

A Survey of Packet-Loss Recovery Techniques

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Overview

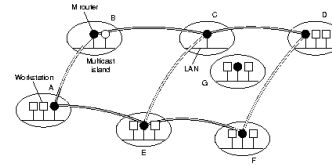


Fig. 7-96. Mbone consists of multicast islands connected by tunnels.

- Development of IP Multicast
- "Light-weight session"
 - Scale to 1000's of participants
- How to handle packet loss?
 - Repair



Overview

- This paper:
 - Loss characteristics of Mbone
 - Techniques to repair loss in a 'light-weight' manner
 - + Concentrate on audio
 - Recommendations
- Other papers:
 - Fully-reliable (every bit must arrive), but not real-time
 - Real-time, but not receiver based approaches



Outline

- Overview
- Multicast Channel Characteristics
- Sender Based Repair
- Receiver Based Repair
- Recommendations

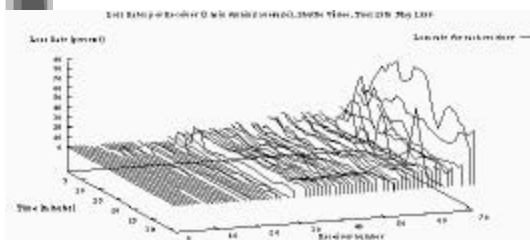


IP Multicast Characteristics

- Group address
 - Client receives to address
 - Sender sends to address, without client knowledge
- Loosely coupled connections
 - Not-two way ('extension to' UDP)
 - Makes it scalable
 - Allows clients to do local-repair
- Multicast router shared with unicast traffic
 - Can have high loss



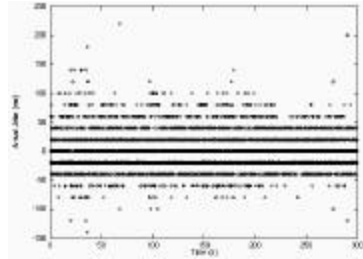
Mbone Loss Characteristics



- Most receivers in the 2-5% loss range
- Some see 20-50% loss
- Characteristics differ, so local decisions



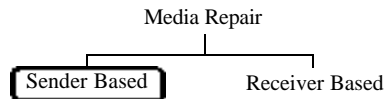
Mbone Jitter Characteristics



- High jitter
 - If too late, will be discarded and look like loss
- Interactive applications need low latency
 - Influence repair scheme



Media Repair Taxonomy



Sender Based Repair Taxonomy

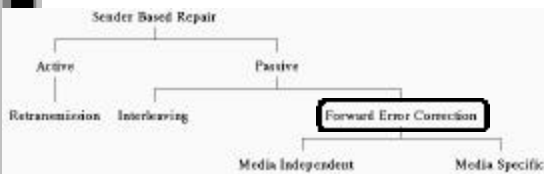
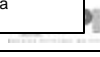


Figure 3: A Taxonomy of Sender Based Repair Techniques

- Work from right to left
- Unit of audio data vs. a packet
 - Unit may be composed of several packets
 - Or one packet may have several units of audio data



Forward Error Correction (FEC)

- Add data to stream
- Use repair data to recover lost packets
- Two classes:
 - Media independent (not multimedia specific)
 - Media dependent (knowledge of audio or video)

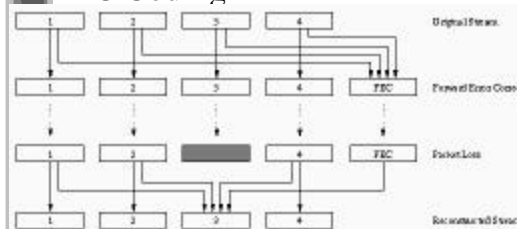


Media Independent FEC

- Given k data packets
- Generate $n-k$ check packets
- Transmit n packets
- Schemes originally for bits (like checksum)
 - Applied to packets
 - So i th bit of check packet, checks i th bit of each associated packet



FEC Coding



XOR operation across all packets
 Transmit 1 parity packet every n data packets
 If 1 loss in n packets, can fully recover
 Reed-Solomon treat as polynomial



Media Independent FEC Advantages and Disadvantages

- Advantages
 - Media independent
 - + Audio, video, different compression schemes
 - Computation is small and easy to implement
- Disadvantages
 - Add delay (repair wait for all n packets)
 - Add bandwidth (causing more loss?)
 - Add decoder complexity



Sender Based Repair Taxonomy

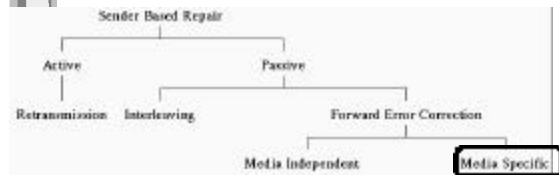
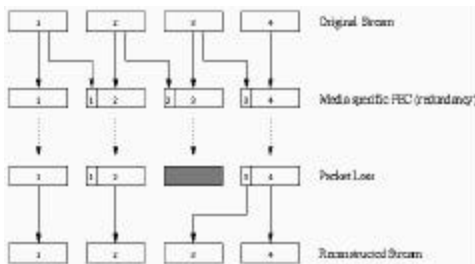


Figure 3: A Taxonomy of Sender Based Repair Techniques



Media Specific FEC



- Multiple copies of data
- "Quality" of secondary frames?



Media Specific FEC Secondary Frame

- Send packet energy and zero crossing rate
 - 2 numbers, so small
 - Interpolate from missing packet
 - Coarse, effective for small loss
- Low bit-rate encoded version of primary
 - Lower number of sample bits audio sample, say
- Full-version of secondary
 - Effective if primary is small (low bandwidth)



Media Specific FEC Discussion

- Typical overhead 20-30% for low-quality
 - [HSK98]
- Media specific FEC can repair various amounts by trading off quality of repair
 - Media independent FEC has fixed number of bits for certain amount of repair
- Can have adaptive FEC
 - When speech changes (cannot interpolate)
 - Add when increase in loss [PCM00]
 - Delay more than 1 packet when bursty loss



Media Specific FEC Advantages and Disadvantages

- Advantages
 - Low latency
 - + Only wait a single packet to repair
 - + Multiple if adapted to bursty losses
 - Can have less bandwidth than independent FEC
- Disadvantages
 - Computation may be more difficult implement
 - Still add bandwidth
 - Add decoder complexity
 - Lower quality (vs. other methods of repair)



Sender Based Repair Taxonomy

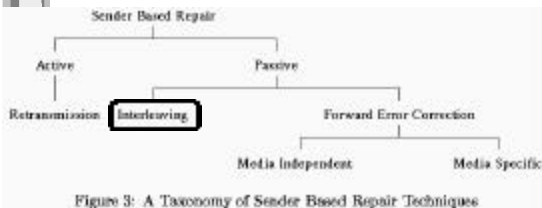
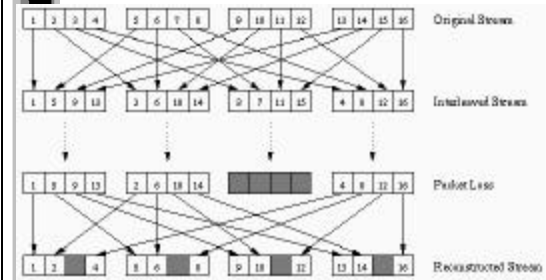


Figure 3: A Taxonomy of Sender Based Repair Techniques



Interleaving



- Disperse the effects of packet loss
- Many audio tools send 1 phoneme (40 ms of sound)



Interleaving Advantages and Disadvantages

- Advantages
 - Most audio compression schemes can do interleaving without additional complexity
 - No extra bandwidth added
- Disadvantages
 - Delay of interleaving factor in packets
 - + Even when not repairing!
 - Gains to quality can be moderate



Sender Based Repair Taxonomy

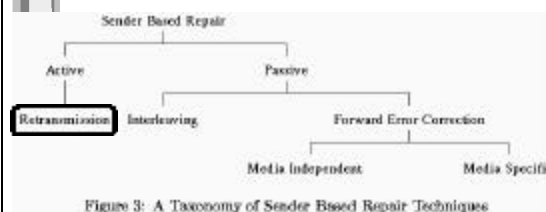


Figure 3: A Taxonomy of Sender Based Repair Techniques



Retransmission

- If delays less than 250 ms, can do retransmission (LAN, faster Internet)
- Scalable Reliable Multicast (SRM)
 - Hosts time-out based on distance from sender
 - + To avoid implosion
 - Mcast repair request (and repair) to all
 - All hosts can reply (timers again stop implosion)



Retransmission Discussion

- In a typical multicast session, can have every packet usually lost by *some* receiver
 - Will always retransmit at least once
 - FEC may save bandwidth
- Typically, crossover point to FEC based on loss rate
- Some participants may not be interactive
 - Use retransmission
 - Others use FEC

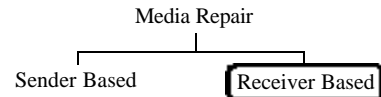


Retransmission Advantages and Disadvantages

- Advantages
 - Well understood
 - Only add additional data 'as needed'
- Disadvantages
 - Potentially large delay
 - + not usually suitable for interactive applications
 - Large jitter (different for different receivers)
 - Implosion (setting timers difficult)



Media Repair Taxonomy



- Do not require assistance of Sender
 - Receiver recover as best it can
- Often called *Error Concealment*
- Work well for small loss (<15%), small packets (4-40 ms)
- Not a substitute for sender-based
 - Rather use both
 - Receiver based can conceal what is less



Taxonomy of Error Concealment



- When packet is lost, replace with fill-in



Splicing

- Splice together stream on either side
 - Do not preserve timing
- Advantage
 - “Easy, peasy lemon-squeezy”
 - Works ok for short packets of 4-16 ms
- Disadvantage
 - Crappy for losses above 3%
 - Interfere with delay buffering



Silence Substitution

- Fill the gap left by lost packet with silence
 - Preserve timing
- Advantage
 - Still easy, peasy lemon-squeezy
 - Works good for low loss (< 2%)
 - Works ok for short packets of 4-16 ms
- Disadvantage
 - Crappy for higher losses (3%+)
 - Ineffective with 40ms packets (typical)



Noise Substitution

- Human psych says can repair if sound, not silence (*phonemic restoration*)
 - Replace lost packet with “white noise”
 - + Like static on radio
 - Still preserve timing
- Similar to silence substitution
- Sender can send “comfort noise” so receiver gets white-noise volume right



Repetition

- Replace missing packet with previous packet
- Can “fade” if multiple repeats over time
 - Decrease signal amplitude to 0
- Still pretty easy, but can work better
- A step towards interpolation techniques (next)



Taxonomy of Error Concealment



- When packet is lost, reproduce a packet based on surrounding packets.



Interpolation Based Repair

- Waveform substitution
 - Use waveform repetition from both sides of loss
 - Works better than repetition (that uses one side)
- Pitch waveform replication
 - Use repetition during unvoiced speech and use additional pitch length during voiced speech
 - Performs marginally better than waveform
- Time scale modifications
 - “Stretch” the audio signal across the gap
 - Generate a new waveform that smoothly blends across loss
 - Computationally heavier, but performs marginally better than others



Taxonomy of Error Concealment



- Use knowledge of audio compression to derive codec parameters



Regeneration Based Repair

- Interpolation of transmitted state
 - State-based decoding can then interpret what state codec should be in
 - Reduces boundary-effects
 - Typically high processing
- Model-Based recovery
 - Regenerate ‘speech’ to fit with speech on either side

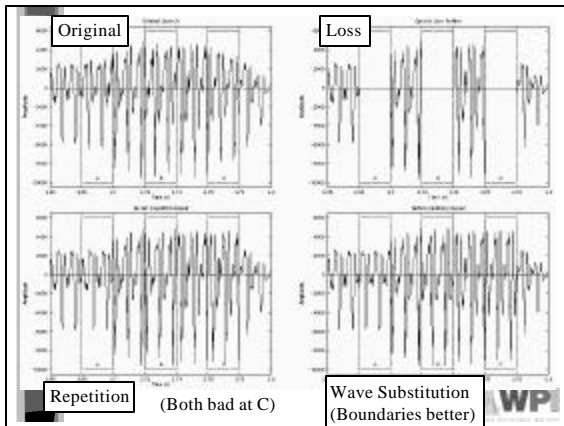


Summary of Receiver Based Repair



- Quality increase decreases at high complexity
- Repetition is at ‘knee’ in curve





Groupwork

- Consider:
 - Interactive voice from Europe to U.S.
 - Multicast broadcast video of taped lecture
 - Multicast replicated database update
 - Interactive voice across city
- Choose a repair technique and why:
 - Interleaving
 - Retransmission
 - Media Specific FEC
 - Media Independent FEC



Recommendations: Non-Interactive Applications

- Latency less important
- Bandwidth a concern (mcast has various bwidth)
- → use interleaving
- → repetition for concealment
- Retransmission does not scale
 - Ok for unicast
- Media independent FEC may be ok



Recommendations: Interactive Applications

- Want to minimize delay
 - → Interleaving delay is large
 - → retransmission delay can be large
 - → media independent FEC usually large
 - + (Or computationally expensive)
- Use media specific FEC
 - Approximate repair ok



Recommendations: Error Concealment

