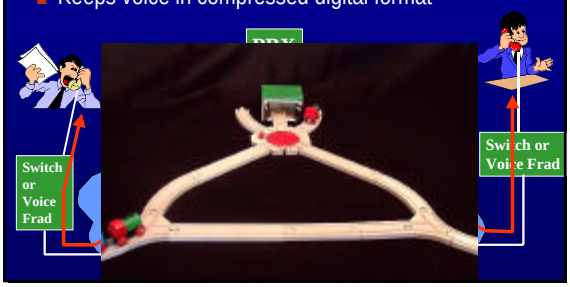
Multiple Tandems

- Every A-to-D conversion or recompression results in decreased quality



Alternate Solution: Switching in IAD / Switch

- Keeps voice in compressed digital format



Multiple Tandem Degradation

- Also prepared by Sipro Lab Telecom Inc.
- For more information, visit http://www.sipro.com.
- Reference Samples
  - 44 khz
  - 8khz
  - 64 kbps PCM

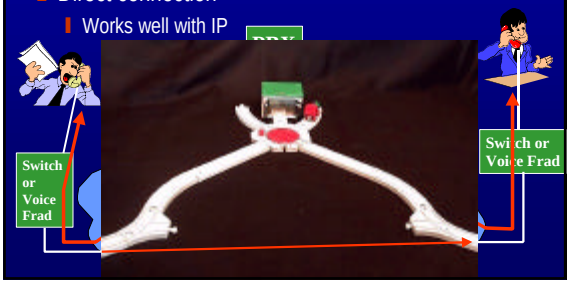
Algorithm	1 Tandem	3 Tandems	6 Tandems	10 Tandems
G.723.1 @ 5.3 kbps				
G.729A @ 8 kbps				

Packet / Compressed Voice Variables

- Three distinct functions may or may not be used:
  - Compression
    - Could packetize 64 kbps PCM
  - Packetizing
    - Same low-bit-rate algorithms can be used over a dedicated connection
    - VoATM may be CBR
  - Silence Suppression

Solution: Call Processing

- Direct connection
  - Works well with IP

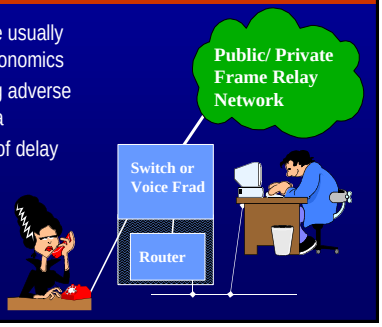


Does it Sound Good?

- ✓Algorithms are excellent
- ✓Silence Suppression is optional
- ✓Multiple Tandem degradation can be controlled

Delay

- Voice & data are usually combined for economics
- Issue is avoiding adverse impact from data
- Data is tolerant of delay
- Voice isn't...



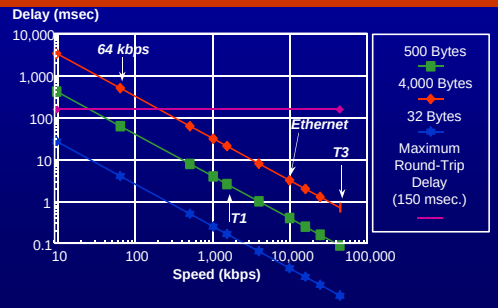
Freeze-Out: Cells

- With frames ***OR*** cells, only one PDU (frame or cell) can occupy the transmission line at a time.

Some Delay Sources

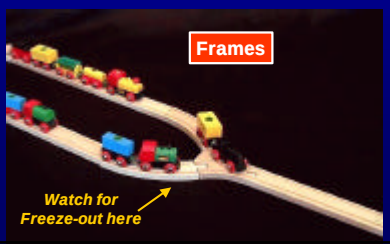
- Delay types
  - Absolute delay
  - "Jitter" (delay variation)
- Delay is generally related to the "packet time"
  - Packet Time = (Packet Size) / Speed
- Multiple factors
  - Freeze-out, Fill time, Last cell, etc.

Freeze-out: Myth & Reality



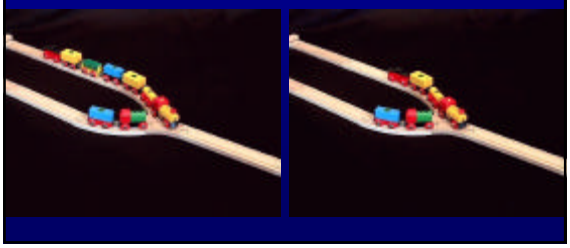
Freeze-Out: Frames

- Only one PDU (frame or cell) can occupy the transmission line at a time.



Freeze-out: Bottom Line

- Freezeout is a problem for long, slow packets

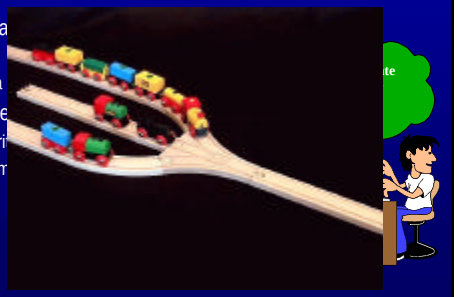


Fill Time

- Limits the maximum allowable packet size for voice

Queuing in Access

- Under a
  control
  - Data
- Relative
  - Priori
  - Segm

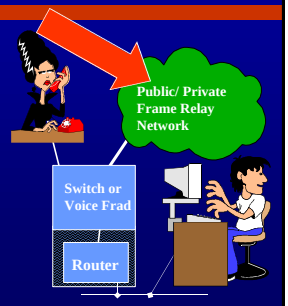


Last Cell and Packet Voice

- Packet voice payloads are very short for Frame Relay and IP

Queuing in the Network: Infrastructure Issues

- Routed vs. Switched Network
  - Processing and delay
- QoS Issues
  - ATM vs. IP vs. FR
    - IP over ATM or Frame Relay
  - MPLS
  - RSVP

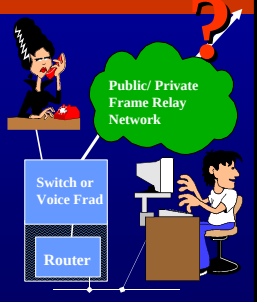


Last Cell and Packet Voice

- Highly compressed voice is not as important for ATM

Output Queuing

- Active issue
- Problem for IP, Frame Relay & ATM
- Possible solutions
  - Subframe Muxing
  - Switch solutions



Signaling (call control)

- Needed for on-hook / off-hook indication, call setup, and advanced functions
- Typical user (enterprise) needs
  - Analog (DTMF)
  - Digital
    - Embedded (Robbed Bit)
    - Common Channel
      - ISDN & Q.SIG
      - "Traditional" European

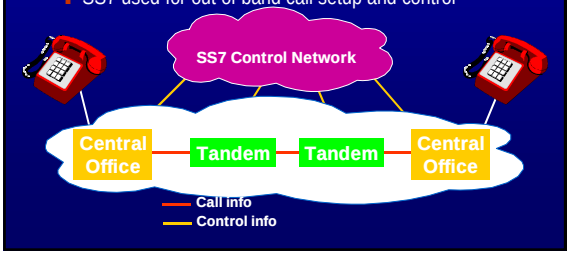
Fax & Modem Traffic

- The Good News
  - Modems & fax machines are inexpensive
  - Everybody has them

- The Bad News
  - Modems & fax machines are inexpensive
  - Everybody has them

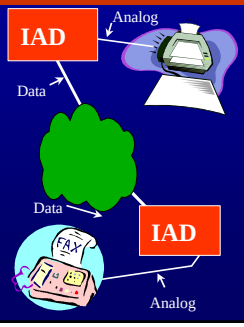
Carrier Signaling

- Traditional telephony network with SS7
  - SS7 used for out of band call setup and control



Remodulation (Fax Relay)

- Detect fax
- Demodulate and remodulate
- Modems are separate problem
  - Very few reasons to need to send "real" modem traffic over these networks

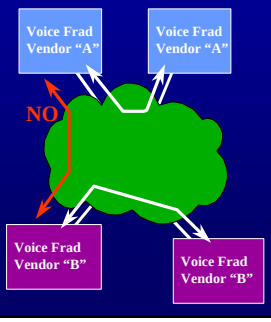


Integrated IP Network

- SS7 needed for network transparency
  - IP calls could be from telephone or workstation

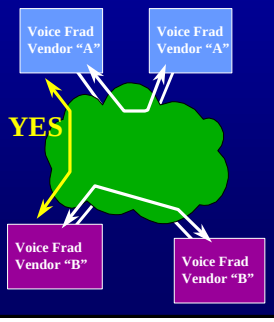
No Standard / Specification

- Proprietary products
- Probably not interoperable
- Not a major problem for corporate voice or ITSP carrier backbone network



With standards

- "Interoperable" products from multiple vendors
- Great for some situations, but not absolutely critical at this point



Enterprise Business Case: ITSP Model

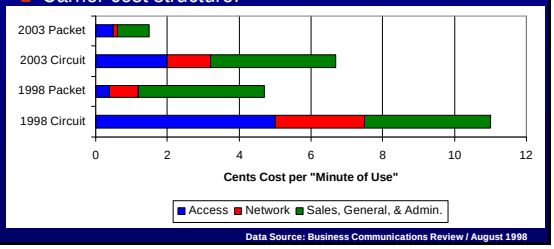
- Economics: Cost per minute versus voice quality
  - Currently *costs* of about half as much as circuit switched
    - Prices reflect a slightly high profit margin
  - Largely due to "Enhanced Service Provider" status and access costs
- Can change rapidly due to regulatory issues
  - Other cost factors may offset the loss of exemption
- Primary attraction – traditional "voice manager"

Does it work?

- ✓ **Sounds good**
- ✓ **Delay can be controlled**
- ✓ **Signaling provides full telephony feature set**
- ✓ **Fax problems are solved**
- ✓ **Standards are sufficiently in place**

Carrier Business Case: ITSP Model

- Decision by enterprise based on cents per minute
- Carrier cost structure:

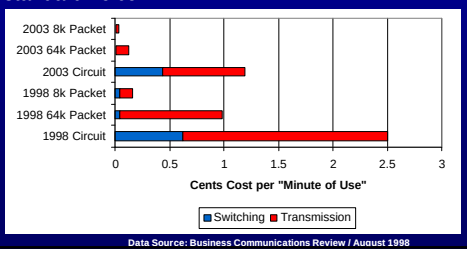


Getting Ready For Prime Time

- Introduction & Technology Background
- Reference Architectures and Implementation Models
- Does Packet Voice "Work"?
- ➡ **Does Packet Voice Make Business Sense?**
  - For the Enterprise?
    - Can enterprises save money?
  - For the Service Provider?
    - What services will the carriers offer?

Carrier Business Case: ITSP Model

- Reduce switching and transmission cost vs. standard voice



Enterprise Business Case: Workstation-Workstation Model

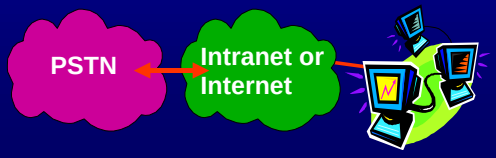
- Integrated into operating system of most workstations
  - Integral feature of "Windows" operating systems
- Can be a "hidden liability"
  - Some managers are custom-building desktops
- Extra cost in network transport facilities if the call leaves the LAN
  - But may be a marginal incremental cost (until video emerges more strongly)

Assumptions for Pricing Models

- Compressed voice at 5.3 kbps for IP or 8 kbps for Frame Relay
  - Then assume 100% overhead for Frame Relay and 200% for IP
  - Result is 16 kbps per call; 4:1 statistical advantage
- Voice Activity Detection (VAD)
  - 2:1 statistical advantage
- Result is 8:1 statistical advantage

Carrier Business Case: Workstation-Workstation Model

- Usually not applicable
  - Just sell some extra data bandwidth
- Possible gateway service at the most



Comparison with Dial Voice: Fixed Cost Comparison

- Assume the following typical situation
  - 3 hours a day
  - 20 days a month
  - 5 cents per minute
  - Eight lines
- Result: $1440 per month
- For Frame Relay:
  - One 64 kbps PVC
    - Additional / new
    - Representative price: $648 MRC
- Saves $792 (55%)
- Admittedly ignores
  - Access lines for both
    - Roughly the same
  - Equipment prices

Enterprise Business Case: Integrated Voice/Data

- Pricing analysis uses representative Frame Relay prices
  - Exact details may vary slightly, but not by a significant amount
- IP and ATM prices should be QUITE similar
  - In fact, IP implementation may very well run over a Frame Relay infrastructure
  - ATM and Frame Relay have very similar (or identical) prices at the same speeds

Alternative Calculation: Break-even Point

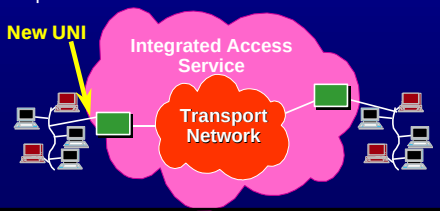
- If 5 cents per minute, then the cost of the frame relay circuit ($550 - $650 per month) is reached with about 200 hours of usage per month
- This is ten hours per day...
  - 1 hour and 15 minutes per phone (assuming 8:1)
  - 35 to 40 minutes a day at 10 cents per minute
- Fine granularity of PVC bandwidth alleviates need for "at least eight" lines
- **Does NOT assume bundling with data service**

Yet Another Option: Usage Rates

- Usage CIR PVC/SVC Rates
  - Within specified CIR - 5.5 cents per Mbyte
  - Discard Eligible - 4.5 cents per Mbyte
- Details
  - Each simplex circuit priced separately
  - Prices per megabyte received (egress)
  - Monthly minimum per PVC: $5.00; capped at 125%
  - Plus usual port and access charges

Carrier Business Case: Integrated Voice/Data *with* CLE

- With "CPE" as "CLE," the demarcation point becomes the LAN (Ethernet, T/R) interface
- "Expands the cloud"



Usage CIR and Voice

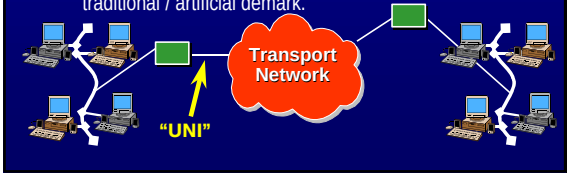
- Assume 16 kbps for a conversation
  - Lots for overhead
  - Assumes half duplex (only one part speaking at a time)
  - Assumes no pauses in conversation
- 16 kbps * 60 sec/min = 960 kb/min
- 960 kb/min ÷ 8 bits/byte = 120 kbytes/min
- 120 kbytes/min = .12 Mbytes/min
- .12 Mbytes/min * 5.5 cents/Mbyte = 0.66 ¢/minute

Carrier Business Case: Integrated Voice/Data *with* CLE

- User Advantages
  - Financial
    - Avoid capital investment
    - Reduce/contain operation costs
  - Flexibility
    - Not locked to a singular technology
- Carrier Advantages
  - Flexibility
    - Respond to user needs
  - Market protection
    - Locks in user
    - If not offered, may lose entire user - both legacy and new applications

Carrier Business Case: Integrated Voice/Data *with* CLE

- Traditionally, customer provides "DTE"
  - Demark is artificial, primarily due to ***traditional*** regulation.
  - Frame relay, SMDS, and ATM "UNI" preserves this traditional / artificial demark.



Summary: Enterprise Business Case

- Voice over Frame Relay, IP and ATM is very cost effective for users
  - But low enterprise costs are not necessarily good news for the carrier
- Margins and the pricing "Catch 22"
- Carriers will eventually adopt packet voice strategies for survival

Getting Ready For Prime Time

- Introduction & Technology Background
- Reference Architectures and Implementation Models
- Does Packet Voice "Work"?
- Does Packet Voice Make Business Sense?
  - For the Enterprise?
  - For the Service Provider?
- **Summary**

Summary

- ✓ The technology works
- ✓ Enterprises save money
- ✓ *SOME* carriers will offer a range of services to exploit this technology
  - ✓ Voice services
  - ✓ Data services
- ✓ Packet technology will ultimately reign