MAC schemes collision reduction for LDACS2

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Abstract

To meet the future capacity requirements in aeronautical communication, new aeronautical systems are proposed, namely LDACS1 and LDACS2, respectively. Since L-band Digital Aeronautical Communication System 2 (LDACS2) is a TDMA system, the possibility for MAC layer collision in the login phase is higher than that of LDACS1, which is FDMA. In this paper, the specified MAC login algorithm in LDACS2 is simulated. The results show high collision rate. On the other hand, extending the LoG2 section shows less collision rate using the same login algorithm.

Keywords: Aeronautical Communication, LDACS2, TDMA, MAC

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I. Introduction

The aeronautical communication systems are used to transfer data from the aircraft (AC) to Ground Station (GS). The current aeronautical communication systems are using the Very High Frequency (VHF) band for more than 70 years. Since the VHF band is already congested with other communication systems, the need to develop a new communication system arose. At the end of the Future Communication Study (FCS) project in 2002, two systems are proposed for final analysis [1]. Those are called L-band Digital Aeronautical Communications System, Type1 (LDACS1) and L-band Digital Aeronautical Communications System, Type2 (LDACS2), respectively. LDACS1 is based on Orthogonal Frequency Division Multiple Access (OFDMA) concept while LDACS2 is based on Time Division Multiple Access (TDMA) [2]. In both systems, the AC has to reserve a resource before being able to transmit. The reservation process takes place in the Login Phase of the frame. The resources are defined as combined time-frequency frames in LDACS1 and time slots in LDACS2. It is obvious that the resources are more scare in LDACS2 than in LDACS1, because the LDACS1 combines different frequency channels while LDACS2 communicate through single channel of 200 kHz [3]. Therefore, this paper studies theLDACS2 login procedure performance in terms of collisions occurred. LDACS2 is based on current TDMA systems, such as UAT, AMACS and LDL, as shown in Figure 1.

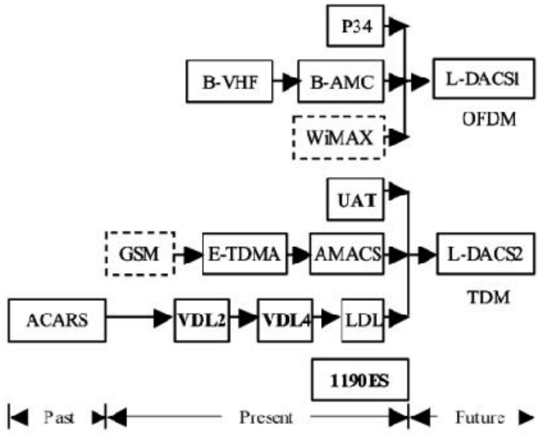

Fig. 1. Evolution of aeronautical data links.

- ACARS: Aircraft Communications Addressing and Reporting.
- VDL2: Digital link. In all aircrafts in Europe by 2015.
- VDL4: Added Aircraft-to-Aircraft. 2001. Limited deployment.
- LDL: L-Band Digital Link. TDMA based like GSM.
- E-TDMA: Extended TDMA. Multi-QoS services possible.
- AMACS: All purpose Multichannel Aviation Communication System(similar to GSM, L-Band)
- UAT: Universal Access Transceiver, 981 MHz. Offers one 16B or 32B message/aircraft/sec

II. Framing Structure

The general LDACS2 structure is based on the Global System for Mobile Communication (GSM) [4]. The LDACS2 modulation scheme is Gaussian Minimum Shift Keying (GMSK). The resulting channel bandwidth is thus minimized to 200 KHz to minimize the out-of-band radiation. LDACS2 is to be operated in the lower part of the L-band, specifically 960 − 975 MHz, as illustrated in Figure 2.

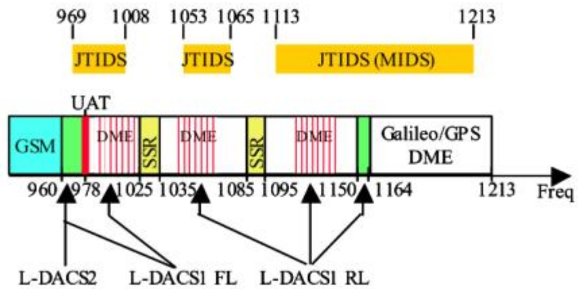

Fig. 2. LDACS2 Spectrum Allocation.

- JTIDS: Joint Tactical Information Distribution System.
- GSM: Global System for Mobile communication.
- L-DACS1 FL: LDACS1 Forward Link (ground to air).
- L-DACS2 RL: LDACS2 Reverse Link (air to ground).
- DME: Distance Measuring Equipment.
- SSR: Soldier System Radio, 400 MHz and 900 MHz.
- Galileo:global navigation satellite system built by the European Union and European Space Agency
- GPS: Global Positioning System.

The main LDACS2 architecture is adopted based on the AMACS MAC layer. The frame length is limited to 1 second, to ensure the delivery of high priority messages.

Each LDACS2 frame consists of 150 basic slots, where each slot is 6.66 ms. The basic slot consists of header, address, user data, trailer and guard fields. Accurate synchronization between the AC and GS avoids the insertion of large guard periods.

At the beginning of each frame, the Ground Station (GS) sends a short message describing the length of each of the five sections. This message is called the Framing Message. Every AC within the range of that GS listens to the framing message and synchronizes itself accordingly.

The frame structure is based on Time Division Duplex (TDD), i.e., either one of the communicating entities (the transmitter or the receiver) is allowed to send or receive at a given time. Each frame is divided into five sections, namely UP1 and UP2 for the up-link, CoS1 and CoS2 for the down-link and the LoG2 section for login procedure. LDACS2 frame structure is shown in Figure 3.

The UP1 and UP2 sections are used to transmit data from the GS to the AC. The GS concatenates all of its messages into two continuous burst, one for each section. The GS has control of its entire UP section, thus it transmits in bursts rather than slots. The minimum size of a UP burst is two basic slots (13.33 ms). The CoS1 section transmits high priority short messages from the AC to GS. The CoS1 slot length is 1.11 ms.If the AC needs access to transmit long messages, it requests access to the CoS2 section during its assigned CoS1 slot and it would be granted access to one or more slots in CoS2 section. While a CoS1 slot is short, CoS2 slot is longer and equal to 6.66 ms.The log-in procedure takes place in the LoG2 section. The LoG2 slot is 3.33 ms.It is used by the AC to have access to a CoS1 slot.

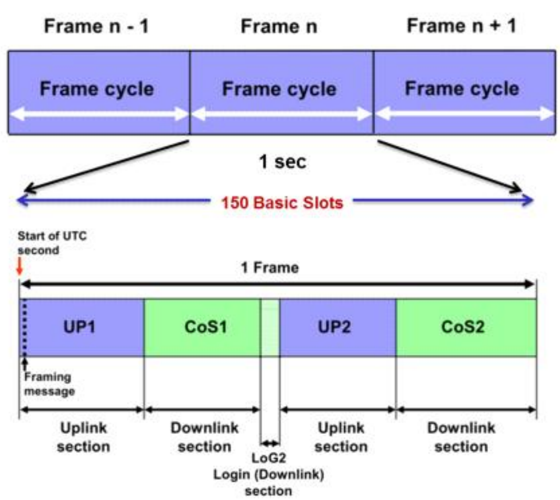

Fig. 3. LDACS2 frame structure.

The LDACS2 specification [3] defines LoG2 section to contain 4 to 33 time slots. During the LoG2 section, collision can occur. This is due to the fact that the new arriving aircraft is trying to reserve resources (time slots in LDACS2). To reserve time slots in CoS1 or CoS2 sections, the aircraft randomly selects a slot in LoG2 section and sends the login request message. The login procedure follows an algorithm, called Persistence LoG2 Algorithm.

In this paper, the specified login algorithm is simulated using MATLAB simulation environment. The performance of this algorithm is measured in terms of the number of collisions occurred. Then, the length of the Login section is extended and the algorithm is simulated against the new structure.

III. Persistence Log2 Algorithm

The LDACS2 specification specifies the Persistence LoG2 Algorithm to be used whenever a mobile station (aircraft) is trying to login. The algorithm defines two parameters:

1) P2: defines the probability of random access attempts in LoG2 section.

2) VS4: a counter defines the maximum number of login attempts. VS4 shall be cleared on initialization and incremented only in case of unsuccessful attempt. On reaching the maximum value, the AC is granted a slot in LoG2 whenever a channel is available.

The non-adaptive, persistent algorithm is described as follows:

(a) The AC selects a slot randomly from the available slots in the LoG2 section, with equal probability among the available slots.

(b) If the AC was able to select a slot, the AC transmits in the slot with a probability p2.

(c) VS4 counter is canceled if the AC was able to transmit.

(d) If the AC could not transmit at the first attempt, and it did not reach the end of the current LoG2 section, and the VS4 timer is not expired, VS4 counter is incremented and the AC shall make a further random access attempt, repeating step (a).

(e) If the mobile station could not select a slot at the first attempt, and it has not reached the end of the current LoG2 section, and the VS4 timer reached its maximum value, the AC selects a slot as in step (a) and then transmit in this slot with probability p2=1.

(f) If the AC was unable to select a slot within the current LoG2 section, VS4 counter is cleared and the login attempt procedure should be repeated in the next frame.

The login flowchart is shown in Figure 4.

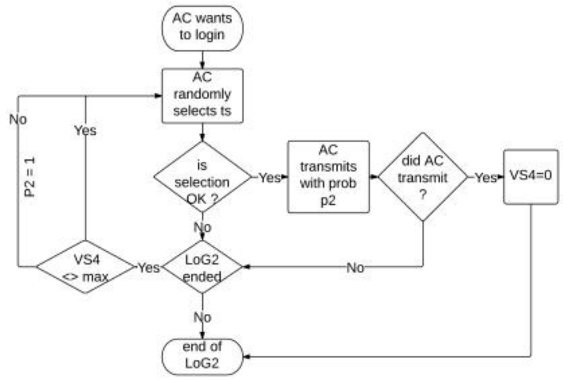

Fig. 4. Login flowchart.

IV. Proposed Modifications

It is expected that by the year 2020, the aeronautical traffic will be doubled. For this reason, the current LoG2 section with a maximum of 32 slots will not be sufficient. Therefore, we propose doubling the LoG2 section to consist of 64 slots instead. This modification has minor effect of the LDACS2 general structure and it will not affect the overall bit rate. On the other hand, it is assumed that the number of collisions occurring in the login phase will dramatically decrease.

V. Simulation Results

To study the effectiveness of the specified algorithm, it is simulated against variable number of aircrafts. Thus, it is assumed that a maximum of 20 aircrafts are trying to get access to the LoG2 section at any LDACS2 frame. The available LoG2 slots are assumed to be 32 slots, which is the maximum value defined by the specifications. Furthermore, VS4 counter starting value is set to 3, and then incremented in the algorithm to a maximum of 6, as defined in LDACS2 specifications [3]. For the sake of worst case condition simulation, P2 probability is fixed at 0.5, which is the recommended default by the specification. It is the maximum probability which indicates that many aircrafts access attempts are occurring in the LoG2 section.

To evaluate the performance of the login algorithm, the collision rate is defined. It is calculated as the number of collisions occurring in every frame, i.e., every second. MATLAB simulator is used to build the MAC persistent algorithm. The aircrafts login attempts and collisions are also simulated. To get a smooth curve, Monte-Carlo simulation method is considered, with an averaging of 10^6 samples for each AC number. The MATLAB code is given in Appendix A. The collision ratio vs. the number of aircrafts is shown in Figure 5. When the number of aircrafts is less than 15, it is expected that only one collision per second occurs. On the other hand, when the number of aircrafts exceeds 15, 2.5 collisions per second are expected. It is worth to mention that the number of aircrafts does not only represent the actual arriving aircrafts but also those which did not succeed to login from the previous frame.

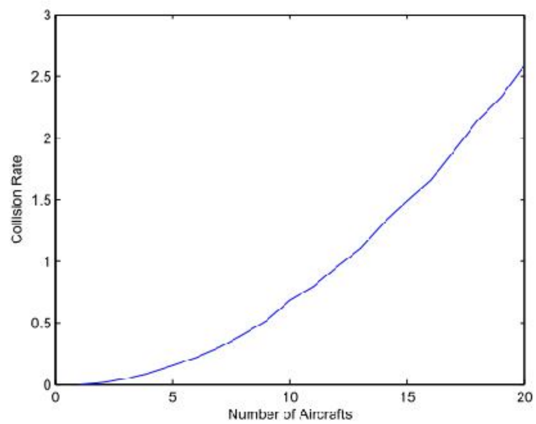

Fig. 5. Collision rate vs. number of AC. LoG2 section = 32 slots.

For small-to-medium size airports, this collision rate is acceptable. On the other hand, the number of approaching aircrafts on large airports is so high that the previous collision rate will not guarantee assigning the required slots. Therefore, we propose extending the LoG2 section up to 64 slots. The extended LoG2 structure length is simulated within the same simulation parameters and shown in Figure 6. It is obvious that the collision rate is approximately decreased to the half, due to the increased login slots. Thus, the mobile stations are less likely to select the same slots. It is shown that up to 17 aircrafts, one collision is likely to occur.

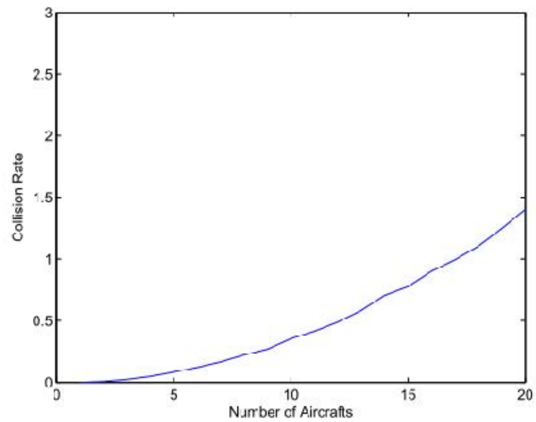

Fig. 6. Improved collision rate. LoG2 section = 64 slots.

VI. Conclusion And Future Work

In this paper, the Persistent LoG2 algorithm is evaluated and simulated. The simulation takes the increasing number of aircrafts into account. The result shows the collision increases when the login mobile stations are more than 15, which is a normal case in loaded airports. We propose increasing the LoG2 section to 64 time slots to solve the congestion problem. The proposal is simulated against the same conditions. The simulation shows the collision rate is reduced by half compared to the specified 32 slots length. Moreover, increasing the LoG2 section to 64 time slots will have minor effect on the overall bit rate. That is, only 14 kbps reduction is observed over a total of 270 kbps. Carrier Sense Multiple Access (CSMA) schemes defines other medium access algorithms, such as 1-persistent, non-persistent and o-persistent. Hybrid and adaptive schemes are also possible. As a future work, those algorithms can be applied and simulated within the specified frame structure.

References

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[4] **Release Note Recommendation GSM 05.04 Modulation**. ETSI/TC SMG, March 1992.

Appendix A

```
clc;
clear all;
login_slots = 64;
Max_AC_number = 20;
collis = zeros(Max_AC_number,1);
norm = 1e3; % Normalization Variable
p=0.5;
VS4_max = 6;


forAC_number = 1:Max_AC_number

collis_sum = 0;
C=zeros(AC_number,1);
VS4 = 3;

for i = 1:norm  % Randomely selecting a slot in the Log2 section

while (true)

for j = 1:AC_number
AC(j) = randi(login_slots,1);
end

% Generating p-persistent probability

b=rand(1,length(AC));
```

```
b(b<=p)=0;
b(b>p)=1;

% Transmission Probability
T_prob = AC.*b;
% Calculate # of collisions

for j = 1:login_slots
C(j) = numel(find(T_prob==j));
end

% [n, bin] = histc(T_prob, unique(T_prob));
% multiple = find(n > 1);
% index    = find(ismember(bin, multiple));

if sum(C(C>1)) ~= 0
VS4 = VS4 +1;
end

if sum(C(C>1)) == 0 || VS4 > VS4_max
break;
end
end
collis_sum = collis_sum + sum(C(C>1));
end
collis(AC_number)=collis_sum/norm;
end
plot(collis)
ylim([0 3])
xlabel('Number of Aircrafts')
ylabel('Collision Rate')
```

خطط للحد من التصادم في المستوى الثاني (MAC) لنظام (LDACS2)

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المستخلص

من اجل تلبية متطلبات انظمة الاتصال الجوية، تم تطوير نظامان جديدان، هما LDACS1و LDACS2. بما ان نظام LDACS2 هو مبني على الوصول المتعدد بالتقسيم الزمنيTDMA، فان امكانية حدوث تصادم في المستوى الثاني MAC Layer عند محاولة تسجيل الدخول للطائرة هي اعلى من مثيلتها في نظام LDACS1 المبني على الوصول المتعدد بالتقسيم الترددي FDMA. في هذا البحث، تم محاكاة خوارزمية تسجيل الدخول الى (MAC(MAC login algorithm في نظام LDACS2. اثبتت النتائج نسبة تصادم عالية Collision Rate. على الجانب الاخر، تمت اطالة جزء تسجيل الدخول LoG2 مما ادى الى تقليل نسبة التصادم باستخدام نفس الخوارزمية.

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