GeoData depicting air-to-air connectivity in AANETs for aeronautical data communication

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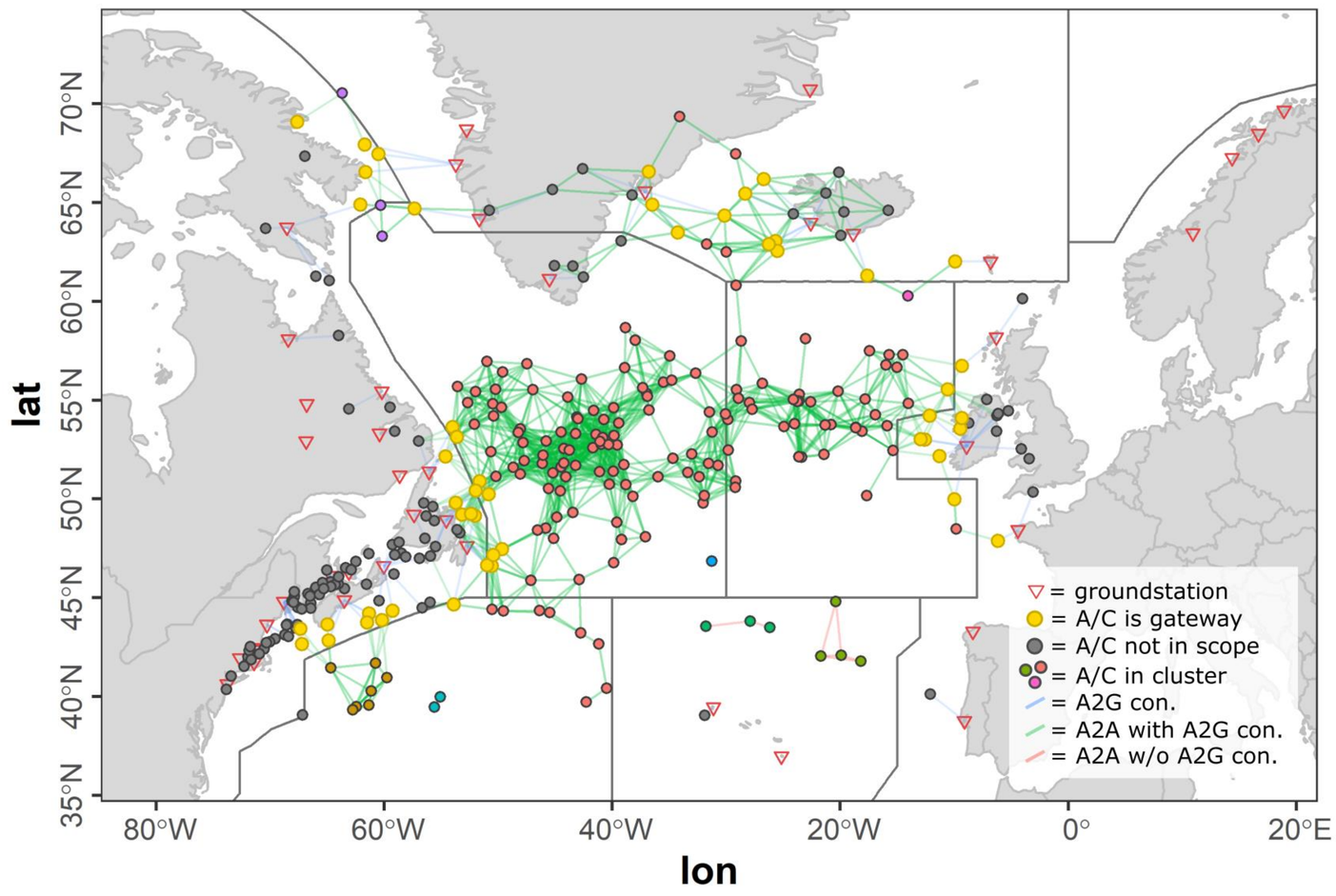


Snapshot of inter-aircraft connectivity in the North Atlantic oceanic airspace showing the interconnected ad-hoc network of air traffic participants. Aircraft within communication range connect to neighbouring aircraft allowing them to indirectly communicate with parties on ground on both sides of the North Atlantic. Few isolated aircraft without connectivity to a ground station or other aircraft remain with the communication range of 330km.

Introduction

Aeronautical ad-hoc networks (AANETs) provide a high potential for data-based applications, especially in oceanic and remote areas with significant air traffic (e.g. North Atlantic airspace; NAT). The potential benefits of an AANET enabled by LDACS air-to-air datalink has been investigated in the project IntAirNet. The spatial and temporal communication performance of AANETs necessitates a geo-referenced analysis.

Data sources

AANET communication demand coverage is dependent on several data sources:

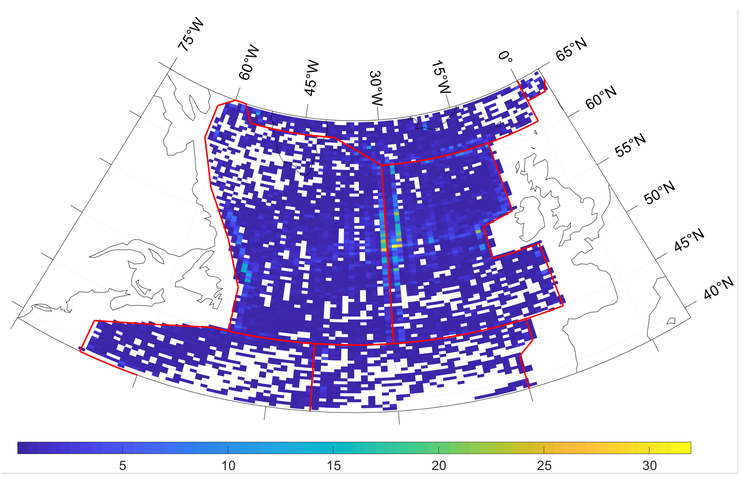
1. **Flight Plan Data**
   The data contains origin and destination airport, aircraft type and fleet as well as flight frequency for a 24h high traffic time window in 2019.
2. **Ground Stations**
   A set of relevant ground stations for VHF and VHF datalink services within and along the borders of the NAT is selected from ICAO provided data and information provided by main communication service providers.
3. **Airspace Geometries**
   Geometries of the six oceanic control areas that make up the NAT: Bodo, Reykjavik, Gander, Shanwick, New York Oceanic East and Santa Maria.
4. **Communication Demand Profiles**
   Comprises a set of communication events for two use cases, air traffic services (ATS) and aeronautical operational communication (AOC), each defined by a message sequence, message data size as well as event or time-based activation triggers.

Data processing

In a two-stepped approach mobility data and communication demand as well as AANET connectivity and communication demand coverage are calculated:

1. **Mobility Data**
   Based on the flight plan data, great circle flight trajectories with optimized altitude profiles are calculated.
2. **Data Communication Demand**
   Using airspace geometries, mobility data and communication demand profiles, the data communication demand with its spatio-temporal distribution is assessed.

Transmitted data volume in byte per square kilometer for communication demand of air traffic services.



3. **AANET Connectivity**
   Based on the mobility data and the distribution of ground stations the AANET-related connectivity of each aircraft within the simulation scenario is assessed for varying communication ranges and equipage fractions. This includes the identification of spatio-temporal connectivity clusters and gateways.
4. **Communication Demand Coverage**
   By mapping the data communication demand on the AANET connectivity, an overall communication demand coverage for the two underlying use cases is being assessed yielding in potentially high coverage of over 85% of aeronautical data communication demand by the LDACS-supported AANET, equipage of air traffic participants of more than 70% and communication range of more than 370km provided.

Data visualization methods

The spatio-temporal dependency of connectivity as well as data communication demand and coverage prompts a data visualization within a geographical frame. This is especially true for mobility data, AANET connectivity and data communication demand. It is to be noted, that the origin of all geographical visualizations are the georeferenced flight paths, ground communication infrastructure and airspace geometries.

1. **AANET Connectivity**
   Data contains flight paths of equipped air traffic and connectivity status of each aircraft. The visualization is centered around the North Atlantic oceanic airspace north of 39° latitude and provides an immediate overview over the AANET network topology, including connected nodes, gateways as well as resulting network clusters with or without ground connectivity.

   (R; ggplot2)
2. **Data Communication Demand**
   The data communication demand reflects the sum of all communication events within the simulated airspace. Vizualisation is done with regard to single communication services or concerning total communication demand per area. For the latter, geo-referenced communication demand is cumulated within grids of 1° latitude and 1° longitude and normalized with the area of each grid cell.

   (MATLAB®; m_map)

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