RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS

Meeting #24

UAT Ground Station Feedback Mechanism

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SUMMARY

This Working Paper is a follow-up to Proposed Change Candidate, Item 29 in UAT WP23-03. That item addressed the possibility of defining a method for airborne UATs to provide feedback to UAT ground stations as to the quality of their uplink signals. In this Working Paper a potential method is proposed. The method assumes that there are extra bits available in *every* ADS-B UAT Message type. It will be shown that it is indeed possible to identify at least one unused byte in every UAT Message type.

This note is a follow-up to Proposed Change Candidate, Item 29 in UAT WP23-03. That item addressed the possibility of defining a method for airborne UATs to provide feedback to UAT ground stations as to the quality of their uplink signals. The feedback mechanism will address the reception performance of only the ground uplink messages, not the performance of TIS-B or ADS-R messages. The uplink messages are convenient because each ground site has a fixed schedule for transmitting them, so the maximum number transmitted in any given time is fixed. This limits the size of the feedback message. The numbers of TIS-B and ADS-R messages, on the other hand, depend on fluctuating traffic levels and other variable parameters, which make their use as performance probes problematical.

The method assumes that there are extra bits available in *every* ADS-B UAT Message type. It will be shown below that it is indeed possible to identify one unused byte in every UAT Message type.

The method is as follows:

1. Each second a UAT will report the number of successful up-link messages it received on a particular data channel (rotating slot assignment). The value it reports is related to how many successes it had in the previous 31 seconds (not counting the current one). This is, at most, a 5-bit number from 0 to 31. It is likely that fewer bits are necessary to provide adequate feedback (see below).

2. The channel that is reported on is the one that happens to be assigned the first time slot in the current second.

Because of the fact that the channels rotate through the slots once each 32 seconds, each channel is reported on by each UAT once each 32-second period. It is *not* necessary that the UATs identify which channel they are reporting on because that information is conveyed by the timing of the transmissions.

An example may clarify how this would work. Suppose there is a single GBT in an area, using channel “5” only. That means it uses slot 5 in second 1, slot 6 in second 2 etc. If there were perfect reception by the aircraft, it would have 31 successes in seconds 6 through 36. The Score (see below) would be 31, which the aircraft would report within its ADS-B message in second 37. In other words, the aircraft radio maintains 32 registers (one for each possible channel) containing a moving-window sum of the number of successes in the previous 31 seconds and sequentially reports on the contents of each one.

Because the UATs report performance on a per-channel basis, it is not necessary that the UATs take into account how channels are combined into DCBs. The ground stations already know that.

It is not really necessary that the UATs include the 4-bit TIS-B Site ID in their messages. (This is contained in the header of the ground uplink message.) If a UAT is within line-of-sight of two ground stations using the same channel, it’s not likely to have a very high reception success rate; and both of the ground stations will see the same (low) number reported. (It could happen that 1 of 2 such GBTs is much closer to the UAT than the other, so the success rate would be high. Potential ambiguities about the meaning of such reports can be sorted out on the ground by taking geometry into account during post processing.)

It may seem like the reporting rate is quite high and bits are being wasted; but an En Route aircraft can move pretty far in half a minute! The 32-second cycle is nice because it allows the UAT *not* to use up bits identifying the channel it's reporting on. We could slow down the reporting rate by various factors; but if we did, we'd have to find some other use for the saved bits that also needed a very slow update rate.

The feedback is based on the number of successful receptions out of 31. Using the maximum 5 bits to send this would be wasteful. A more economical method, using only 2 bits, differentiates between only 3 levels of performance as follows:

Feedback Code	**Score (N_C)**
11	29-31
10	22-28
01	0-21
00	No Information

This is a logarithmic scale given by

$$Code = 3 - Int\left(\frac{3}{5} Log_2(32 - N_C)\right) \qquad 0 < N_C \leq 31$$

$$Code = 1 \qquad 0 = N_C$$

with N_C equal to the number of successes out of 31. The message success rates of the break points correspond to 93.5% (29) and 71.0% (19). The Feedback Code 00 = No Information is necessary because some UAT radios (particularly transmit-only Equipage Classes B0 through B3) may not have the capability to provide such information.

If more resolution is needed, then a 3-bit field can be defined as follows:

Feedback Code	**Score (N_C)**
111	31
110	30
101	28-29
100	25-27
011	21-24
010	13-20
001	0-12
000	No Information

The corresponding equations are as follows:

$$Code = 7 - Int\left(\frac{7}{5} Log_2(32 - N_C)\right) \qquad 0 < N_C \leq 31$$

$$Code = 1 \qquad 0 = N_C$$

The bits needed to convey this (and other additional) information can be found within the current protocol definitions. Some of the defined Payload Types (0, 3 and 4) already have a reserved byte. The remaining Payload Types all contain the Auxiliary State Vector element. This element contains 28 bits reserved for future definition. One byte of the reserved bits can be defined for new functions (an "Extension" field) as shown in the hypothetical Table 2-10 below. Each Payload Type now concludes with a byte labeled "Ext."

Table 2-10: Composition of ADS-B Payload

Payload Type Code	**ADS-B Message Payload Byte Number**						
	1 ---- 4	5 ---- 17	18 --------- 24	25 ---- 28	29	30 --- 33	34
0 *(Note 1)*	HDR	SV	*Ext*	*Byte 19-34 Not present in Type 0*			
1	HDR	SV	MS			AUX SV	*Ext*
2	HDR	SV	*Reserved (Note 2)*			AUX SV	*Ext*
3	HDR	SV	MS			TS	*Ext*
4	HDR	SV	*Reserved for TC+0 (Note 2)*			TS	*Ext*
5	HDR	SV	*Reserved for TC+1 (Note 2)*			AUX SV	*Ext*
6	HDR	SV	*Res. (Note 2)*	TS	*Res*	AUX SV	*Ext*
7	HDR	SV	*Reserved (Note 3)*				
8	HDR	SV					
9	HDR	SV					
10	HDR	SV					
11 through 29	HDR	*Reserved (Note 2)*					
30, 31	HDR	Reserved for Developmental Use (*Note 4)*					

Two (or three) bits of this redefined byte can carry the Feedback Code defined above. That would leave 6 (or 5) additional bits in reserve for future fields that need to be in every Payload Type.

This would not adversely affect backward compatibility since all of the Extension bits are in locations that are "reserved" in the existing version of the MOPS.

Recommendation

WG-5 is invited to consider whether or not to include the proposed feedback capability (or a similar one) in the next version of the UAT MOPS.