Intelligent Multiration System for Air Transport

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Abstract
Aircraft data networks are fast becoming more of a necessity due to their support for user mobility. Many aircraft manufacturers are planning to deploy data networks within their airplanes and provide internet connectivity to their passengers. The aim of this thesis is to describe the usage of the Multilateration surveillance system (MSS). MSS represents a new, certified, costs-effective and high-performance surveillance system that outperforms Monopulse Secondary Surveillance Radar (MSSR). This system is flexible and expandable. Additional ground stations, interrogators and reference transponders can be easily added to the system. MSS can provide an accurate and reliable real-time location and identification of all aircrafts, vehicles and other objects equipped with a Mode A/C/S transponder.

Keywords: Modeling, air data, service network

1. Introduction
MSS can provide an accurate and reliable real-time location and identification of all aircrafts, vehicles and other objects equipped with a Mode A/C/S transponder. For ATC (Air Traffic Control) application provides multilateration system the same level of coverage as traditional SSR (Secondary Surveillance Radar).

The main advantages of multilateration system are:
- flexibility and expandability - additional ground stations, interrogators and reference transponders can be easily added to the system;
- higher accuracy;
- higher refresh rate;
- better coverage;
- improved reliability in comparison with traditional SSR;
- increase of capacity and throughput of airspace while maintaining high security;
- lower initial price with lower annual costs;
- multilateration systems can be applied for area

Future generation networking will be characterized by the need to adapt to the demands of agile networking, which include rapid response to changing customer requirements, automated design and engineering, lower-cost services, transparent distributed networking, resource allocation on demand, real-time planning and scheduling, increased quality, reduced tolerance for error, and in-process measurement and feedback.
2. Multilateration system

Multilateration Surveillance System determines the target position by Time Difference Of Arrival (TDOA) multilateration principle based on income and on-board signal processing transponders of Secondary Surveillance Radar (SSR). In the field there are located receivers $S_0$ and $S_1$ on two different sites, which are designed for receiving signals from aircraft transponders. At a defining moment the transponder on the board sends out impulse signal, which spreads to both receivers at the speed of light after two different lines. Since the speed of propagation of electromagnetic waves is constant (usually known as the speed of light $c$), the lengths of the lines are proportional to the time of signal propagation. Except one case the signal reaches each of the receivers in a different moment. Signal arrival times are measured and recorded for each of the receivers, so it is possible to determine their difference $t_d$. For constant speed of light and constant position of receivers $S_0$ and $S_1$ results of the foundations of geometry that the target must be located on a hyperbola with foci $S_0$ and $S_1$ and the length of the transverse axis $t_d$. From the time sequence of signal arrival (i.e., whether the signal comes earlier to the station $S_0$ or station $S_1$) it can be determined on which branch of the hyperbola is the objective.

The adding of another receiver ($S_2$) creates the second hyperbola (with foci $S_1$ and $S_2$). The intersection of the two hyperbolas then determines the target position in two-dimensional (2D) system. Station $S_0$ is called central processing station, stations $S_1$ and $S_2$ are called lateral or remote stations. The distance from each other stations is typically 10 to 30 km and their position must be directed with accuracy $±0.3$ m.

In the same way (adding another receiver) it can be obtained the target position in three dimensions (3D). In comparison with 2D system acquires 3D system more useful feature - it can work as omni-directional. Removing of location ambiguity solves used software. For the correct operation of the system is necessary that the same impulse signal was adopted at all stations. Time difference of arrival signal to the remote station and to the central station defines hyperboloid with foci $S_0, S_n$. The resulting target position $C$ is determined by intersection of all the hyperbolas, which have one common focus $S_0$.

Multilateration systems can be either passive or active.

Passive systems rely on the transmission of aircraft transponders which is activated by other equipment, and broadcast of squitters that broadcast their signals periodically. Passive techniques can be used to track aircrafts approaching the airport and aircrafts which are still in a range of MSSR. For low-flying aircrafts, which descend below the height of MSSR coverage, it can be used interrogator with the shorter range.

Active systems may require own answers from the aircrafts. Multilateration interrogator is simpler than MSSR interrogator. It is not necessary rotating antenna, instead is used either omnidirectional or sector antenna. Moreover, it can be changed level of radiation performance and thus be changed the reach of the antenna according to the distance of the monitored plane. One of the areas where it can be used active multilateration system is the terminal manoeuvring area.

MSS can be used at the airports (Surface system) and in the area (WAM system).

Surface system is the part of the system A-SMGCS (Advanced Surface Movement Guidance and Control System).

WAM system is used where is not radar coverage and implementation of a radar is not suitable for economical, technical and other reasons. They are acceptable especially in mountain area. In comparison with the Surface system, the WAM system covers much bigger part of airspace (PRM – Precision Runway Monitoring, terminal area and en-route surveillance). The first exploited
An operational WAM system was established as an instrument of the accurate measuring of the aircraft height in the project RVSM (Reduced Vertical Separation Minima). This is a reduction of vertical separation between FL 290 and FL 410. The original vertical separation 2000 ft is changed to 1000 ft. This reduction requires accuracy of aircraft altitude measurement up to 25 ft.

A system can be configured as Central Time (CT) or Distributed Time (DT) or a combination of both. The Central Time architecture is where a central processing station evaluates and processes all signals. The receiving stations are very simple. Each station is composed of a receiver with an antenna and a real-time signal transmitting facility. Time delays of signals transmitted from the receiving stations to the central processing station must be constant, stable and known, as the processor to eliminate them.

The Distributed Time architecture is where signal pre-processing and time stamping is done at each receiving station. These receiving stations are more complex. Each station is composed of a receiver with an antenna, signal processor, precise clock and data transmission facility.

3 System description and location uncertainty

The topological layout of an integrated network in Fig. 2 shows that the coverage area of an individual sub-network can be discontinuous (e.g., a set of disconnected islands of 802.11-based hot-spots). Accordingly, the set of sub-networks that can be accessed concurrently by an Mobile Node (MN) is not constant, but a function of its current location. Mathematically, let the integrated network consist of \( N \) sub-networks or access technologies \( S_1, S_2, ..., S_N \), where each sub-network is a collection of (either partitioned or overlapping) cells. Let \( C_i^j \) represent the \( j \)-th cell in the \( i \)-th sub-network \( S_i \), and let \( |S_i| \) represent the cardinality of (number of cells in) \( S_i \). The location of an MN at any instant can then be represented as a vector-valued random variable \( \mathbf{X} \) of dimension \( N \), where the \( i \)-th element of the vector corresponds to the current cell of sub-network \( S_i \). For example, if \( \mathbf{X} \in C_1 \), the MN is currently located in the first cell of sub-network \( S_1 \). As some of the sub-networks may be hotspot-based (e.g., 802.11), thus providing isolated islands of coverage, an MN may frequently roam outside the coverage of a specific individual sub-network. For notational convenience, let each sub-network have an additional cell \( \emptyset \) to capture this disconnected state. Accordingly, if the MN is currently out of coverage of \( S_i \), its location vector includes the cell \( C_i^\emptyset \).

To model the multi-system environment, where different sub-networks may have different paging and location update costs per transmitted message, let \( PG_i \) represent the cost of transmitting a single paging message in a single cell, and let \( LU_i \) be the cost of transmitting a single location update message in a cell of the \( i \)-th sub-network \( S_i \).
4. Conclusion

MSS will represent a good solution in all phases of flight. Future generations of air traffic management will need to be able to achieve greater security and efficiency. The density of air traffic will be in the year 2020 twice larger than in the year 1997, which will result in a glut of flight paths. Benefit of MSS is mainly that they allow the increase of capacity and throughput of airspace while maintaining high security. Because of low price are a good alternative for the poorer states to obtain the coverage of its airspace. These systems are currently used to complement existing systems (mainly primary and secondary radars). In the future the system will be used as the sole source of surveillance information in the field. Multilateration systems can be applied for area navigation in the future. Aircraft will receive information about the location of satellite navigation. Satellite navigation provides high location accuracy, but it can not be used as the sole source of information. The combination of MSS and satellite navigation provides the best solution. Usage of MSS is still in the development, but future forecasts show that their application is perspective. They have many advantages (mainly accuracy and pricing modesty).

References

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Fig. 1 Hyperbolic principle

Fig. 2 Principle MLAT system


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