Aeronautical communications using hybrid satellite constellations with feeder links for backhaul

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***Abstract*—A design & analysis for integration of satellite gateways with terrestrial networks capable of transmitting high throughput to fast moving planes is proposed. The solution allows back-hauling traffic through terrestrial base stations while achieving higher bandwidth and lower latency communication links over communication links. Using feeder links in parallel with minimal ground network topology alternations, the solution will provide real-time services to satellite constellations in the Earth orbit and enhances the performance with their In-Flight Connectivity (IFC).**

I. Introduction

The In-Flight Connectivity (IFC) ecosystem consists of three major components: the satellite technology, the hardware onboard of the aircraft and the service & support on the ground. High Throughput Satellite (HTS) communications can provide seamless global coverage to support any mission. Today Ku-band (12-18 GHz) frequency is dominantly deployed, while Ka-band (26-40 GHz) frequency satellite communications are expected to be vastly deployed in the coming years.

Using a Very High Throughput Satellite (VHTS) in the geostationary orbit link with user links in Ku-band or Ka-band, which can allow higher data throughput and provide fiber like user experience to the aircraft. Every IFC approach has practical limitations based on the route being served, aircraft type and technology used for that mission. For a specific airline, the flight routes might vary based on the season and traffic demands.

In this study, we will be delivering a hybrid architecture design for satellite systems which incorporates high throughput links between satellite gateways and feeder links for microwave backhaul. In addition, the delay can be mitigated at the user gateway by using a cellular relay node which is equipped with Global Navigation Satellite System (GNSS) that provides autonomous geo-spatial location position throughout the globe which would facilitate airlines for tracking purposes.

II. System Design

Some of the limitations for these aeronautical networks are the lack of compatibility for exchanging data between different constellations. Using beam hopping techniques, several dynamic traffic allocation solutions have been proposed to enhance the network performance [1]. Nevertheless, the main challenge is the algorithm that assigns the illumination plan and coordinates with the Network Management System (NMS). Studies have shown both non-beam hopping and hybrid beam-hopping HTS systems which use optimization techniques to demonstrate the overall capacity demands and power limitations [2],[3]. In this study, we will be delivering a hybrid architecture design for satellite systems which incorporates high throughput links between satellite gateways and feeder links for microwave backhaul.

A. Network Architecture

The Radio Frequency Terminals (RFT) are located at various geographical locations to provide diversity on the ground infrastructure [4]. Each gateway consists of multiple elements including switches and routers which interconnects to the backhaul infrastructure. A range of modulations from QPSK, 8PSK and 16APSK are supported. The backhaul is connected to one or multiple data centers; quantity is dependent on the computation level complexity. Each data center includes two main structure. First the Transport component which operates as a bandwidth manager and second the networking layer which includes all the IP gateways.

B. Gateway Platform

Data centers provide a comprehensive automatic redundancy for all traffic carrying components and is designed for remote light-out operations [5]. The data center receives user traffic destined for terminals from the Internet via a terrestrial link and sends the traffic to the gateway. In the return direction, the data center receives traffic from the gateways and sends it back via a terrestrial link to the Internet as illustrated in Figure 1. The characteristic of the traffic for this study can be obtained via operational scenarios in the Simulation Results section. Usually the burst uplink user data access requests traffic needs with less bandwidth where the lengthier and steadier user traffic downlink requires a lot more bandwidth.

C. Network Management System (NMS)

NMS can be scaled up and provides Web browser and provisioning API access for a Host Network Operator (HNO), as well as Virtual Network Operators (VNOs) that use host-provided bandwidth to run their infrastructure [6]. In addition, systems at the Network Control Center provide centralized carrier monitoring and remote terminal performance verification.

The NMS optionally supports secure access to the Operations Support System (OSS) and the Business Services System (BSS). The management application provides a comprehensive set of service functionalities towards the provisioning of network level service parameters, service plans, end user terminals, and real-time terminal status and diagnostics. The dynamic carrier reconfiguration feature allows forward and return frequency plan reconfiguration along with the change of carrier sizes. The NMS interfacing with the gateway platform, communicates scheduled plan updates in real-time.

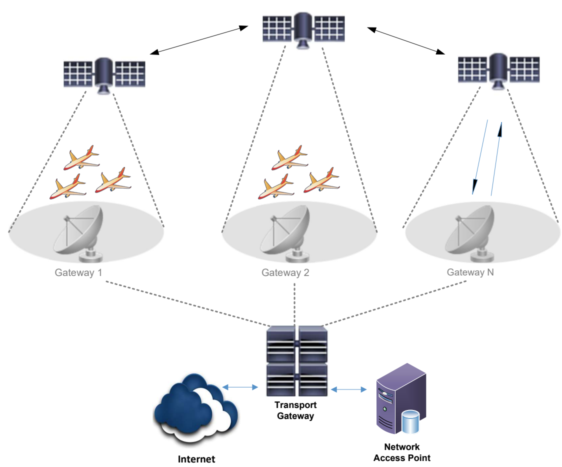

Fig. 1. Distribution of the traffic with the feeder link model

III. Simulation Results

For the purpose of this study, we have selected six regions across the United States in addition to the gateway beam shown in Figure 2 . In this simulation, the spot beams are all considered to include 36 MHz available bandwidth for each transponder. Table I summarizes the characteristic of each region considered in this simulation. This table provides regions, ModCod, FEC rates, symbol rate, throughput and link availability.

IV. Conclusion

This study shows high throughput achievement with efficient spectrum improvement results can be gained by using higher baseband modulation using Forward Error Control (FEC) and Adaptive Coding and Modulation (ACM) techniques. We reviewed a transport gateway architecture for backhauling connection of a satellite link through a terrestrial network based on the use of feeder links for backhaul.

TABLE I
Regional achieved throughput with link availability

Region	**FWD Mod-Cod FEC**	**FWD Symbol Rate (Msps)**	**FWD Through-put (Mbps)**	**Link Avail-ability**
Northeast	16APSK 2/3	34	99.66	99.79%
Southeast	16APSK 2/3	34	98.51	99.86%
Northwest	16APSK 2/3	34	98.06	99.77%
Southwest	16APSK 1/2	34	99.54	99.87%
South Central	16APSK 2/3	34	98.14	99.87%
North Central	16APSK 1/2	34	97.06	99.48%

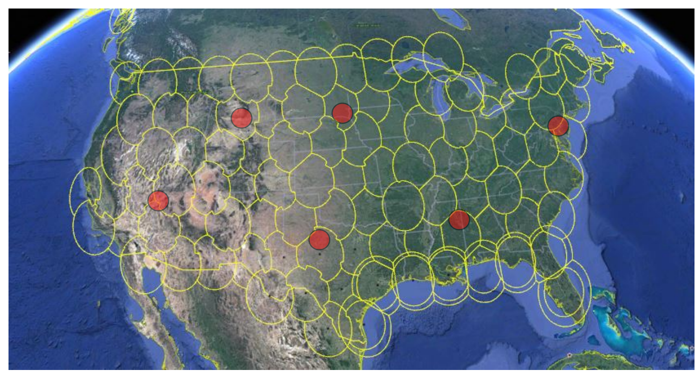

Fig. 2. Six regions across the United States selected for study

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