OpenSky

Using A Large-Scale Sensor Network For Air Traffic Research

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Due to increasing congestion of the commercial airspace more efficient air traffic management methods are required. The world's aviation authorities are currently undertaking a major upgrade from conventional air-traffic management to the Next Generation Air Transportation (NextGen) system. The Automatic Dependent Surveillance - Broadcast (ADS-B) protocol is at the heart of NextGen and is currently being rolled out in most countries. Traditional air traffic control technologies such as Primary Surveillance Radar (PSR) and Secondary Surveillance Radar (SSR) use ground-based antennas to independently measure the range and bearing of airborne objects. With ADS-B, on the other hand, aircraft determine their own position using Global Navigation Satellite Systems and broadcast it periodically over the 1090 MHz radio frequency to ground stations or other aircraft in the proximity (see Fig. 1a) for a graphical overview). Thus, one of the main advantages of ADS-B is being able to continuously broadcast exact information about altitude, heading, velocity, and other flight data, decreasing the dependence on expensive and less accurate PSR and SSR technologies. Besides lowering separation requirements between aircraft (and thus enabling more efficient higher-density airspaces), this improves the overall situational awareness of pilots and air traffic controllers significantly while reducing the costs of air traffic surveillance [3].

Whereas ADS-B strongly enhances the capabilities of air traffic surveillance systems, there are many facets of the technology that need further evaluation to ensure a quick and safe adoption. As various concerns with the ADS-B protocol such as security vulnerabilities and problems with the capacity of the wireless channel have emerged over the past years [2], it is important that these and other issues are thoroughly investigated.

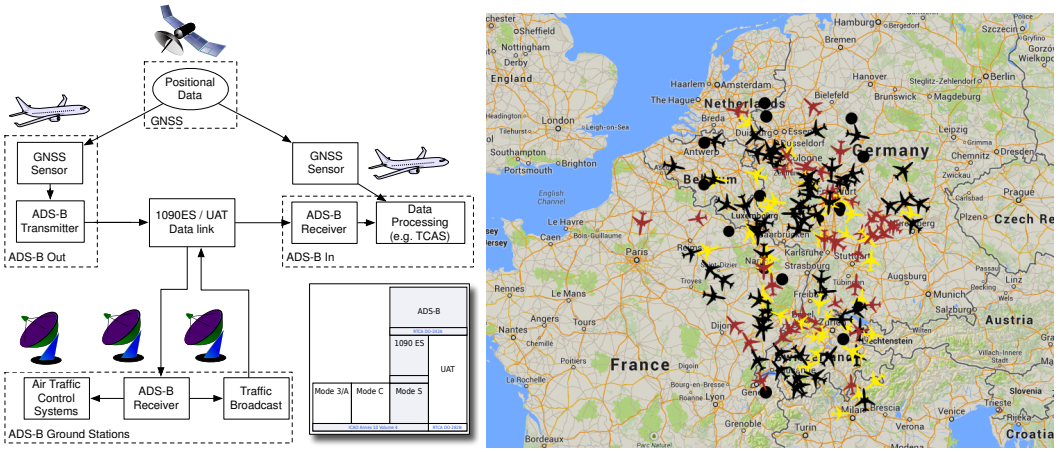

Fig. 1. a) ADS-B system architecture, including protocol hierarchy. b) Live screenshot of OpenSky reception over Central Europe.

However, until recently only closed government- and industry-related groups had the potential to utilize large-scale real-world data since collection required specialized and costly hardware. To facilitate experimental research with real data, we created **OpenSky**, a sensor network based on low-cost off-the-shelf equipment connected over the Internet [1]. It currently covers more than 700,000 km^2, seeing around 30% of Europe's commercial air traffic, and makes it possible to analyze ADS-B messages and related metadata.

While similar, commercial, services using ADS-B messages to visualise flight tracks have been available on the Internet, none of them store and provide the valuable raw data required for in-depth research. Therefore, we have made OpenSky an open network that collects and stores all ADS-B traffic as it is being captured. We have been deploying sensor nodes in Central Europe (see Fig. 1b) for a view of the coverage), utilizing volunteers who install sensors at their homes and institutions and deliver their data over the Internet. OpenSky uses cheap off-the-shelf sensors, creating a low barrier of entry for volunteers. During OpenSky's operational phase, we have been working with the data in different ways, including but not limited to:

- **Error and fault diagnosis**: OpenSky can help to discover misbehaving and erroneous transponders which do not comply with standards, detecting safety-related issues prior to wide-scale adoption.
- **Performance evaluation**: OpenSky can assess the performance of the ADS-B channel such as the message loss rate or the number of collisions at various locations and times, identifying bottlenecks in the system capacity.
- **Localization**: When a signal is received by four or more sensors, the position of the sender can be calculated independently through multilateration, providing a backup system to verify the location of an aircraft.
- **Security research**: Several security vulnerabilities have been shown to affect ADS-B which can not be easily addressed as the application of cryptography would require an expensive new system and decades of standardisation. With OpenSky, ground-based attack detection methods and security mitigation techniques can be explored.

The network has been operational for over two years, collecting billions of ADS-B messages for further analysis. All of the stored data is accessible to the volunteers contributing with their sensors, and to anyone else on request on `http://opensky-network.org`.

OpenSky is a joint effort between the University of Oxford, the University of Kaiserslautern, Germany and armasuisse, Switzerland.

References

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2. Strohmeier, M., Lenders, V., and Martinovic, I. Security of ADS-B: State of the Art and Beyond. *arXiv preprint arXiv:1307.3664* (2013).
3. Strohmeier, M., Schäfer, M., Lenders, V., and Martinovic, I. Realities and Challenges of NextGen Air Traffic Management: The Case of ADS-B. *Communications Magazine, IEEE 52*, 5 (2014).