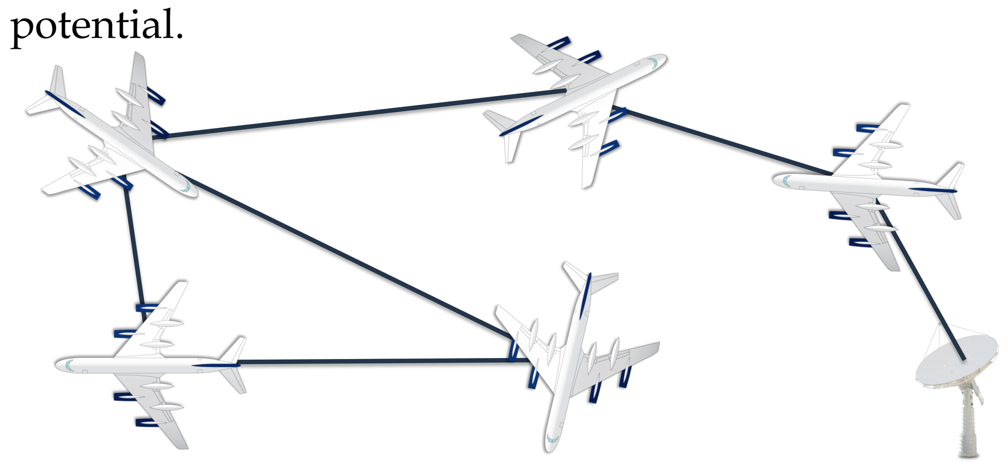
Efficient Management of a High-Capacity Airborne Network of Commercial Aircraft

THE UNIVERSITY *of* NORTH CAROLINA *at* CHAPEL HILL

Research Problem

Given thousands of commercial aircraft, flying regular routes, and a small number of ground station gateways, can an architecture be developed to connect these nodes into a robust high-capacity Airborne Network (AN) which can be efficiently managed?

We believe the complex infrastructure of thousands of passenger & cargo aircraft is vastly underutilized. These high-flying nodes are uniquely positioned for a host of applications, yet no one has succeeded in utilizing this infrastructure to its full potential.



[Aircraft artwork: Gilberto Bradford used with permission]

Applications

An Airborne Network connecting aircraft to one another and the Internet enables a myriad of applications [1], including:

On-board Internet

Streaming weather data

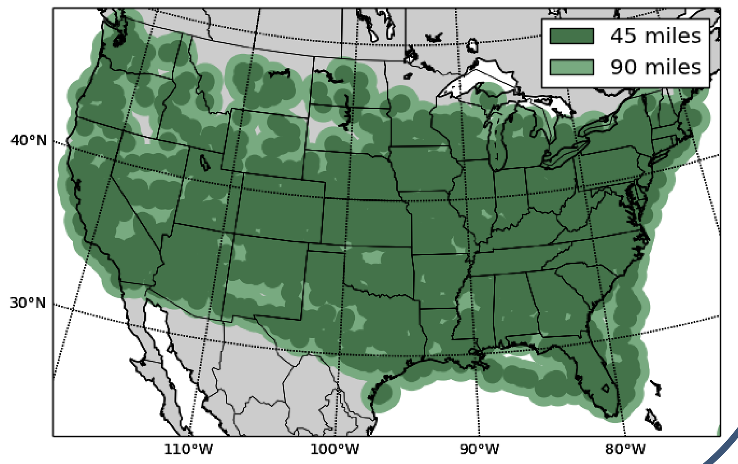
Streaming aerial images

FAA Interests

UAS/UAV Coordination

Internet Service

This map shows the approximate coverage which could be expected using 2,291 aircraft in the air on Sep 9, 2013 to provide internet service, assuming 45 and 90 mile transmission radii.



Solution Requirements

Our envisioned high-capacity network utilizes directional antennas, which require explicit topology control. Further, to limit overhead, a specialized routing protocol is needed.

- High Capacity (~10 Gbps) → Directional Links → Explicit Topology Control
- High Connectivity → Long Range (~120 miles) → Directional Links
- Explicit Topology Control → Specialized Routing Protocol
- Efficient → Limited Overhead → Specialized Routing Protocol
- Robust → Mesh Network Topology

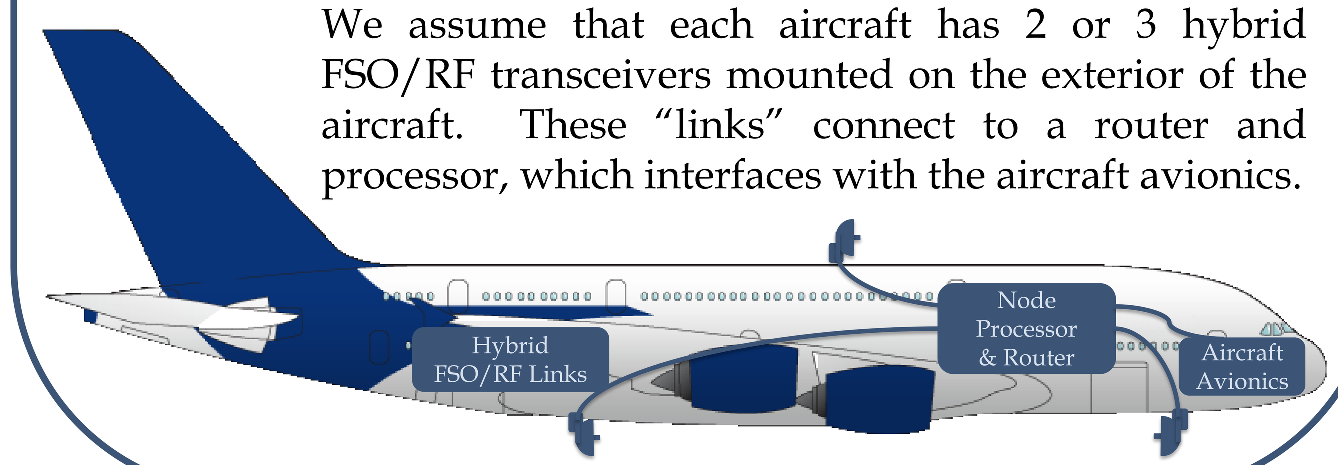
The focus of our research is the design and simulation of a topology control and routing protocol suited for a dynamic airborne network among commercial aircraft.

Approach

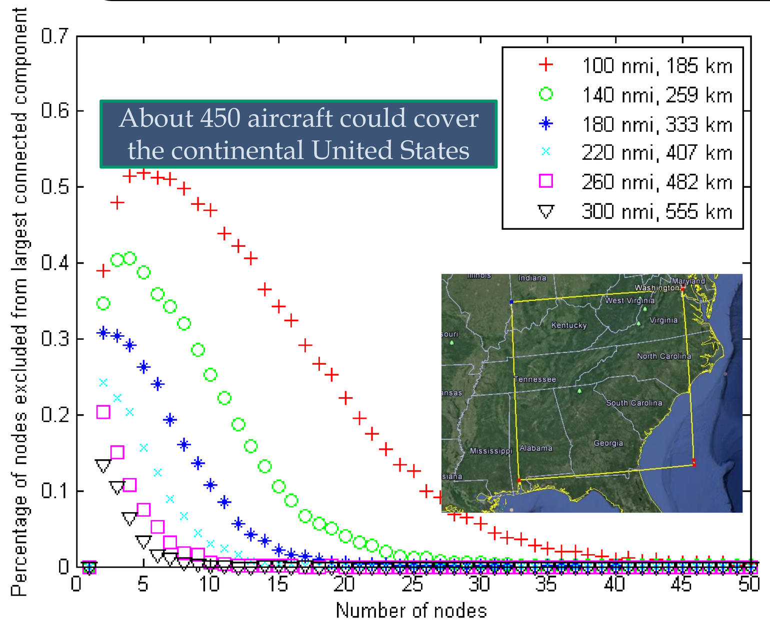
While Ad-hoc, sensor, and vehicular networks, have elements in common with Airborne Networks, experience [2-3] has shown that the unique challenges and advantages of airborne networks warrant specialized protocols.

One unique advantage of commercial aircraft is their flight plans, which we intend to use to predict the future topology of the network, such that topology changes can be commanded before connections are broken as nodes move about.

We assume that each aircraft has 2 or 3 hybrid FSO/RF transceivers mounted on the exterior of the aircraft. These "links" connect to a router and processor, which interfaces with the aircraft avionics.

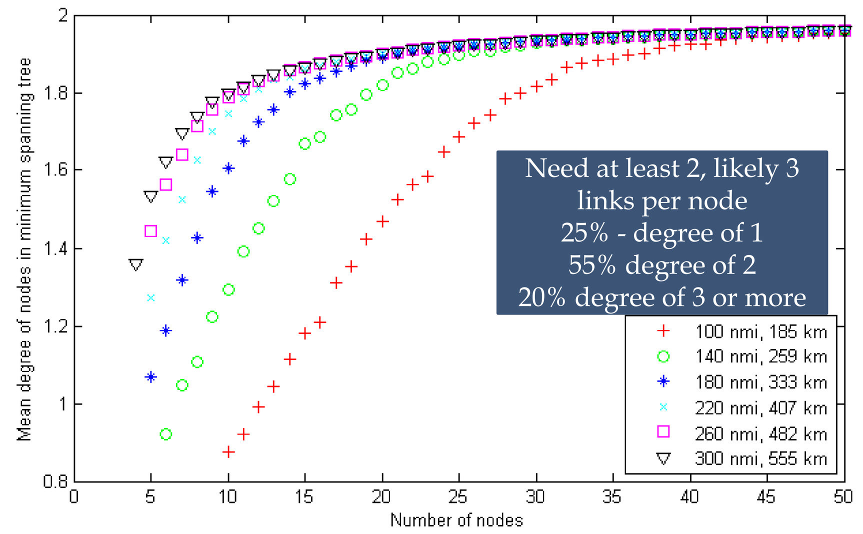


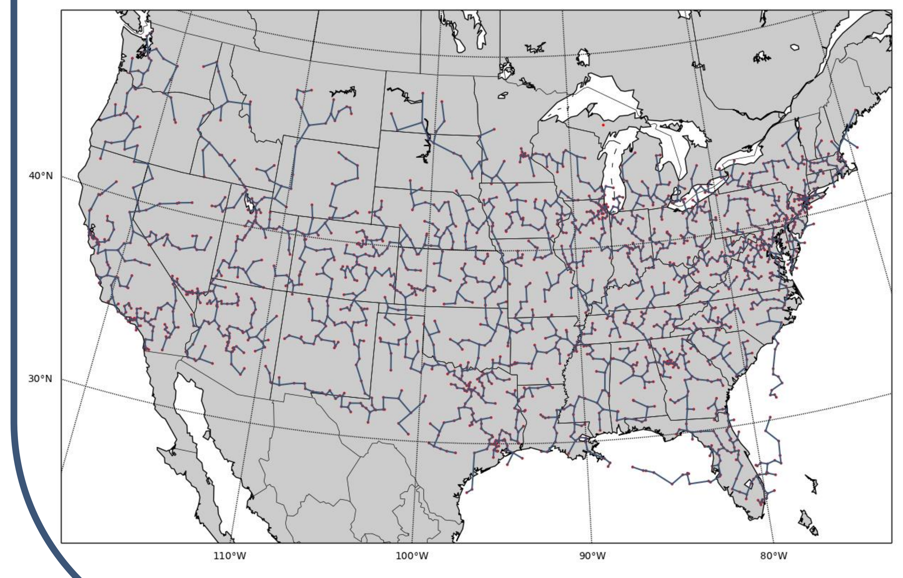
Preliminary Results



The number of randomly placed nodes needed to ensure connectivity in a 575x575 mile area is considered in this experiment. The percentage of nodes excluded from largest connected component of the Minimum Spanning Tree are plotted for various max ranges.

The average degree of nodes in the Minimum Spanning Tree is shown here for the same max ranges. 20% of the nodes require 3 or more links, while about half of the nodes act as a relay between two other nodes.





Degree Constrained Spanning Tree (DCST) with max degree 3 and max range ~120 miles among 2,291 real aircraft positions at mid-day Sep 9, 2013. No ground stations are considered here.

Future Work

Once our initial protocol is designed, we plan to evaluate and compare it via simulation with existing protocols. We will also augment it by considering platform occlusions, ground station placement, unexpected outages, and flight plan changes and deviations.

[1] K.-D. Buchter, A. Reinhold, G. Stenz and A. Sizmann, "Drivers and Elements of Future Airborne Communication Networks," in *German Air and Space Congress 2012, Berlin*, - Lilienthal-Oberth eV, Bonn, 2012.
[2] A. Jabbar and J. P. Sterbenz, "AeroRP: A geolocation assisted aeronautical routing protocol for highly dynamic telemetry environments," in *International Telemetering Conference*, 2009.
[3] N. Krishnamurthi, A. Ganguli, A. Tiwari, B.-H. Shen, J. Yadegar and G. Hadynski, "Topology control for future Airborne Networks," in *Military Communications Conference, 2009. MILCOM 2009. IEEE*, 2009.

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2014 NSF Young Professionals Workshop on Exploring New Frontiers in Cyber-Physical Systems