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Title: Adaptation of the G.723.1 Audio Codec to the H.221 Multiplex
Purpose: Proposal

Adaptation of the G.723.1 Audio Codec to the H.221 Multiplex

1. *Introduction*

This contribution proposes a method for adapting the bitstream produced by the G.723.1 audio coder for transport over the H.221 multiplex as used in H.320 terminals. G.723.1 audio frames are aligned with H.221 frame timing as with other audio codecs supported in H.221. The adapted G.723.1 bitstream uses a full 8kbps sub-channel of the H.221 multiplex regardless of G.723.1 audio mode. Any difference in clock rate between G.723.1 encoder and H.221 transport is accommodated through the use of adaptation "slip frames" which contain no G.723.1 audio data and which allow clock slip in units of 10ms. Alignment information is coded to detect and correct single bit errors and the H.223 AL2 CRC is applied to G.723.1 audio frames to detect bit errors.

2. *Proposed Text for H.221 Section 4.2*

There are three types of G.723.1 frame, the type being indicated by the first two bits of the G.723.1 frame itself. The three frame types are "high rate" frames containing 24 octets (192 bits) of data, "low-rate" frames containing 20 octets (160 bits) of data, and "SID" or "Silence Insertion Descriptor" frames containing 4 octets (32 bits) of data. G.723.1 frames contain 30ms of audio; during silences at the encoder, it is possible that no frames will be produced.

The bitstream for the G.723.1 codec is transmitted in Sub-channel 1 of the H.221 multiplex. G.723.1 frames are aligned with H.221 frames. The first octet in Sub-channel 1 of each H.221 frame contains audio frame alignment information. This octet is known as the "Alignment Octet" or AO. Each G.723.1 audio frame shall be transmitted in three sequential H.221 frames; the set of frames containing a full G.723.1 audio frame is called a "frame triple."

Audio frame alignment coding occupies the first three bits (starting with MSB) of the AO. The codes for the three frames (leading frame, middle frame, trailing frame) of a triple shall be 100, 010, and 001, respectively. The alignment code "111" indicates that the current H.221 frame is not part of a frame triple and contains no G.723.1 data; such a frame is a "slip frame" used to accommodate clock slip and periods when no audio frames are produced by the encoder. The least significant five bits of the AO are reserved for future use and shall be set to 1.

The G.723.1 data shall immediately follow the AO in each frame of a triple. G.723.1 data shall be packed as specified in Recommendation G.723.1, with the most significant octet transmitted first and all octets transmitted from MSB to LSB. A CRC shall be computed according to the procedure specified for the "AL2 CRC" of H.223 for the G.723.1 audio data only, not including the AO or any padding bits, and this one octet value shall immediately follow the G.723.1 audio data with the MSB of the CRC transmitted first. The remainder of the frame triple shall be filled with the padding pattern 11111111.

If start of transmission of a G.723.1 frame is required by audio frame alignment but no G.723.1 encoded audio is available to the H.221 transmitter the transmitter shall transmit a slip frame. This situation might arise due to clock slip between the encoder clock and transport clock or because the encoder has detected silence and is not producing audio frames. After the AO, a slip frame shall be filled with the pattern "11111111". If no audio frame is available after the transmitter has sent a slip frame, the transmitter shall continue to send slip frames until audio is available. No CRC shall be present in slip frames. Receivers shall seek new G.723.1 alignment with H.221 framing after receiving any number of slip frames.

Figure 1 illustrates the bit allocation of the three G.723.1 frames and of slip frames.

Figure 1: Bit Positions for G.723.1

Value	Bit Number	Sub-Channel 1	Sub-Channel 2	Sub-Channel 3	Sub-Channel 4	Sub-Channel 5	Sub-Channel 6	Sub-Channel 7	Sub-Channel 8
AO	1	1							*F*
AO	2	0							*A*
AO	3	0							*S*
AO	4	1							
AO	5	1							
AO	6	1							
AO	7	1							
AO	8	1							
G.723.1 Frame MSB of Octet 1	9								
...	...								
End G.723.1 Silence Frame	40								
AL2 CRC MSB (Silence Frame)	41								
...	...								
AL2 CRC LSB (Silence Frame)	48								
Fill pattern begins (Silence Frame)	49								
End of first H.221 Frame	80								
AO (Second H.221 Frame)	81	0							*F*
AO	82	1							*A*
AO	83	0							*S*
...	...								
G.723.1 Frame Octet 9 MSB	88								
...	...								
End of second H.221 Frame	160								
AO (Third H.221 Frame)	161	0							*F*
AO	162	0							*A*
AO	163	1							*S*
...	...								
G.723.1 Frame Octet 19 MSB	168								
...	...								
End of G.723.1 Low-rate Frame	184								
AL2 CRC MSB (Low-rate)	185								
...	...								
AL2 CRC LSB (Low-rate)	192								
G.723.1 Low-Rate fill begins	193								
...	...								
End of G.723.1 High-rate Frame	216								
AL2 CRC MSB (High-rate)	217								
...	...								
AL2 CRC LSB (High-rate)	224								
Fill pattern	225	1							
...	...	1							
End of frame triple	240	1							

3. Background

At the May/June 1996 ITU-T SG 15 meeting use of the G.723.1 audio codec in the H.221 multiplex was discussed. The proposals for adaptation of G.723.1 were presented in TD 89(P) and three alternatives were discussed: "Alternative A" places the codec bitstream in an 8 kbps sub-channel of the H.221 multiplex by filling unused bit positions in the sub-channel with HDLC flags; this proposal did not attempt to align G.723.1 audio frames with H.221 frame timing. "Alternative B" and "Alternative C" aligned the G.723.1 frames with H.221 frames and presented proposals to make the bandwidth in the sub-channel beyond G.723.1 requirements available for video or data transmission. Consideration of requirements for simplicity of implementation suggests that use of fixed 8kbps bandwidth allocation is preferable for use of G.723.1 with H.320 terminals.

"Alternative A" could be adopted in H.221 and provide this fixed sub-channel mode of operation. However, it is not clear that this alternative will allow use of CRCs on G.723.1 high-rate audio frames. The need for a CRC with G.723.1 is discussed in section 4. The lack of alignment to the H.221 frame structure may raise implementation difficulties, and the extraction of the useful bitstream from the flags may be challenging for software implementations of H.320. Also, G.723.1 would be the only audio codec supported in H.221 which did not align audio frames with FAS.

An issue which does not appear to have been explicitly addressed in earlier discussions is the possibility of "clock slip" between G.723.1 encoder and ISDN time bases. "Alternative A" implicitly provides a mechanism for accommodating "clock slip" by permitting shifts in G.723.1 timing of eight ISDN octet times of 125 microseconds each, i.e. 1ms or about 3% of a G.723.1 frame time. Adaptation schemes based on alignment of G.723.1 to H.221 frame timing should provide some mechanism for accommodating clock slip.

One approach to handling clock slip with alignment of G.723.1 frames to H.221 frames would be to drop a complete G.723.1 frame whenever overrun or underrun of the transport takes place. This approach would require adding a 30ms buffer to accommodate clock slip. The method proposed here allows for accommodation of clock slip in 10ms units and requires only a 10ms buffer because alignment can be shifted in units of one H.221 frame (10 ms).

4. G.723.1 Adaptation Issues

One issue not discussed at the Geneva SG 15 meeting is that a G.723.1 codes 30ms of audio and is likely to produce audible and objectionable artifacts from a single bit error. When G.723.1 is used in the H.223 multiplex in H.324, the errors are detected by the CRC applied to the multiplexed data. No error detection is provided by H.221, so adaptation of G.723.1 to H.221 requires explicit use of a check value for G.723.1 data to avoid audible and objectionable effects from bit errors. An obvious candidate for this is *the AL2* CRC specified in H.223, which is one octet in length.

In the worst case expansion of the G.723.1 bitstream under "Alternative A," the high-rate bitstream would expand by 20%. With the "flag" octet and a single CRC octet, the size of a single G.723.1 frame is 208 bits, and with worst-case bit stuffing this expands to 248 bits. Since only 240 bits are available for transmitting G.723.1 frames every 30ms, in the worst case bit stuffing would prevent the use the AL2 CRC from H.223.

Another issue is clock mismatch and resulting clock slips. The G.723.1 encoder is producing frames at "30ms" intervals using some timing basis such as a quartz crystal oscillator. The H.221 transport of these frames requires "30ms" using the timing basis of the ISDN network clock. If the encoder clock is faster than the network clock, frames will be generated more quickly than they can be delivered, resulting in a need to drop some audio frames due to overrun of the ISDN link. If the encoder clock is slower than the network clock, some H.221 frames will be transmitted when no audio frame is ready for transmission. To accommodate the underrun or overrun of the H.221 transport the G.723.1 adaptation mechanism must allow for transmission of H.221 frames which do not contain G.723.1 data. In the proposed scheme, a single H.221 frame may be marked as a "slip frame" to allow for these underruns; a sequence of two slip frames allows for overruns.

Since the alignment of G.723.1 frames with the H.221 frames may vary with time (e.g. when resuming audio transmission after a silent interval or when accommodating clock slip) a mechanism to recover G.723.1 frame alignment is required. We propose the use of the first three bits of each frame of the H.221

sub-channel carrying G.723.1 frames for alignment coding. The use of three bits allows the consecutive numbering of the three H.221 frames carrying a single G.723.1 frame with a code that detects single bit errors. Single bit errors in the numbering of a frame which is part of a frame triple can be corrected as well as detected. The code for a slip frame also allows detection of single bit errors. The alignment codes are the three bit values with odd parity. In order to simplify software implementations of G.723.1 for H.320 terminals, a full octet is allocated for the alignment code.

The proposal presented in this contribution allows use of the G.723.1 audio codec with the H.221 multiplex in a manner which is compatible with the methods used for other audio codecs. Audio frames are aligned with FAS and a constant rate channel is occupied by audio data. The use of slip frames allows the use of G.723.1 in H.221 with minimal additional audio delay for adaptation and transmission. Slip frames also accommodate the G.723.1 feature of producing no audio frames during silent periods.