BROADBAND WIRELESS COMMUNICATIONS VIA STRATOSPHERIC HALO™ AIRCRAFT

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ABSTRACT

Broadband wireless communications services provided from a High Altitude Long Operation (HALO™) Aircraft are now feasible. Our talk will emphasize the conceptual design of a “bandwidth-on-demand” wireless network whose data rates to and from the user will measure in the multi-megabit per second range. The network will use the millimeter wave range of the spectrum (> 20 GHz). The HALO™ Aircraft is specially designed for stratospheric operation (> 50,000 feet).

The HALO™ Aircraft fuselage will house packet switching circuitry and fast digital network functions. The communications antenna and related components will be located in a pod suspended below the aircraft fuselage. To offer “ubiquitous” service throughout a large region, the HALO™ antenna will utilize multiple spot beams arranged in a typical cellular pattern. Broadband channels to users in adjacent cells will be separated in frequency. As the beams traverse over a user location, the virtual path through the packet switch will be changed to perform a beam-to-beam handoff.

1. BACKGROUND

This paper describes the system in its commercial application. It should be easy for the reader to imagine how this broadband wireless network can also be used for battlefield communications.

1.1 Introduction

The convergence of innovative technologies and manufacturing capabilities affecting aviation, millimeter wave wireless, and multi-media communications industries enables Angel Technologies Corporation and its partners to pursue new wireless broadband communications services. The HALO™ Network will offer ubiquitous access to any subscriber within a “super metropolitan area” from an aircraft operating at high altitude. The aircraft will serve as the hub of the HALO™ Network serving tens to hundreds of thousands of subscribers. Each subscriber will be able to communicate at multi-megabit per second data rates through a simple-to-install subscriber unit. The HALO™ Network will steadily evolve at a pace with the emergence of data communications technology. It will be deployed globally on a city-by-city basis. The HALO™ Network will be a universal wireless communications network solution.

The nature of the equipment needed for this broadband wireless service is evolutionary, not revolutionary. Most of the technology already exists. The engineering effort will focus primarily on adapting and integrating components and subsystems from terrestrial markets. Proven technology will be used to the maximum extent. Since the HALO™ Aircraft operate from regional airports, the equipment will be routinely maintained and calibrated. The operating plan assumes equipment upgrades as technology advances yield lower cost and weight and provide increased performance.

1.2 A Broadband Wireless Metropolitan Area Network (or Battlefield Wireless Information Network)

An airplane specially designed for high altitude flight with a payload capacity of approximately one ton is being developed for commercial wireless services. It will circle at high altitudes for extended periods of time and it will serve as a stable platform from which broadband communications services will be offered (see figure on next page). The High Altitude Long Operation (HALO™) Aircraft will maintain station at an altitude of 52 to 60 thousand feet by flying in a circle with a diameter of about 5 to 8 nautical miles. Three successive shifts on station of 8 hours each, for example, can provide continuous service for 24 hours per day, 7 days per week. Such a system can cost-effectively provide broadband multimedia communications to diverse business groups and to the general public.

If a viewing angle of 20 degrees or higher is chosen to facilitate good line-of-sight coverage at millimeter wave (MMW) frequencies (20 GHz or higher), one such platform will cover an area of approximately 2800 square miles encompassing a typical metropolitan area. Operation at MMW frequencies enables broadband systems to be realized, by providing spectrum bandwidths of 1 to 6 GHz. MMW systems also permit very narrow beamwidths to be realized with small aperture antennas.

The HALO™ Network can utilize a cellular pattern on the ground so that each cell uses one of four frequency sub-bands, each having a bandwidth up to 60 MHz each way. A fifth sub-band can be used for gateways (connections to the public network or to dedicated users). Each cell will cover an area of a few square miles. The entire bandwidth will be reused many times to achieve total coverage throughout the 2800 square mile area served by the airborne platform. The total capacity of the network supported by a single airborne platform can be greater than 100 Gbps. This is comparable to terrestrial fiber-optic networks and can provide two-way broadband multimedia services normally available only via fiber-optic networks.
The HALO™ Network provides an alternative to satellite- and ground-based communications systems. Unlike satellite systems, however, the airborne system concentrates all of the spectrum usage in certain geographic areas, which minimizes frequency coordination problems and permits sharing of frequency with ground-based systems. Enough power is available from the aircraft power generator to allow broadband data access from small user terminals (i.e., lower gain antennas can be used).

1.3 A New Layer in the Wireless Infrastructure

Raytheon Systems Company and Angel Technologies Corporation have the opportunity to serve the growing wireless communications market by using a HALO™ Aircraft that transmits high-speed data traffic throughout a metropolitan region. The goal is to interconnect more than 100,000 subscribers within a metropolitan center and its surrounding communities through a star topology network. This HALO™ Network has the benefits of low cost, high flexibility, and high quality of service.

HALO™ Aircraft provide a new layer in the traditional hierarchy of wireless communications. The HALO™ Network can be thought of as a “tall tower” approach that provides better line of sight to customers without the high cost of deploying and operating a satellite constellation.

This paper will describe the architecture and the concept of operations of the HALO™ Network. It will also describe key characteristics of the HALO™ Aircraft, the communications payload, and subscriber units. An earlier paper2 entitled “The Cone of Commerce™” covered the business and market aspects of the HALO™ Network. The paper by Djuknic3 provides an overview of the various options and highlights the unique advantages of stratospheric platforms for providing wireless communications services.

2. THE HALO™ NETWORK CONCEPT

2.1 Overview

The attributes of the HALO™ Network are illustrated in the figure on the next page. Many types of subscribers—schools, families, hospitals, doctors’ offices, and small- to medium-size businesses—will benefit from the low price of HALO™ Network broadband services.
The equipment will connect to existing networks and telecommunications equipment using standard broadband protocols such as ATM and SONET. The HALOTM Gateway provides access to the Public Switched Telephone Network (PSTN) and to the Internet backbone for such services as the World Wide Web and electronic commerce.

### 2.2 Service Attributes

There are various classes of service to be provided: (a) 1-5 Mbps communication links to consumers; and (b) 5-12.5 Mbps links for business users. Since the links would be "bandwidth-on-demand," the total available spectrum would be shared between concurrent active sessions. The nominal data rates would be low while the peak rates would expand to a specified level. A gateway type service can be provided for "dedicated" links at 25-155 Mbps.

Based on the LMDS spectrum and 5-fold reuse, the service capacity would be 10,000 to 75,000 simultaneous, symmetrical T1 circuits (1.5 Mbps) per Communications Payload. The HALOTM Aircraft would provide urban and rural coverage from a single platform to provide service to:

a) 100-750,000 subscribers
b) 40-60 mile diameter service area (1,250 to 2,800 square miles)

### 2.2.1 Network Access

Various methods for providing access to the users on the ground are feasible. The figure in the upper right shows one approach where each spot beam from the payload antenna serves a single "cell" on the ground in a frequency-division multiple access fashion with 5-to-1 frequency reuse.

### 2.2.2 Network Services

The HALOTM node provides a multitude of connectivity options as shown below. It can be used to connect physically separated Local Area Networks (LANs) within a corporate intranet through frame relay adaptation or directly through LAN bridgers and routers. Or it can provide videoconference links through standard ISDN or T1 interface hardware. The HALOTM Network may use standard SONET and ATM protocols and equipment to minimize the cost of the equipment and to take advantage of the wide availability of these components.

#### 3. HALOTM NETWORK ARCHITECTURE

At the apex of a wireless Cone of CommerceTM, the payload of the HALOTM Aircraft becomes the hub of a star topology network for routing data packets between any two subscribers possessing premise equipment within the service coverage area. A single hop with only two links is required, each link connecting the payload to a subscriber. The links are wireless, broadband and line of sight. Single link delays range from ~50 μsec under the airplane to ~200 μsec at the edge of the signal footprint.

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The HALOTM Network Accommodates a Variety of Interfaces
Information created outside the service area is delivered to the subscriber's consumer premise equipment (CPE) through business premise equipment (BPE) operated by businesses, Internet Service Providers (ISPs), or content providers within that region, and through the HALO™ Gateway ("HG") equipment directly connected to distant metropolitan areas via leased trunks. The HG is a portal serving the entire network. It avails system-wide access to content providers or advertisers, and it allows any subscriber to extend their communications beyond the HALO™ Network service area by connecting them to dedicated long-distance lines such as inter-metro optical fiber.

The HALO™ Network Architecture

As with all wireless millimeter wave links, high rainfall rates can reduce the effective data throughput of the link to a given subscriber. Angel plans to ensure maximum data rates more than 99.7% of the time, reduced data rates above an acceptable minimum more than 99.9% of the time, and to limit outages to small areas (due to the interception of the signal path by very dense rain columns) less than 0.1% of the time. Angel plans to locate the HG close to the HALO™ orbit center to reduce the slant range from its high-gain antenna to the aircraft and hence its signal path length through heavy rainfall.

4. HALO™ AIRCRAFT

The HALO™ Aircraft is under development and flight testing is expected to occur by mid-1998. The aircraft has been specially designed for the HALO™ Network with the Communications Payload Pod suspended from the underbelly of its fuselage.

The HALO™ Aircraft will fly above the metropolitan center in a circular orbit of five to eight nautical miles diameter. The Communications Payload Pod is mounted to a pylon under the fuselage. As the aircraft varies its roll angle to fly in the circular orbit, the Communications Payload Pod will pivot on the pylon to remain level with the ground. Other details on the aircraft can be found in the Cone of Commerce™ paper.²

5. COMMUNICATIONS PAYLOAD

The HALO™ Network will use an array of narrow beam antennas on the HALO™ Aircraft to form multiple cells on the ground. Each cell covers a small geographic area, e.g., 4 to 8 square miles. The wide bandwidths and narrow beamwidths within each beam or cell are achieved by using MMW frequencies. Small aperture antennas can be used to achieve small cells. A more detailed description of the communications payload equipment is given in another technical paper.¹

6. SUBSCRIBER UNITS

A block diagram describing the CPE (and BPE) is shown below. It entails three major sub-groups of hardware: the RF Unit (RU) which contains the MMW Antenna and MMW Transceiver; the Network Interface Unit (NIU); and the application terminals such as PCs, telephones, video servers, video terminals, etc. The RU consists of a small dual-feed antenna and MMW transmitter and receiver which is mounted to the antenna. An antenna tracking unit uses a pilot tone transmitted from the HALO™ Aircraft to point its antenna at the airplane.

The MMW transmitter accepts an L-band (950 - 1950 MHz) IF input signal from the NIU, translates it to MMW frequencies, amplifies the signal using a power amplifier to a transmit power level of 100 - 500 mW of power and feeds the antenna. The MMW receiver couples the received signal from the antenna to a Low Noise Amplifier (LNA), down converts the signal to an L-band IF and provides subsequent amplification and processing before outputting the signal to the NIU. Although the MMW transceiver is broadband, it typically will only process a single 40 MHz channel at any one time. The particular channel and frequency is determined by the NIU.

The NIU interfaces to the RU via a coax pair which transmits the L-band TX and RX signals between the NIU and the RU. The NIU comprises an L-band tuner and down converter, a high-speed (up to 60 Mbps) demodulator, a high-speed modulator, multiplexers and demultiplexers, and data, telephony and video interface electronics. Each user terminal will provide access to data at rates up to 51.84 Mbps each way. In some applications,
some of this bandwidth may be used to incorporate spread spectrum coding to improve performance against interference (in this case, the user information rate would be reduced).

The subscriber equipment can be readily developed by adapting from existing equipment for broadband services.

7. SUMMARY

The HALO™ Network is capable of providing high rate communications to users of multimedia and broadband services. The feasibility of this approach is reasonably assured due to the convergence of technological advancements. The key enabling technologies at hand include:

- GaAs (Gallium Arsenide) RF devices which operate at MMW frequencies
- ATM/SONET Technology and Components
- Digital Signal Processing for Wideband Signals
- Video Compression
- Very Dense Memory Capacity
- Aircraft Technology

These technologies are individually available, to a great extent, from commercial markets. The HALO™ Network seeks to integrate these various technologies into a service of high utility to small and medium businesses and other multimedia consumers at a reasonable cost.

REFERENCES


BIOGRAPHIES

James Martin is the lead systems engineer and project manager for the HALO™ communications payload under development at Raytheon Systems Company for Angel Technologies. At AT&T Bell Labs, he developed cellular wireless telecommunications equipment and underwater fiber optic transmission systems. Mr. Martin has recently published a "Systems Engineering Guidebook" with the CRC Press. His specialty is systems engineering management, systems architecting and the total systems engineering process.

Dr. Nicholas J. Colella is the Chief Technology Officer of Angel Technologies Corporation. In prior years, he held senior technical positions at Lawrence Livermore National Laboratory. He invented the RAPTOR/TALON theater ballistic missile defense concept and served as DOD’s executing agent for pioneering low-cost, high-altitude, long-endurance unmanned aircraft, high mass fraction kinetic kill interceptors, electro-optics and communications systems. He co-created Brilliant Pebbles, led LLNL’s spacecraft design and survivability projects, and developed one-steradian wide field of view (WFOV) cameras employing spherically concentric refractive optics for tracking satellites and space objects. He is a founding partner of a multi-chip module company and the National Robotics Engineering Consortium at Carnegie Mellon.

For more information on Angel’s HALO™ Network Concept, see their website at:

http://www.angelcorp.com