The Orbcomm Experience

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INTRODUCTION

The ORBCOMM satellite system is a wide area, packet switched, two-way data VHF based communication system that has been established between 1995 and 2000 by a company called Orbcomm Corp. Satellites and launches were provided by Orbital Science Corporation (OSC). The total costs for the system were roughly 800 Million US Dollar brought into Orbcomm through OSC and other investors. Shortly after the launch of the last satellites the company went into chapter 11 and was bought by private investors – among them OHB. Following a number of years of restricted operations and financial capabilities the new company, now called Orbcomm LLC entered into a new financing round with OHB and SES Global becoming major industrial shareholders of the company. Orbcomm, being now cash flow positive, currently plans to replenish its first generation satellite fleet. A first demonstration satellite is under contract and will be placed into orbit at the end of 2005. Today roughly 100,000 customers use Orbcomm services. The number customers will largely grow within the next few year due to services required for pay-per-view users in the US and global car industry needs for emergency and service calls which can not be provided by GSM networks in a reliable way.

SYSTEM

Communications to and from Subscriber Communicators (SC) to ORBCOMM Gateways are accomplished through a constellation of low-Earth orbit (LEO) Microstar satellites. ORBCOMM Gateways are connected to dial-up circuits, private dedicated lines or the Internet. The ORBCOMM System consists of a Network Control Centre (NCC) that manages the overall system worldwide and three operational segments:

- a space segment consisting of 30 LEO Satellites;
- a ground segment consisting of Gateway Earth Stations (GES)
- control centres located throughout the world;
- a subscriber segment consisting of communicators used by ORBCOMM System subscribers to transmit and receive information to and from the LEO Satellites.

RF communication within the ORBCOMM System operates in the very high frequency (VHF) portion of the frequency spectrum between 137 and 150 (MHz). The ORBCOMM Satellites have a subscriber transmitter that provides a continuous 4800 bps stream of packet data. Each Satellite also has multiple subscriber receivers that receive short bursts from the SCs at 2400 bps. Once the full Satellite constellation is deployed and the ORBCOMM Gateways are installed, the ORBCOMM System will be capable of providing near real-time wireless data communications service around the world. All communications within the ORBCOMM System must pass through an ORBCOMM Gateway. An ORBCOMM Gateway consists of one Gateway Control Center (GCC)—the facility that houses the computer hardware and software that manages and monitors message traffic—and a GES. The GES provides the link between the Satellite constellation and an ORBCOMM GCC.

EXAMPLE: Using the ORBCOMM System, a typical messaging scenario will proceed, as shown in the following sequence:

1. An ORBCOMM System subscriber creates a message, which is intended for receipt by another subscriber's home computer. Using an e-mail program on a laptop PC, the subscriber downloads the message to a SC.
2. The SC transmits the message to the Satellite that receives, reformats and relays the message to a GES.
3. The GES transmits the message over a dedicated line to the GCC that places the message on the public switched network for delivery to the receiver subscriber's PC Internet provider.
4. The receiver subscriber downloads the message once the computer makes a connection via modem to its Internet service provider.

5. A message from the home base to the subscriber follows the reverse route: PC to the Internet over a public switched network to the GCC, GCC to GES, GES to Satellite, and finally Satellite to SC and SC to the user display. Even “direct” subscriber-to-subscriber transmissions must pass through an ORBCOMM Gateway.

The interrelationship of these elements is shown in Figure 1.

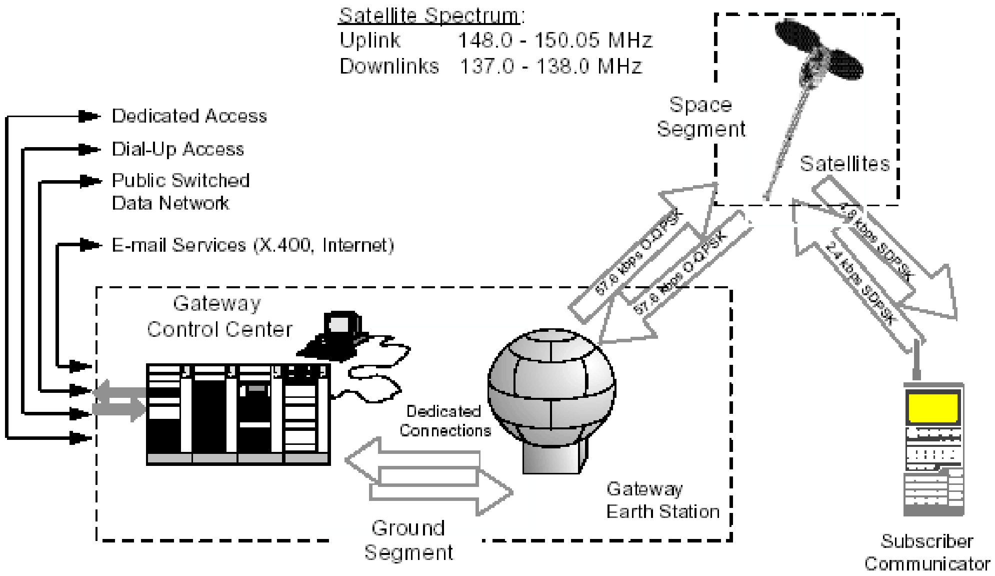

Figure 1: ORBCOMM System Overview

ONSTELLATION COVERAGE AND AVAILABILITY: The ORBCOMM System currently consists of 30 Satellites in 4 orbital planes. The first demonstration satellites, launched in two polar planes, are not in function anymore. ORBCOMM has received a license to launch up to 48 Satellites. The main constellation will consist of four orbital planes (planes A, B, C and D) of eight Satellites each. The first three planes are inclined at 45° to the equator, launched to an altitude of approximately 825 km (451 nautical or 513 statute miles) and separated 45° apart in each of the four main planes. Two supplemental orbital planes (planes F and G), containing two Satellites each, could provide coverage from approximately 780 km altitude and are spaced 180° apart. Plane F is inclined at 70° and plane G is inclined at 108°. The fourth plane of eight Satellites (plane D), is to be inclined at 0° (equatorial orbit) at an 825 km altitude and spaced 45° apart. The functional design of all satellites are substantially identical.
Figure 2 illustrates the configuration of the ORBCOMM System Satellite constellation.

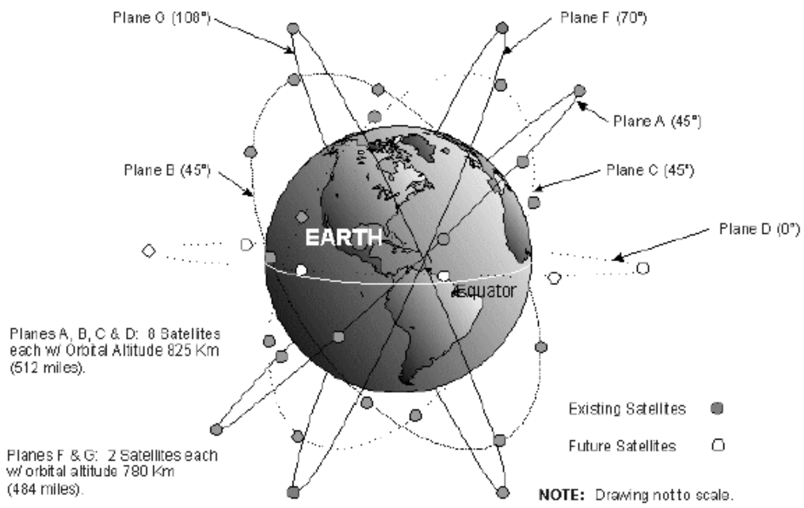

Figure 2 - ORBCOMM System 30 Satellite Constellation including potential positions for 48 satellites

The amount of time available each day on the ORBCOMM Satellite network depends on the number of Satellites and Gateways in operation and the user's location. As the Satellites move with the Earth, so does the approximately 3200-mile diameter coverage pattern of each satellite.

SATELLITE DESCRIPTION: All ORBCOMM Satellites have been launched using the Orbital Pegasus® XL launch vehicle. Each of the Satellites comprising the ORBCOMM System Satellite constellation is an Orbital Microstar Satellite. Undeployed, the Microstar Satellite resembles a disk weighing approximately 90 lbs (43 kg.), measuring approximately 41 inches (1 meter) in diameter and 6.5 inches (16-cm.) in depth. The Satellite solar panels and antennas fold up into the disk (also called the "payload shelf") with the remainder of the payload during launch and deployment. Once fully deployed, its length is approximately 170 inches (4 meters) and the width of its solar panels is approximately 88 inches (2.2 meters). Figure 3 shows the main parts of a fully deployed Microstar Satellite.

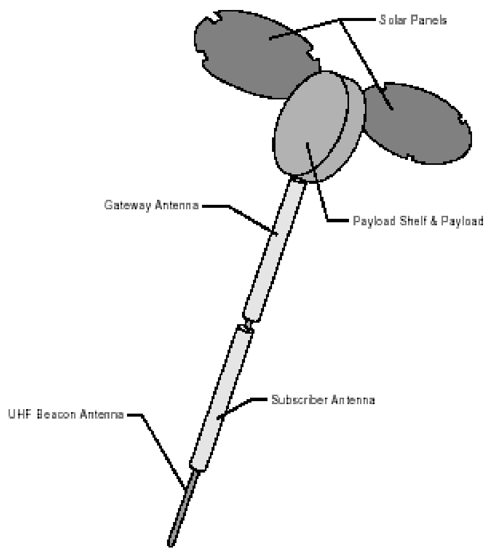

Figure 3 - Main Parts of a Fully Deployed Microstar Satellite

The Microstar Satellite electrical power system is designed to deliver approximately 70 Watts on an orbit-average basis, near the end of its expected life while in a worst case orbit. The following sections briefly describe the Satellite's principal subsystems.

COMMUNICATION PAYLOAD: The communication subsystem is the principal payload flown on the Satellite. This subsystem consists of four major parts: the subscriber communications section, the ORBCOMM Gateway communications section, the Satellite network computer, and the UHF transmitter.

SUBSCRIBER COMMUNICATION SECTION : The subscriber communications section consists of one subscriber transmitter, seven identical receivers and the associated receive and transmit filters and antennas. Six of the receivers are used as subscriber receivers and the seventh is used as the DCAAS receiver. The subscriber transmitter is designed to transmit an operational output power of up to approximately 40 Watts, although the output is to be less during normal operation. The power of each transmitter varies over a 5 dB range, in 1 dB steps, to compensate for aging and other lifetime degradations. The subscriber transmitter power is controlled to maintain a maximum power flux density (PFD) on the surface of the Earth of slightly less than 125 dB (W/m^2 in 4 kHz). The output transmitter receives downlink packets from the Satellite network computer, modulates and amplifies the signal and feeds it to the antenna subsystem. Symmetric Differential Phase Shift Keying (SDPSK) modulation is used on the subscriber downlink, at a data rate of 4800 bps. SDPSK is defined by a 'zero' ('space') data state causing a negative 90° phase shift and the "one" ("mark") data state causing a positive 90° phase shift. Raised cosine filtering is used to limit spectral occupancy. Subscriber receivers are direct conversion digital signal processor (DSP)-driven receivers incorporating a fast fourier conversion process. A ground command can select any
combination of the seven subscriber receivers to act as the DCAAS, random access or reservation receivers. Each receiver, when selected for DCAAS operation, is designed to scan the uplink band with a 2.5 kHz resolution in 5 seconds or less. The actual portion(s) of the receiver frequency band used in the DCAAS process is ground selectable. The remaining subscriber receivers are used to process inbound traffic. The subscriber receivers and the Gateway receiver operate through a single uplink antenna. The Low-Noise Amplifier (LNA) associated with SC receivers have

been designed to operate linearly in the presence of high levels of interference. Analogue and digital filters process the signals after the LNA to reduce the impact of the terrestrial mobile systems on the subscriber receivers. Once received, the subscriber signals are demodulated and routed to the Satellite network
computer. The uplink modulation is SDPSK, with a data rate of 2400-bps. Raised cosine filtering is used to limit spectral occupancy.

ORBCOMM GATEWAY COMMUNICATIONS SECTION: Both the ORBCOMM Gateway Satellite transmitter and receiver are contained in a single package. Separate right-hand circularly polarized (RHCP) antennas are used for the transmit and receive functions. The ORBCOMM Gateway transmitter is designed to transmit 5 Watts of RF power. The 57.6 kbps downlink signal to the GES is transmitted using an Offset Quadrature Phase Shift Keying modulation (OQPSK) in a TDMA format. The Satellite gateway receiver is designed to demodulate a 57.6 kbps TDMA signal with an OQPSK modulation. The received packets are routed to the onboard Satellite network computer.

SATELLITE NETWORK COMPUTER: Functionally, the Satellite network computer receives the uplinked packets from the subscriber and ORBCOMM Gateway receivers and distributes them to the appropriate transmitter. The computer also identifies clear uplink channels via the DCAAS receiver and algorithm, and interfaces with the GPS receiver to extract information pertinent to the communications system. Several microprocessors in a distributed computer system aboard the Satellite perform the Satellite network computer functions.

UHF TRANSMITTER: The UHF transmitter is a specially constructed 1-Watt transmitter that is designed to emit a highly stable signal at 400.1 MHz. The transmitter is coupled to a UHF antenna designed to have a peak gain of approximately 2-dB.

ORBCOMM SERVICE FEATURES DESCRIPTION: There are four basic service elements that the ORBCOMM System is capable of providing Data Reports; Messages; GlobalGrams; and Commands. **Data Reports**. A Data Report is the basic service element for a SC to generate a short report¾a single packet containing less than or equal to 6 bytes of user defined data¾that is transmitted via the random access protocol. A Data Report may be generated as needed or on a periodic basis. A Data Report also may be sent on request¾polled by the ORBCOMM System¾or may be sent when data is available. A Data Report can require an acknowledgment of successful delivery to the ORBCOMM Gateway or be unacknowledged to the originator to save space segment resources. **Messages**. A Message is the basic service element for a longer sequence of data to be transferred to or from a SC. Message lengths are typically less than 100 bytes, although the ORBCOMM System can handle Messages that are longer in length. To ensure reliable Message transfer, Messages are transferred via short packets containing a checksum over the Satellite reservation channels, with all packets acknowledged or retransmitted. Messages are accepted/delivered via public or private data networks. Messages from SCs may originate at the request of the subscriber (random access) or at the request of the network (polled). In either case, the transfer of Message packets is in a reservation (polled) fashion. **NOTE:** The term "Message" with an upper case "M" refers to a specific type of subscriber data, as described. The term "message" with a lower case "m" refers to *any* subscriber data that passes over the ORBCOMM System. **GlobalGrams**. A GlobalGram is the basic service element for a SC to send or receive a single, self-contained data packet from a Satellite when the Satellite does not have access to an ORBCOMM Gateway. For a SC-Terminated GlobalGram, the relaying Satellite stores the data packet in memory and transmits it upon request from the destination SC. For a SCOriginated GlobalGram, the Satellite receives the GlobalGram from the SC, acknowledges it and archives it in Satellite memory until the destination ORBCOMM Gateway establishes contact with the Satellite. This allows remote and oceanic areas to be served in a "store and forward" mode. **Commands**. A Command is the basic service element for a short command¾single packet containing less than or equal to 5 bytes of user defined data¾to be transmitted to a SC. Commands may be signals to initiate action by devices attached to the SC. Acknowledgments may or may not be required.

OVERVIEW OF THE ORBCOMM GATEWAY: The principal role of the ORBCOMM Gateway is to provide message processing and subscriber management for a defined service area. This role includes serving as the "home" for ORBCOMM System subscribers, as well as providing the interface between the subscriber and the interconnected Public and Private Data Networks (PDN) and the Public Switched Telephone Network (PSTN). Each ORBCOMM Gateway incorporates four major subsystems: the Gateway Message Switching System (GMSS), the GES, the Network Management System (NMS) and the ORBCOMM Command and Control Network (OCCNet). The NMS and GMSS are located within the GCC facility. For redundancy, a GES contains two completely independent systems, each capable of communicating with a Satellite. The GCC Local Area Network (LAN) and GES LAN are considered to be part of the global OCCNet Wide Area Network (WAN). All ORBCOMM Gateway systems are designed to be redundant.
Figure 4 shows an elementary schematic of an ORBCOMM Gateway.

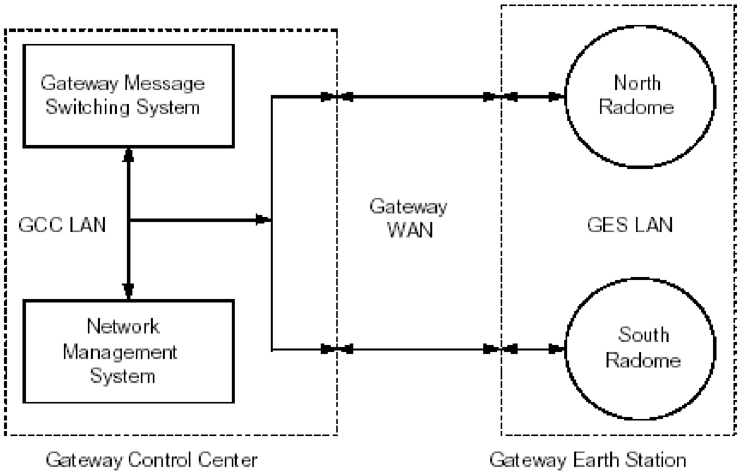

Figure 4 - The ORBCOMM Gateway

The GCC is the operations centre for ORBCOMM Gateway activities. Auxiliary systems such as the subscriber management and business support systems are typically located in the GCC. However, a GES is typically remotely located to provide optimum coverage for the required service area. Figure 5 illustrates the logical interconnection among the hardware elements incorporated in the GCC.

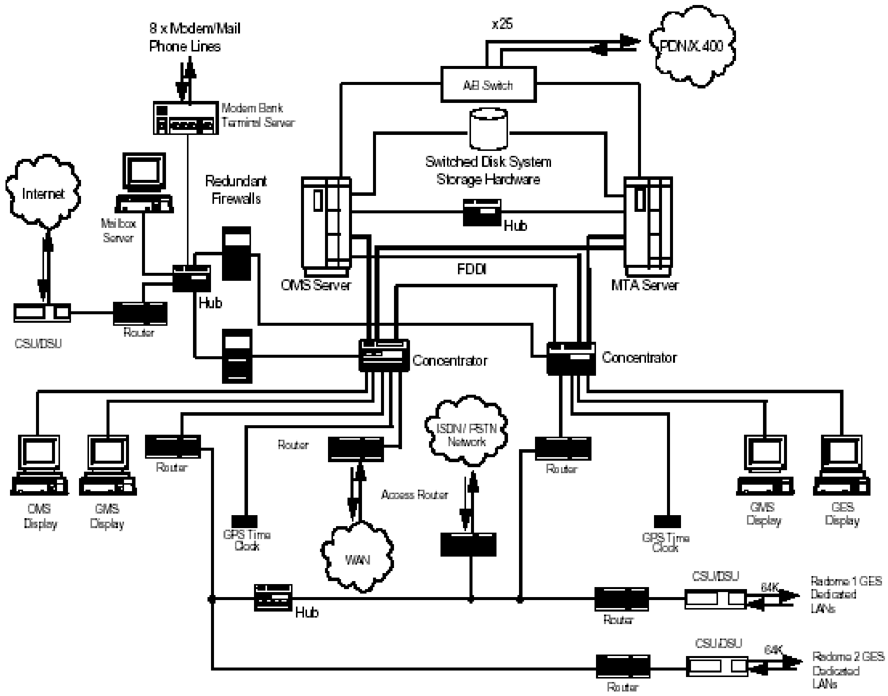

Figure 5 - ORBCOMM Gateway Control Centre

SUBSCRIBER COMMUNICATORS: The SC is a wireless VHF modem that transmits messages from a user to the ORBCOMM System with delivery to an addressed recipient, and receives messages from the ORBCOMM System intended for a specific user. Manufacturers have different proprietary designs and are free to include unique features in their SC design. However, each design must be type approved by ORBCOMM and adhere to the *ORBCOMM Air Interface Specification, Subscriber Communicator Specifications,* and *ORBCOMM Serial Interface Specification* (if an RS232 port is available). Different versions of SCs are currently available in production quantities from Stellar (Delphi Production and Quake). Current options on a number of SCs include internal GPS receivers and/or additional digital and analogue input and output ports. Other models with different features are planned, under design or in a pre-production status.

THE EXPERIENCE

A number of lessons can be drawn from the first six years of operation of the Orbcomm System:

- Satellite Life Time: The initially planned life time of the Orbcomm satellites was five years. However, using intelligent manoeuvring and satellite command software, this active orbit time will be expanded to about eight to ten years as an average figure for the constellation. The next generation of satellites will be placed into orbit step by step allowing a gradual replacement of different satellites in different orbit planes through a limited number of launches.
- Ground Segment: Aside the number of satellites in orbit and their position, the latency strongly depends on the number of GES installed – the installation of the ground segment at an appropriate location allowing cost effective maintenance and the possibility to run software updates through dedicated lines have shown to be the major effects on providing an accepted service.
- Modems: As already mentioned in the beginning of this paper, roughly 100,000 modems (called users) are connected to the system via their SCs. This corresponds to a average usage rate of the complete system of about 5-10%. Only when reaching roughly two million users the latency of the system will be reduced. On the modem cost side there has been a dramatic change within the past years. Whilst a modem was at a price of 1000 $ during the first year of operation, prices now touch the 100 $ barrier and it is expected that the prices will go down to 50 $ within the next two years.
- Market: Within the first years, the capabilities of the systems have been oversold – trying to come into a real competition with the real time GSM system. However the effective market areas for Orbcomm are
    - Fixed assets in remote areas without GSM coverage
    - Mobile assets in trans national traffic
    - Back up solution for GSM data communication
- By this reason major current users of Orbcomm are Caterpillar, GE TIP or the rail sector.

NEXT GENERATION SATELLITES

The concept of the Orbcomm Next Generation demonstrator satellite is based on a robust small satellite design which offers extreme reliability and cost effectiveness through proven technologies. The payload will consist of a new design which provides full backward compatibility and proven capabilities. The small mass of the proposed mission allows to inject the satellite as piggyback payload an already planned satellite mission into a near polar orbit at roughly 1000 km height using for example the Russian COSMOS-3M launch vehicle proven through more than 750 successful starts.

The first satellite of the new generation key features will be:

- Robust design – simple mechanical structure with a minimum of deployable or moving parts;
- No propulsion system - only one satellite will be launched in a polar orbit without a need of constellations maintenance;
- Rigid mounted large solar generators without risk of sun pointing systems failure;
- Modular and low cost satellite design approach using the high reliable and redundant already successful used in space subsystems;
- Low cost launch as piggyback payload on high reliable launcher (e.g. COSMOS-3M) with stack launch options for future first generations satellite replacement;

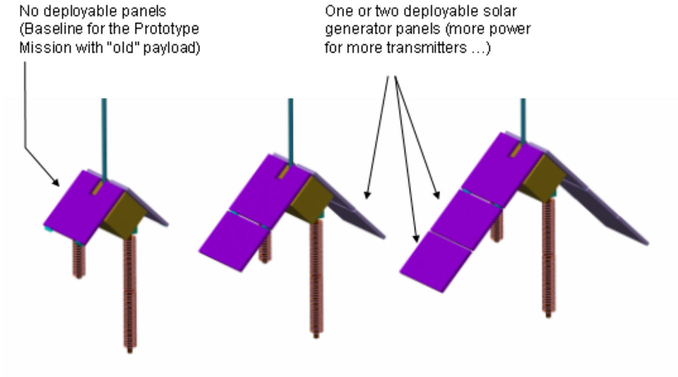

Figure 6 - ORBCOMM next Generation Satellite