WingStream Network

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Introduction

The WingStream network is envisioned as a low cost system for providing diverse digital communication services to the aeronautical transportation market throughout the continental US (CONUS) and surrounding costal waterways. WingStream capitalizes on the fact that most of the time aircraft flying over the CONUS and surrounding airspace are within a distance of less than 400 km from at least one other aircraft. Seamless communications covering extremely large areas can be established through a small number of ground stations by fitting wireless routers to aircraft. These airborne routers serve as nodes in an airborne mesh-network, which maintains connectivity without imposing any operational constraints on the host aircraft. Broadband communications services are provided to passengers and crew onboard host aircraft. A few ground stations serve as gateways linking the airborne network with the terrestrial Internet.

WingStream operates in two frequency bands. Ground-to-air channels are in the 902-928 MHz band and air-to-air and air-to-ground channels are in the 2400-2483 MHz band. Ground stations are spaced 300-600 km apart in a cellular arrangement, which allows us to reuse the ground-to-air channel frequency. The ground-to-air channel occupies approximately 5.5 MHz.

Air-to-air and air-to-ground channels associated with a ground station time-share the same frequency using a combination of time division multiple access and time division duplexing. The band is divided into 4 channels each occupying 20 MHz. To prevent intra-system interference a frequency reuse factor of four is used so that frequency of channel's associated with adjacent ground stations are different. The principal advantages of the envisioned system are:

- Scalable infrastructure that can be deployed quickly and at very low cost
- Highly robust communication network
- Wide area coverage
- Scalable capacity that easily adjusts to meet changing traffic needs
- Uses radio spectrum efficiently

These advantages stand in stark contrast to the two traditional methods of delivering digital communications to mobile users: cellular and satellite.

Cellular provides service only to users that are in direct line-of-sight of the ground station. The range of coverage to aeronautical mobile users is typically less than 120 km due to terrestrial obstructions (buildings, hills, trees, etc.), altitude and the curvature of the earth. Consequently, in order to deliver service to large areas many ground stations are required; e.g. AirFone uses more than 130 to deliver service aeronautical mobile users in just major air corridors in continental US. A cellular network architecture cannot provide service to users in oceanic areas and continuity of service to lower altitude aircraft is poor.

Satellites are presently capable of providing broadband services from 37,000 km above the Earth's equator. Satellites relay communication between earth stations and the mobile users. From their vantage point, satellites have a very large field of view and therefore can deliver service to areas not reached by cellular networks. However, owing to the vast distance traversed by the communication signal, propagation delay and attenuation loom large. Consequently, expensive, large antennas must be fitted to the mobile platforms, the satellite and earth stations in order to support broadband traffic and cumbersome techniques must be employed to compensate for signal delays and attenuation. This complexity drives up equipment cost and is difficult to install on aircraft, which discourages service uptake.

Aegeus has developed a novel, patent-pending solution for delivering broadband services to aeronautical mobile users that combines the best elements of cellular and satellite technologies and avoids the propagation issues. Our approach involves fitting wireless routers (SkyNodes) to any aircraft. Certain SkyNodes are dynamically assigned the role of SkyHub, relay communication traffic between other SkyNodes and the ground stations and thus extend the effective communication range of a ground station to all areas within the aircraft's field of view. We take this approach a step further by not only relaying traffic between the ground station and aircraft but also relaying traffic between aircraft. This bucket brigade like approach dramatically extends the coverage area that can be served by a single ground station and allows broadband service to be offered to oceanic areas as well. When deployed, Aegeus can provide service to the continental US and surrounding oceanic areas with only 30 ground stations. Moreover, because communication signals are only sent between aircraft or between aircraft and ground, the distance traversed by any given signal is less than 400 km. Signal propagation delay is negligible and attenuation is low, which allows us to use small and inexpensive antennas and much simpler transmission equipment in the airborne terminals.

The end result is that the Aegeus mobile communication package is light, small and easily installed on all forms of aeronautical mobile platforms. The required sparse terrestrial infrastructure ensures that capital and operating costs are low.

Purpose and Scope

The purpose of this application is to allow Aegeus to deploy and operate the WingStream network on an experimental basis conducting field measurements. The principal tasks that will be undertaken are:

Task 1: Propagation Model and Link Analysis (months 0 – 8)

Confirm through actual field measurements the propagation characteristics of the ground-to-air (G/A), air-to-air (A/A) and, air-to-ground (A/G) channels including path loss, fading bandwidth, multipath effect, interference, etc.

Aegeus will construct first-generation ground station and airborne systems. Two (2) ground stations will be deployed and the airborne systems will be installed on up to 5 aircraft. Three sets of experiments will be performed.

Aircraft will be flown at different altitudes over populated and rural areas and the equipment will passively sample terrestrial-originated RF emissions in the two operating bands. This data will be analyzed to assess the levels of terrestrial emissions received by the deployed airborne antenna subsystem as compared with our models.

The second set of experiments will investigate the propagation characteristics of the G/A and A/G radio channels. The ground stations will be deployed for a period of time at different locations corresponding to various terrain environments that will be encountered in an operational system deployment. Dummy traffic will be transmitted by the ground station in the allocated spectrum in the 902-928 MHz band. Aircraft fitted with instrumented airborne systems will be flown at prescribed attitudes and will sample the transmission and measure propagation characteristics of the G/A radio channel. These same aircraft will also transmit dummy traffic in the allocated spectrum in the 2400 – 2483 MHz band. Instrumented ground station equipment will sample the transmission and measure the propagation characteristics of the A/G channel.

The third set of experiments will investigate the propagation characteristics of the A/A channel and seek to establish the maximum communication range between WingStream equipped aircraft for reliable communication. Aircraft fitted with instrumented airborne systems will be flown at prescribed attitudes over various terrain. One aircraft will transmit dummy traffic that will be sampled by other equipped aircraft which will measure the propagation characteristics of the A/A channel.

The data collected from these experiments will be analyzed and adjustments will be made to the WingStream transmission system if necessary.

Task 2: Transmission System Study (months 6 – 14)

Confirm through field measurements the performance of the three communication links comprising the system: G/A, A/A and A/G. A minimum of three (3) ground stations and 5 pre-production airborne systems will be deployed. The ground stations will be connected to a first generation Network Operations Center (NOC). Simulated communication traffic will be exchanged between the ground stations and airborne systems.

Instrumented versions of the Physical and MAC/Link Layers of the WingStream transmission system will be deployed in the ground station and airborne systems. Aircraft fitted with airborne systems will be flown on controlled routes and simulated communication traffic exchanged between air and ground systems as the airborne systems switch roles between SkyNodes and SkyHubs under the control of the NOC. The performance of the communication links and the traffic routing algorithms will be analyzed and adjustments made to the WingStream system if necessary.

Task 3: Communication Network Study (months 18-30)

Confirm through field measurements the performance of the routing mechanisms that form and sustain the WingStream airborne mesh-network including throughput efficiency, robustness, delay and, ability to provide reliable Internet connectivity. Up to fifteen (15) ground stations and fifty (50) pre-production WingStream avionics systems (FAA Red-Label avionics) will be deployed. The ground stations will be connected to the Internet as well as to the NOC. Internet traffic will be exchanged between ground stations and WingStream avionics fitted to prospective customer aircraft. These aircraft will fly their normal operational routes.

Task 4: Market Research

Confirm WingStream ability to meet market requirements for Internet connectivity and communication applications such as email, WEB access, streaming radio and TV, etc. through monitored customer trials of the WingStream network. Up to fifteen (15) ground stations and two hundred (200) WingStream avionics systems (FAA Black-Label avionics) will be deployed. Internet connectivity will be extended to passengers and crew who will fully exercise the capabilities of the WingStream network. Passenger and crew surveys designed in conjunction with third party specialists will collect data measuring user experience.