AEROSPACE SYSTEMS FOR MONITORING AND CONTROL

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INVESTIGATION OF ADS-B MESSAGES TRAFFIC VIA SATELLITE COMMUNICATION CHANNEL

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Abstract. *For modelling of ADS-B messages transmition with the help of low-orbit satellite complex Iridium different models of communication channel "Aircraft-to-Satellites-to-Ground Stations" were built using NetCracker Professional 4.1 software. Influence of aircraft and satellites amount on average link utilization and message travelling time was studied for telecommunication channels with intersatellite link and bent-pipe architecture. The effect of communication channel "saturation" during simultaneous data transmission through a satellite communication channel from many planes was investigated.*

Keywords: average utilization; data bit rate; message travelling time; models for communication channel “Aircrafts-to-Satellites-Ground Stations”; satellite communication channel; traffic.

1. Introduction

Process of continuous aviation developing leads to necessity of conversion from ground-based CNS systems to satellite-based systems in order to increase the possible operational areas mainly in the Poles regions and regions with reduced radar coverage [2].

That’s why the new programs of ADS-B surveillance systems development using capabilities of satellite communication are produced in the scope of SESAR (Europe) and NEXTGEN (USA) [10, 11].

Communication channels consisting of on-board ADS-B equipment and Iridium satellites could help to resolve the bottlenecks by allowing the relocation of aviation traffic from the regions with the high density to the regions that cannot be used due to its remote location or inability of ground surveillance equipment installation [9].

For that reason the deep analysis of traffic parameters for “Aircrafts-to-Satellites-to-Ground Stations” channel is urgently needed.

2. Analysis of researches and publications

Nowadays aviation is faced the problem of fast information exchange with high quality.

The difficulties appear when insufficient number of radars or the lack of radar visibility cause “gaps” in aircraft tracking.

This problem needs creation of modern data transmission systems.

One of the best ways for their further development is the use of satellite technologies.

This leads to a simplification of the equipment and reducing of the cost of installation and maintenance.

They also provide coverage even in those places where the ground-based systems could not do this.

During last 20 years technologies have stepped forward and today there is a set of satellite communication systems that are able to provide information exchange in general aviation: INMARSAT, COSPAS/SARSAT, Iridium, Globalstar and Thuraya.

Each of them has its benefits, but in terms of global data transferring Iridium has the absolute advantage, that is 66 satellites and coverage of the whole Earth surface [4, 5].

With the help of satellite technologies and airborne ADS-B equipment air traffic management agencies around the Earth will be able to track any aircraft at any point of the globe.

ADS-B system detects aircraft position, generates report about current velocity, vertical velocity, and altitude and other relevant data and broadcasts this information at the frequency 1090 MHz.

Ground stations and other aircraft equipped with ADS-B systems can receive and use these data.

Transmission of ADS-B messages via satellite constellation Iridium was investigated in papers [7, 8].

The **aim** of this work is:

1) to create models of communication channel "Aircraft-to-Satellites-to-Ground Stations" using NetCracker Professional 4.1 software;

2) to consider and analyze the dependencies of Average Utilization (AU) in downlink and massage traveling time on the number of aircraft and satellites;

3) to investigate satellite links with different architecture;

4) to study effect of communication channel „saturation“ during simultaneous data transmission from many planes via different number of satellites.

3. Structure of models

For modeling of ADS-B messages transmission through satellite communication channel computer software Professional NetCracker 4.1 was used.

The following notations for the channel models were used: kAmSnG, where k – is the number of aircraft A, m – is the number of Satellites S, and n – is the number of ground stations G.

On Fig. 1 a model 1A5S1G with intersatellite link is shown: one airborne station, which is the aircraft ADS-B system, five Iridium satellites and terrestrial air traffic control centre.

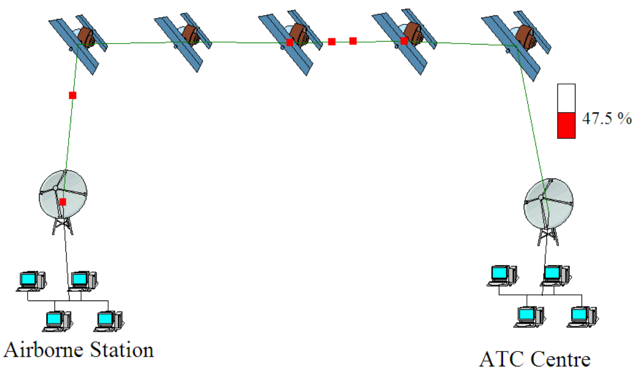

Fig. 1. Model 1A5S1G with intersatellite communication link

The following parameters of the model were chosen for Iridium satellites and the ADS-B system.

Data streams have stochastic nature and are described using distribution laws for random values.

Traffic parameters in NetCracker Professional 4.1 software were specified similar to queuing theory [1, 2, 6, 12]: transaction size – 8 Kbits with Uniform distribution law; time between transactions – 0,1 s with Exponential distribution law; packet latency – 0,02 s with Constant distribution law; packet fail chance – 0,01; aircraft/ground workstations; antennas data rate – 100 Kbyte/s (medium), links bit rates – T1 (1,544 Mbit/s).

The same parameters were used in most models, except those for which changes of traffic parameters were defined separately.

On Fig. 2 a model 1ASGSGS1G is shown with bent-pipe architecture: one airborne station; three Iridium satellites; two Wireless Local Area Network (WLAN) stations; terrestrial air traffic control centre.

On Fig. 3 a model 1ASCSCS1G is shown with bent-pipe architecture: one airborne station; two Wide Area Network (WAN) clouds; terrestial air traffic control centre.

On Fig. 4 a model 3A10S1G with intersatellite link is shown: three airborne stations; ten satellites; terrestial air traffic control centre.

On Fig. 5 a model 13A4S1G with intersatellite link is shown: thirteen airborne stations; four satellites; terrestial air traffic control centre.

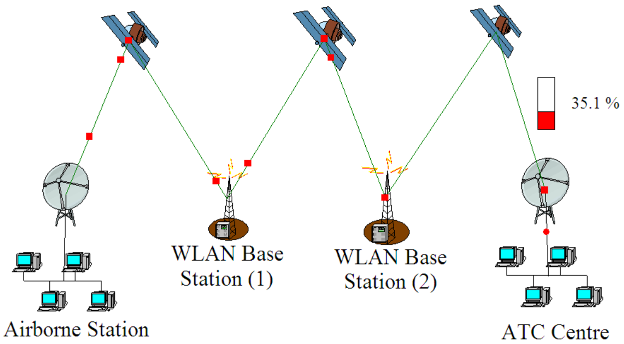

Fig. 2. Model 1ASGSGS1G with satellite bent-pipe communication link

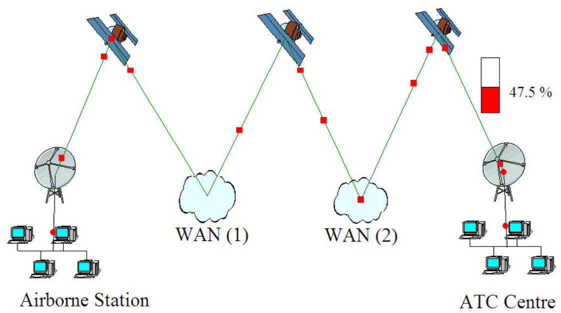

Fig. 3. Model 1ASCSCS1G with satellite bent-pipe communication link

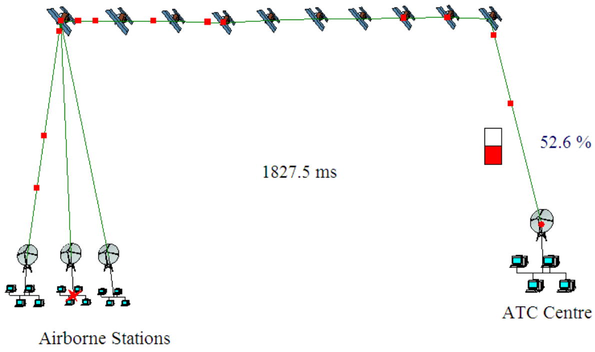

Fig. 4. Model 3A10S1G with intersatellite communication link

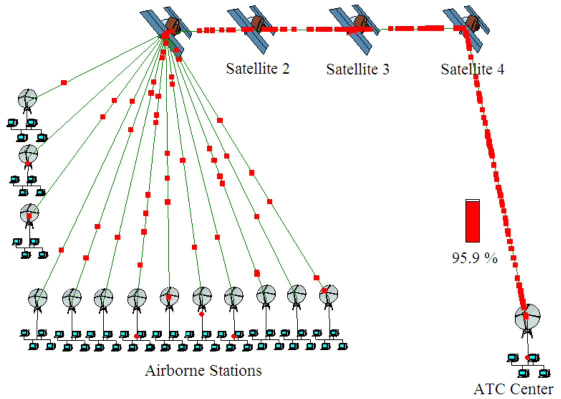

Fig. 5. Model 13A4S1G with intersatellite communication link

A satellite altitude is 780 km, a distance between satellites – 1000 km, a frequency band is 1616 MHz, a bit rate in intersatellite links – T1 (1,544 Mbit/s), initial Bit Error Rate and Latency equal 0, Packet and Circuit Switching are available for the links ADS-B System – Iridium Satellite Transponder and Iridium Satellite Transponder – Ground Transceiver.

4. Simulation of data transmission

Especially important to investigate the dependence of the data traveling time and downlink average utilization on channel architecture.

As seen from Table values for travelling times and average downlink are of the same order.

Increasing the length of the channel (compare models 1A3S1G and 1A5S1G, 1ASGS1G and 1ASGSGS1G, 1ASCS1G and 1ASCSCS1G) results in a slight increase in travelling times and does not alter the average downlink utilization.

The fastest channel is WLAN bent-pipe link, and the slowest – WAN bent-pipe link.

Bit rates of all links were T1.

Dependence of message traveling time on different number of satellites for several aircraft (Fig. 4) was investigated with the help of models (1-3)A(1-10)S1G (one of which is shown on Fig. 4).

In this case bit rates of all links were T1.

The range of traveling times variation is rather small (1300-1940 ms) and indicates the possibility of satellite real-time data transmission for air traffic management purposes in real-time.

Since here the model estimations take place, it is more correct to speak about the relative changes of travelling times during data transmission due to increasing the number of satellites and aircraft and not about the absolute values of the data travelling times.

When the number of planes simultaneously transmitting data through a single satellite communications channel to the terrestrial centers becomes very large a channel will be "saturated" and a data channel will not be able to operate.

Modeling showed (Fig. 5) that the channel is “saturated” for 13 aircraft.

This means that the communication channel with the given parameters (transaction size – 8 Kbits with Uniform distribution law; time between transactions – 0,1 s with Exponential distribution law; packet latency – 0,02 s with Constant distribution law; packet fail chance – 0,01; aircraft/ground workstations and antennas data rate – 100 Kbyte/s (medium), links bit rates – 1,544 Mbit/s) is able to serve no more than 13 planes simultaneously.

Certainly, for air traffic control purposes it is not enough.

But it should be remembered that this result is estimation and is valid only for selected software environment, designed model and selected traffic parameters.

Moreover, properties of “servicer engine” in the NetCracker software are not determined in details and are given only in the form of a fixed delay of service and absolute speed limit for receiving of requests.

However, these assessments can be useful for further research.

Increasing the number of satellites and downlink data bit rate leads to an interesting effect (Fig. 7). There is a significant difference between whether the data are transmitted through a single satellite (model 13A1S1G) to the terrestrial ATC centre or via several satellites. Increasing the number of satellites models 13A2S, 13A3S1G, 13A4S1G) gives practically the same dependencies of average downlink utilization on the downlink bit rate.

But in case of using satellite constellation the average downlink utilization is much less for the same downlink bit rates.

5. Conclusions

1. For modelling of ADS-B messages transmition with the help of low-orbit satellite constellation Iridium original models of „Aircraft-to-Satellites-to-Ground Stations“ link were built using NetCracker Professional 4.1 software.

2. Influence of aircraft and satellites number on average downlinklink utilization and message travelling time was studied.

3. Telecommunication channels with intersatellite link and bent-pipe architecture were analized.

4. The effect of communication channel „saturation“ during simultaneous data transmission via satellite communication channel from many planes was investigated.

Traveling times and average downlink utilization for different link architectures

Model	Message traveling time (ms)	Average utilization (%)
1A3S1G (intersatellite link)	1400	48
1ASGS1G (WLAN bent-pipe link)	1355	35
1ASCS1G (WAN bent-pipe link)	1397	47
1A5S1G (intersatellite link)	1489	48
1ASGSGS1G (WLAN bent-pipe link)	1402	35
1ASCSCS1G (WAN bent-pipe link)	1494	47

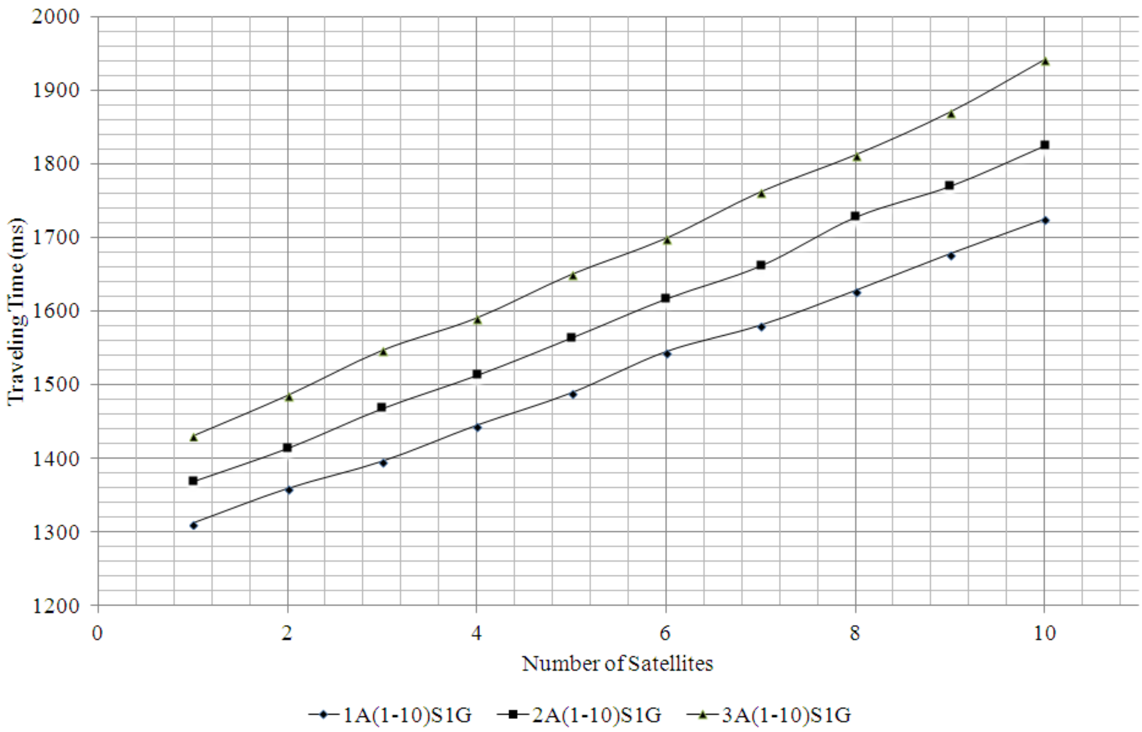

Fig. 6. Dependence of message traveling time on the number of satellites

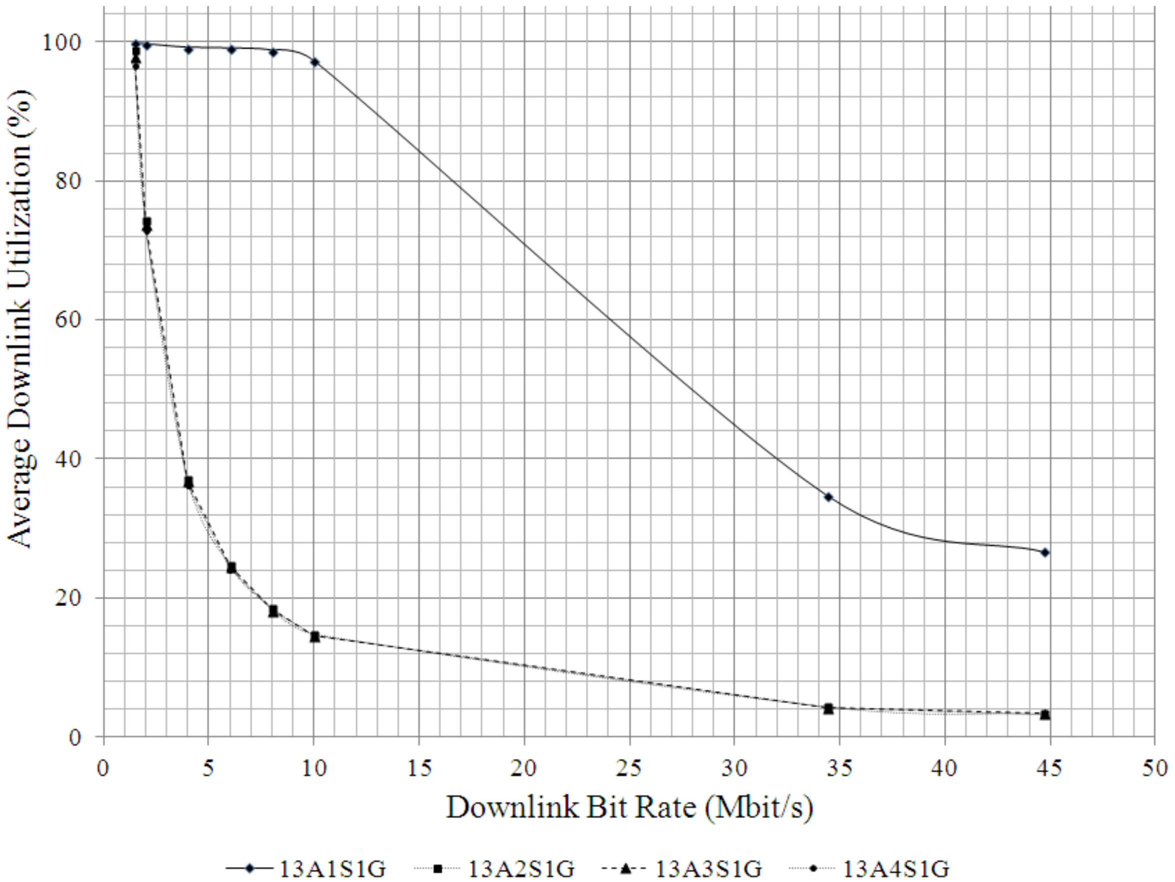

Fig. 7. Dependence of average downlink utilization on its bit rate

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В.П. Харченко[1], Wang Bo[2], А.М. Грехов[3], М.А. Коваленко[4]. Дослідження трафіку ADS-B повідомлень при передачі через супутниковий канал зв’язку
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Для моделювання передачі ADS-B повідомлень за допомогою низкоорбитального сузір'я супутників Iridium з використанням програмного комплексу NetCracker Professional 4.1 побудовано оригінальні моделі комунікаційного каналу «Літаки-Супутники-Наземні станції». Вивчено вплив кількості літаків і супутників на середнє завантаження каналу донизу і час передачі повідомлень. Розглянуто різні архітектури телекомуніка-ційних каналів: тільки з міжсупутниковими зв'язками та зв’язками «Супутник-Земля-Супутник». Досліджено ефект «насичення» каналу зв'язку при одночасній передачі даних через один канал супутникового зв’язку від багатьох літаків.

Ключові слова: канал супутникового зв'язку; моделі для каналу зв’язку «Літаки-Супутники-Наземні станції»; середня завантаженість каналу; трафік; час передачі повідомлення; швидкість передачі даних.

В.П. Харченко[1], Wang Bo[2], А.М. Грехов[3], М.А. Коваленко[4]. Исследование траффика ADS-B сообщений при передаче через спутниковый канал святи
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Для моделирования передачи ADS-B сообщений с помощью низкоорбитального созвездия спутников Iridium с использованием программного комплекса NetCracker Professional 4.1 построены оригинальные модели коммуникационного канала «Самолеты-Спутники-Наземные станции». Изучено влияние количества самолетов и спутников на среднюю загрузку канала вниз и время передачи сообщений. Рассмотрены различные архитектуры телекоммуникационных каналов – только с межспутниковыми связями и связями «Спутник-Земля-Спутник». Исследован эффект «насыщения» канала связи при одновременной передаче данных через один канал спутниковой связи от многих самолётов.

Ключевые слова: время передачи сообщения; канал спутниковой связи; модели для канала связи «Самолеты-Спутники-Наземные станции»; средняя загруженность канала; скорости передачи данных; трафик>

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