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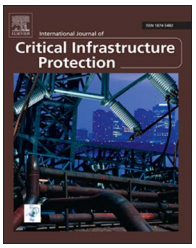

System specifications for developing an Automatic Dependent Surveillance-Broadcast (ADS-B) monitoring system

Busyairah Syd Ali

Department of Software Engineering, Faculty of Computer Science and Information Technology, University of Malaya, Kuala Lumpur 50603, Malaysia

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ABSTRACT

Automatic Dependent Surveillance-Broadcast (ADS-B) is a surveillance system placed in aircraft that periodically transmits state vector estimates and other information to air traffic control centers and other nearby aircraft (and may also receive traffic and weather information from various entities). The state vector estimates are derived from navigation avionics and are transmitted via a common communications channel, which means that ADS-B is highly dependent on aircraft navigation and communication systems. ADS-B also requires ground stations to receive information from aircraft. As a result of this complex architecture, the ADS-B system is prone to various failure modes.

A systematic and comprehensive performance monitoring system is required to ensure the safe use of ADS-B data for air traffic control operations. It is vital that such monitoring systems are in place before a global ADS-B implementation date is mandated by the International Civil Aviation Organization. A number of air navigation service providers and regulators have developed ADS-B performance monitoring methods without a standardized guideline for system specifications. These include Airservices Australia, the U.S. Federal Aviation Administration, EUROCONTROL, the Civil Aviation Authority of Singapore and the Civil Aviation Department of Hong Kong.

This paper presents a holistic set of system specifications for ADS-B monitoring systems. In particular, the paper analyzes the ADS-B infrastructure, conducts a systematic review of existing ADS-B monitoring systems, classifies the system characteristics to identify gaps, and derives a set of specifications for developing ADS-B monitoring systems. The paper also assesses the compliance of existing ADS-B monitoring systems against the proposed specifications using a mapping exercise. The system specifications serve as a foundation or minimum requirements for air navigation service providers and original equipment manufacturers to develop systematic and comprehensive ADS-B monitoring systems.

E-mail address: busyairah@um.edu.my

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1. Introduction

Automatic Dependent Surveillance-Broadcast (ADS-B) [1,14] is an automated surveillance system placed in aircraft that uses satellite navigation technology to periodically transmit important information to and receive information from air traffic control centers and other nearby aircraft. It provides several benefits to air traffic control and pilots, including enhanced aircraft situational awareness, the transmission and receipt of flight information, and the receipt of weather information. ADS-B has two services: (i) ADS-B Out, which broadcasts information about aircraft (e.g., aircraft identification and real-time position, altitude and velocity); and (ii) ADS-B In, which receives traffic and weather information.

The implementation of ADS-B Out is actively taking place in many regions of the world. This includes voluntary efforts by air navigation service providers, airline operators, regulators and manufacturers, ahead of a globally mandated implementation date that will be imposed by the International Civil Aviation Organization (ICAO).

In order to ensure that the implementations of mixed-mode (radar and ADS-B) and sole operations of ADS-B in non-radar airspace are operationally safe, numerous safety assessment methods have been put in place by air navigation service providers and researchers [3,4,8,9,13,14,20,21]. According to ICAO, ADS-B shall only be used for the provision of air traffic services when an assessment proves that ADS-B performance in a particular airspace exceeds the required performance level [15]. Therefore, it is compulsory to conduct a safety assessment before an ADS-B system becomes operational. However, this is a one-off process and is inadequate because system performance may degrade over time for a variety of reasons. Hence, periodic safety monitoring of the ADS-B system is essential; this includes the monitoring of ADS-B ground stations, avionics and performance levels.

This paper discusses ADS-B operations and conducts a detailed analysis of the ADS-B infrastructure and implementation requirements. It also reviews the efforts undertaken by a number of air navigation service providers, including Airservices Australia, the U.S. Federal Aviation Administration, EUROCONTROL, the Civil Aviation Authority of Singapore and the Civil Aviation Department of Hong Kong, in developing and implementing ADS-B monitoring systems. Based on an analysis and systematic review, a set of specifications for developing ADS-B monitoring systems is presented. The system specifications adopt a holistic view of the ADS-B system, including ground stations, avionics and performance. The compliance of the reviewed ADS-B monitoring systems against the derived specifications is also assessed via a mapping exercise.

2. ADS-B operation

ADS-B is a service implemented on an aircraft (or surface vehicle operating within its movement area) that periodically broadcasts its position and other information without knowing the recipients and without expecting acknowledgements as the system only supports one-way broadcasts. The system is automatic in the sense that it does not require external intervention to transmit the information. It is characterized as dependent due to its reliance on aircraft navigation avionics to obtain the required surveillance information. ADS-B is a cooperative system because it requires common equipage for aircraft and surface vehicles to exchange information. It provides aircraft state information such as horizontal position, altitude, vector, velocity and trajectory intent information. The latter is critical for trajectory prediction, which is the basis of the trajectory-based operations concept of the Single European Sky ATM Research (SESAR) [19] and Next Generation Air Transportation (NextGen) [12] systems.

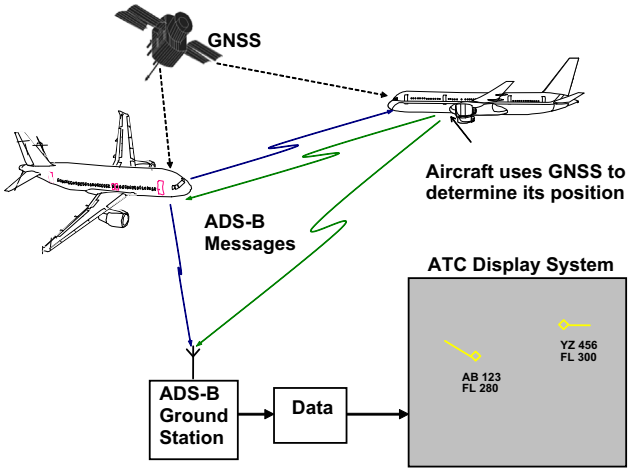

Fig. 1 – Automatic Dependent Surveillance-Broadcast (ADS-B) system [17].

Fig. 1 presents a schematic diagram of the ADS-B system. ADS-B has two subsystems: (i) ADS-B Out; and (ii) ADS-B In. ICAO [1] defines ADS-B Out as the broadcast of ADS-B transmissions from an aircraft, without the installation of receiving equipment to process and display ADS-B data on cockpit displays. The complementary subsystem, ADS-B In, provides air-to-air situational awareness to pilots. ADS-B Out has the ability to operate independently to provide air-ground surveillance services to support air traffic control (ATC). However, the implementation of ADS-B In requires a fully operational ADS-B Out as a prerequisite, the certification of cockpit displays, the consideration of pilot human factors and other activities that have a longer deployment schedule.

An aircraft equipped with ADS-B uses an on-board navigation system to obtain the aircraft position from the Global Navigation Satellite System (GNSS). ADS-B periodically broadcasts aircraft position, velocity and trajectory intent data to other ADS-B equipped aircraft and ADS-B ground stations within its range via a data link service. The ground stations transmit the received ADS-B reports to a surveillance data processing system for use by air traffic control.

3. ADS-B infrastructure

The ADS-B infrastructure includes ground and airborne infrastructures. Figs. 2 and 3 illustrate the avionics for ADS-B Out and ADS-B In, respectively. Note that GNSS denotes the

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