

DVB-S2/RCS Suitability for the Provision of Air Traffic Management Services

Cristina Párraga Niebla, *Member, IEEE*, Núria Riera Díaz, Sandro Scalise, *Member, IEEE*, Christian Kissling.

Abstract—Safe flying in a future (busy) airspace will require significantly increased volumes of information exchanges, as well as reliable and adequate transfer mechanisms for both the air/ground and the air/air segments. However, current communications systems will not be able to support the estimated traffic growth using today's operating concept or the upcoming operating concepts already under development. A new Air Traffic Management communications infrastructure is required for the future. A very likely scenario for forthcoming aircraft communications architecture includes satellite links as an essential component in order to meet the required QoS such as coverage, availability, priority and integrity.

I. BACKGROUND AND MOTIVATION

THE continuous and significant growth in aircraft passenger demand, especially in Europe and the U.S., is expected to exceed the capacity limitations of current Air Traffic Control (ATC) systems around 2020 [1] and possibly even earlier. This, together with the fact that most of the Air Traffic Management (ATM) procedures are still based on analog voice communications, interfaces and technologies, claims for a modernization of ATM concepts, and in particular of communications systems for ATC, aiming at the absorption of three times the current air traffic load. This is considered in the European vision for ATM in 2020 that places Europe in a leading position for global aviation, focusing on the increase of flight security (reduction of accidents), capacity enhancement, passenger service and reliability, and environmental care. These challenges require the development of tailored and sophisticated ground- and satellite-based communication, navigation and surveillance systems, aiming at the ultimate and challenging objective to support free flight capabilities.

A first approach to the modernization of ATC communications will be the shift from voice to data as primary means of communications. As shown in Figure 1, current forecasts predict that data services will become dominant starting from 2020. Furthermore, global coverage will allow squeezing distance between flights in areas with currently limited communications means (e.g. North-

Atlantic), and in turn airspace capacity usage will increase. Satellite systems can and shall be a decisive ingredient to achieve the required global coverage and connectivity, high reliability and availability in such a scenario. These considerations are currently a very hot topic in Europe and North-America, with focus on seamless integration and interoperability, rapid re-configurability and flexibility that can cope with future demand growth.

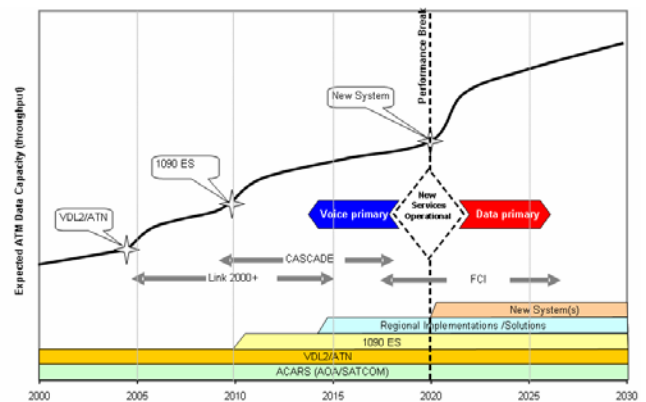


Figure 1: Evolution of Data Demand for ATM (source: Eurocontrol)

To complete the picture, it is important to mention that the deployment of commercial systems to provide wireless communications services to aircraft passengers has already started and it is likely to become a sound commercial reality within the next decade. Datarate requirements to serve a large aircraft can easily reach several Mbps, if In-Flight Entrainment (IFE) services are considered in addition to personal voice and data communications. Using mobile satellite systems for backhauling appears in this case the most natural choice. Furthermore, a recent in-flight demonstration of aeronautical communications over satellite during the WirelessCabin project [2], highlighting different QoS classes and the capability of the system to easily block passengers' communications in emergency situations, has shown that the use of satellite systems also for cockpit and/or crew communications is not only technically feasible but also very appealing. This is especially true considering the typical lifetime of an aircraft (several tens of years) and the high certification, installation and maintenance costs of any equipment installed on-board.

The forthcoming paper examines the suitability of current DVB-S2/RCS standard [3] and its possible extensions to

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Sandro Scalise (corresponding author), Cristina Párraga Niebla, Núria Riera Díaz and Christian Kissling are within the German Aerospace Center (DLR), Institute for Communications and Navigation, PO Box 1116, 82230 Wessling, Germany. Tel. +49 8153 282856, Fax +49 8153 282844, E-mail Sandro.Scalise@dlr.de.

mobile users to fulfill the requirements for the provision of ATM services and the possible enhancements and modifications that can be devised to improve the present situation.

II. THE ANASTASIA PROJECT – AN OVERVIEW

The ANASTASIA Project (Airborne New and Advanced Satellite techniques and Technologies in A System Integrated Approach) is an integrated project which receives funding from the European Community's Sixth Framework Programme (DG research); see www.anastasia-fp6.org.

In the context exposed in section I, the ANASTASIA project aims to contribute to the evolution towards future Communication, Navigation and Surveillance (CNS) by carrying out research, evaluation and cost-benefit analysis to define satellite-based Communications and Navigation new technologies as well as new avionics architecture, suitable for aircraft operation in the future satellite-based European Air Traffic Management environment. The aforementioned evaluation will be completed with mock-up and in-flight tests.

Currently, most long range aircraft are equipped with satcom systems for global communications over the ocean and remote regions. However, those are mainly used for passenger communications (APC), with small penetration into the ATM communications, especially for safety critical applications, such as Air Traffic Control (ATC). A deeper penetration of satcoms in ATM will depend mainly on cost concerns (equipment, operation and maintenance), institutional issues (service provision assurances, ownership, and liability) and performance concerns (QoS, security).

ANASTASIA addresses two of these drivers for the satcom system design: costs and performance. For a cost-effective solution, the exploitation of synergies with revenue-generating passenger communications appears to be very attractive. For this reason, the satcom system design is being developed departing from existing or planned satcom systems that can provide aeronautical passenger communications services.

As a first step, the needs and requirements associated to the different aeronautical communications services have been investigated within ANASTASIA. Next, the suitability of several existing and planned satcom systems has been evaluated for the support of cockpit and cabin communications (including voice and data services) [4]. In order to focus the design phase towards the most competitive candidates for the established needs and requirements, where Inmarsat BGAN and extensions to the DVB-S2/RCS standard to support mobile applications (short Mobile DVB-RCS) are being considered as short and long term solutions, respectively.

The key question to be solved within ANASTASIA is: can these satcom systems be made robust enough, even adding some enhancements, to meet requirements of ATC use? If yes, how? Section IV discusses our vision on the

Mobile DVB-RCS opportunity to be a cost-effective and competitive solution for ATC services, exploiting the synergies with passenger communications.

III. ATM SERVICES OVER SATELLITE

A. Evaluation Procedure for a Suitability Study

In the framework of ANASTASIA, an evaluation study among several existing and upcoming satellite communications systems from an ATM usage perspective has been conducted [4] aiming to assess their suitability to provide ATC/ATM services. The provision of passenger services over the same satellite systems is also evaluated there, since recent studies encourage the idea of providing cockpit and cabin services through the same satellite system, as already mentioned above.

The evaluation procedure is inspired in the systematical approach followed in [5], where the focus is not in satellite communication systems but in all type of current and future wireless communication systems. Most of the requirements used for the scoring in [5] have been adapted to the satellite case and new ones have been introduced.

The rating is done in three steps. First a score is given to a set of functional, capacity and performance requirements, second a weighting factor considering current ATM specific requirements is calculated, and finally a weighted averaged is obtained:

1) First evaluation step

Requirements covering functional, capacity and performance aspects are defined for three categories to be evaluated within each satellite system: cockpit voice communications, cockpit data communications and cabin data communications. Each of these requirements is scored with 0, 0.5 or 1 depending on the level of fulfillment and the average is finally calculated. Cockpit voice and data requirements include future ATC needs such as increased capacity, support of selective addressing, broadcast capability, and pilot to pilot communication support. Certain requirements are defined as veto, i.e. if they are not fulfilled the final score for that category becomes 0. The interested reader should refer to [4] for more details.

2) Second evaluation step

A set of seven current ATM specific requirements are identified and scored separately. They influence the results of the three categories defined above. These separated requirements are: technology readiness level (TRL), possibility to be certified for safety related services, avionics costs, spectrum allocation fitting with the AMS(R)S (Aeronautical Mobile Satellite Regional Service) band, support of authentication and integrity, coverage offered, and link availability. Again, each of these requirements is scored with 0, 0.5 or 1 and a weighted average is calculated.

3) Third evaluation step

Results of cockpit voice and cockpit data are multiplied by the cockpit weighting factor, and results of cabin data by

the cabin weighting factor. The final score is averaged with a 40-40-20 percentage respectively, in order to strengthen ATC/ATM services influence in front of APC services. If one system gets a 0 for a certain category, the final score becomes also 0, since the evaluation requires that all three categories shall be supported simultaneously.

B. Evaluation Results

The satellite communication systems taken into account in this study are Inmarsat BGAN, MTSAT, Iridium, Globalstar, Connexion by Boeing, SkyLink, and future extensions of DVB-S2/RCS standards to support mobile users (called from now on Mobile DVB-RCS).

The bars in Figure 2 show the results corresponding to the first step of the evaluation procedure for each category mentioned above and the lines in Figure 2 correspond to the weighting factors obtained from the second evaluation step for cockpit and cabin services.

Results show that Mobile DVB-RCS systems look very appealing, especially for data exchange for both cockpit and cabin services. This fact places Mobile DVB-RCS in a very promising situation to cover future increase of ATM data exchange. However, after weighting voice and data cockpit results from one side and cabin data results from the other with the corresponding weighting factors, the final Mobile DVB-RCS rate is rather penalized, as showed in Figure 3.

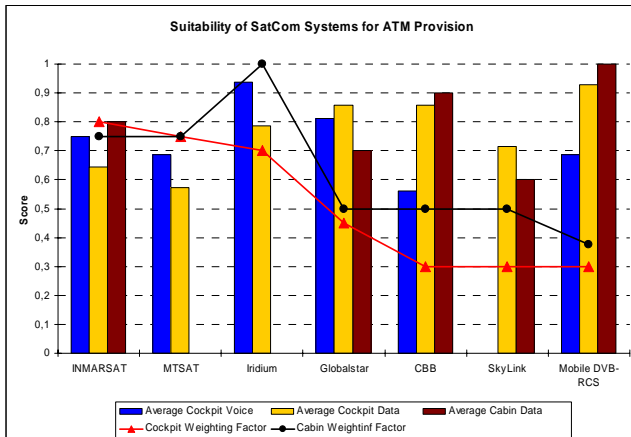


Figure 2: Suitability of current and upcoming satellite systems for ATM provision (source [4]).

Since Mobile DVB-RCS is not yet standardized, it is obviously not 100% fulfilling any of current ATM specific requirements. It scores zero for TRL, certification for safety related services and spectrum allocation. The rest of requirements related with the second evaluation step are rated 0.5.

It must be highlighted that these results are very sensitive to the requirements definition and the evaluation criteria. Even though, they point to one clear direction: Inmarsat BGAN would be most appropriate satellite system to provide ATM services in a short/mid-term perspective, while Mobile DVB-RCS would be the system best fitting from a long-term perspective.

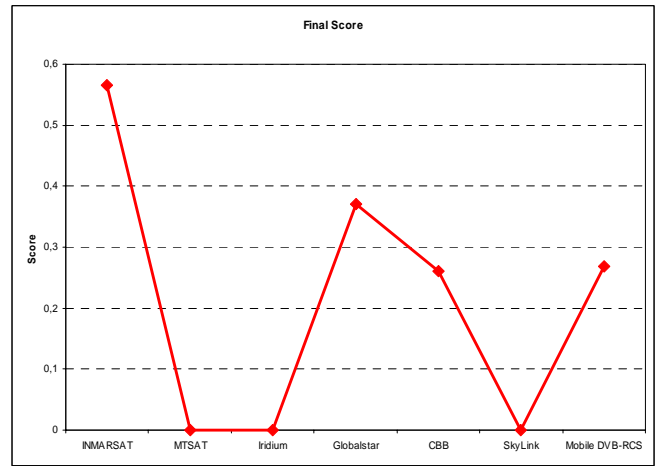


Figure 3: Final scoring of the suitability study for ATM provision after weighting current ATM specific requirements (source [4]).

IV. DVB-S2/RCS FOR ATM SERVICES

A. ATM Services – A Case for Mobile DVB-RCS

For the time being, the issues that have conditioned the disadvantaged position of future Mobile DVB-RCS systems are for sure relevant. However, in a long term perspective the situation might change, especially in what the spectrum allocation, technology readiness level and certification are concerned, and therefore those should not be interpreted as a limitation.

The motivation of considering Mobile DVB-RCS technology as a competitive candidate for ATM communications is mainly driven by the broadband capacity available in Ku and Ka bands, where the standard is applicable, that can be demanded mainly by passenger communications and used also for ATM services.

Upon the publication of the DVB-RCS standard [3], the availability of a return channel over satellite allowed the support of interactive services. This specification was defined with the aim at enabling several features, such as reliable network and user security mechanisms, incorporation of an efficient transport layer and making possible interfaces with other infrastructures, such as IP [3]. However, the protocol stack to support IP over DVB defined in this standard was pretty complex and inefficient: IP/MPE/MPEG or IP/AAL5/ATM for the return link and IP/AAL5/ATM (optionally also IP/AAL5/ATM/MPEG) for the forward link.

In the last years, a second generation of the DVB-S standard (DVB-S2), has been published [7]. It introduces several features that significantly enhance the spectrum utilization and makes the transport of multimedia traffic much more efficient and flexible. The first enhancement is achieved by applying adaptive coding and modulation in order to reach the required availability without the need of designing the link margin according to the users at the cell edge and in worse propagation conditions. This allows for a much more cost-effective system design, reducing the power

requirements in the space segment and significantly cheaper operational costs, that can be translated into cheaper services for the end users. In what the transport of multimedia traffic is concerned, the new standard supports Generic Streams (GS) in addition to the traditional and less flexible MPEG Transport Streams (TS). This allows for a more flexible and efficient encapsulation of IP (or other) traffic on top of DVB. This feature is very promising for the support of a variety of services with disparate requirements, which is the case of ATM applications (ATC, AOC, AAC, etc.) together with APC.

Furthermore, recent discussion within the DVB Technical and Commercial Modules to re-open the standard in order to better support mobile services mainly for collective terminals, opens the door for a more efficient system design in different mobility scenarios, i.e. land mobile (especially for high-speed trains), maritime and aeronautical.

Finally, another feature that makes this technology very attractive from an institutional point of view, is the fact that it is an open standard not linked to any proprietary solution, which is not only very appealing for the definition of a global solution, but also for the service provision continuity assurance.

B. Enhancing Future Mobile DVB-S2/RCS for ATC Services

Although the features of future Mobile DVB-S2/RCS standard look very appealing for the transport of cockpit and passenger communications and the results of the competitive analysis presented in section III.B show a good positioning of such a technology in a long term perspective, there are open points that need to be developed, especially for a real rollout of safety critical services, such as ATC.

First, the frequency bands for which the current standards (and the forthcoming one) are designed require directive antennas to achieve a sufficient link margin. Mechanically steered antennas will suffer from vibrations in the fuselage of the aircraft where they are installed, which results in a very reduced antenna lifetime. Furthermore, penalization in terms of fuel consumption due to the relatively big antenna and radome is not negligible. The alternative is to consider electronically steered antennas. As for today, this is a relatively immature and expensive technology that covers a limited range of elevations. Although costs are an important driver, the poor performance is in this case more critical: for ATC applications the required system availability is very stringent throughout a very wide range of elevations. For this reason, the ANASTASIA project is also investigating further in the field of electronically steered antennas in Ku band.

Second, the propagation in Ku and Ka bands are especially affected by the weather conditions. According to this, deep fades can occur due to rain fading. This effect does not appear when flying over the clouds; however, ATC services must be available also in lower altitudes. The DVB-S2 standard offers very powerful fade mitigation techniques

in order to achieve high availability also during rain fades, at the cost of higher spectrum waste, i.e. Adaptive Coding and Modulation (ACM) with a wide range of possible modulation and coding rates combinations that offer a margin of up to 18.4 dB for rain fading, being still able to receive with an $E_s/N_0 = -2.35$ dB [7]. Within ANASTASIA, it is also being investigated whether this margin is sufficient for the availability requirements for ATC services. For the case that the achieved availability is insufficient, fade mitigation techniques are being also investigated, eventually complementing countermeasures at the physical layer with higher layer techniques, such as packet layer coding, and even by switching to terrestrial network.

Finally, the system must be able to provide QoS guarantees, traffic differentiation and security features that satisfy the needs of the most restrictive ATM services (ATC). Furthermore, the possibility to reduce equipment, maintenance and operational costs by providing passenger and cockpit communications via the same satellite system highlights the need for traffic differentiation and security features. Hence it follows that the DVB-S2/RCS protocol stack must be completed, not only to support the aforementioned functions, but also to provide a compatible interface with the standardised Aeronautical Telecommunication Network (ATN) protocol stack, in order to allow the transport of ATN data over DVB.

The ATN standard [8] allows the use of different subnetworks for physical transmission of air/ground communication. Figure 4 shows the operational environment of the ATN.

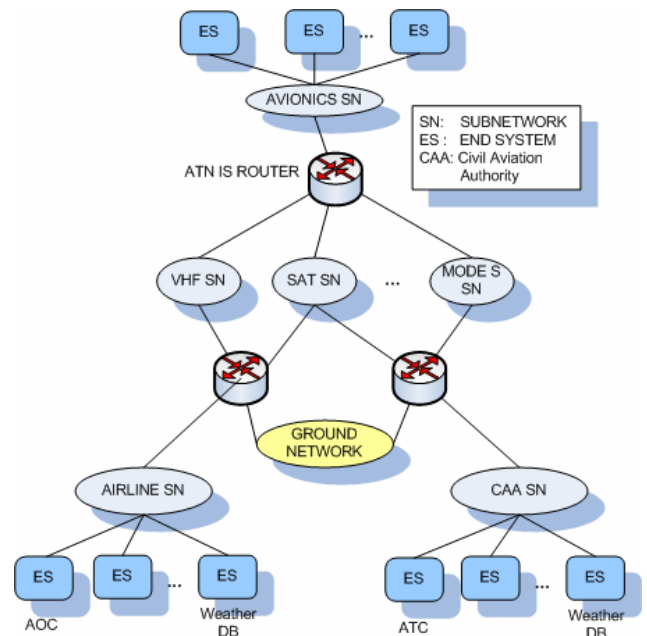


Figure 4: ATN data communication environment (source [8]).

Within an aircraft the different ATN applications (“end systems”, ES) are connected via an avionics subnetwork (SN) to the air/ground intermediate system (ATN IS router).

This intermediate system controls the connection to the air/ground subnetworks which can be for instance VHF, Mode S or satellite subnetworks. The matching ground router can then forward the ATN data to the corresponding parts of the ATN such as airline subnetworks or civil aviation authority networks. The ATN protocol stack as standardised in [8] is shown in Figure 5.

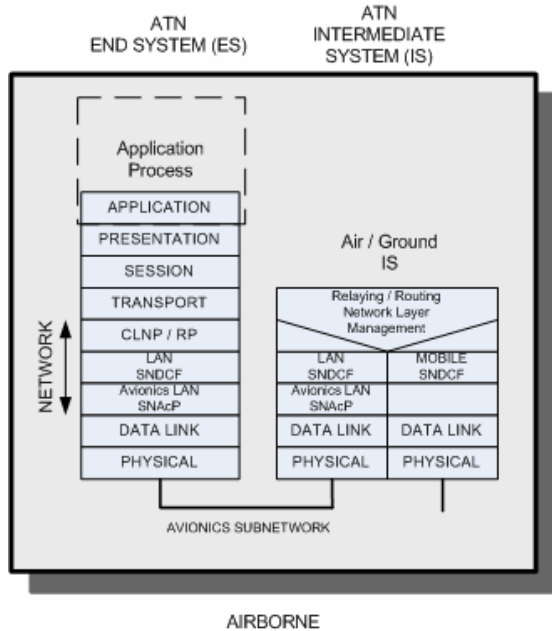


Figure 5: Protocol stack of ATN airborne network (source [8]).

For the use of DVB as mobile subnetwork the corresponding layers in the air/ground IS up to the network layer have to be implemented. The remote ground station has to implement the counterpart to the A/G IS which decapsulates the DVB datagrams and forwards the ATN datagrams into the ATN network. Since the ATN protocol architecture is based on the layered structure of the ISO/OSI model, the ATN typical data are not aware of the means of the mobile subnetworks that are actually used for transmission and since the data transfer is organized in datagrams the subnetwork can be switched without affecting higher layer ATN connections.

In the ANASTASIA project, a complete end-to-end architecture for full connectivity between DVB-S2/RCS-based satellite networks and ATN is being developed, enclosing a QoS concept that supports typical IP networks QoS concepts (such as DiffServ), extended to support also service differentiation and prioritization, as well as the various service requirements of different ATM services. In addition, handover and security concepts that fulfill the requirements of ATC services are being investigated.

V. SUMMARY

DVB-S2/RCS standards and future extensions of it to support mobile users are a very attractive solution for ATC communications over satellite. The broadband capacity

available in Ku and Ka band allows for a cost-effective system design that supports on the one side ATM services, including safety critical applications, and on the other side. In addition, basing the satcom system design in an open standard facilitates worldwide operability, without the need of harmonising proprietary solutions, and makes certification processes easier.

However, there are indeed open issues that must be investigated and fixed in order to fulfill the specific requirements of ATM services, especially of ATC, and to provide full connectivity with aeronautical networks. The ANASTASIA project is intensively investigating solutions for the open issues, i.e. antenna design, fade mitigation techniques and end-to-end system design and protocols to support QoS, service prioritization, handover and security.

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