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Architecture of Orbcomm Ground Segment for Global Mobile Satellite Communications (MSC) Networks

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ABSTRACT

In this paper is introduced the Orbcomm ground segment as a wide area packet switched and global two-way data transfer network providing satellite communication, tracking, monitoring and logistics services between mobile, remote, semi fixed or fixed Subscriber Communication Units (SCU) in Mobile Satellite Communications (MSC) and Gateway Earth Stations (GES) or Gateway Control Centres (GCC) accomplished via LEO satellites and Network Control Centres (NCC). Orbcomm Global, L.P., from placeCityDulles, StateVirginia, country-regionUSA equally owned by Teleglobe and the Orbital Sciences Corporation, provides global services via the world's first LEO satellite-based data and messaging communications system. The US Federal Communications Commission (FCC) granted Orbcomm a commercial license in October 1994 and the Commercial service began in 1998. Orbital Sciences was the prime contractor for the design project of Orbcomm satellites. The Company owns and operates a network consisting in 36 Little LEO satellites and several GES deployed around the world, connecting small, low-power and commercially proven SCU terminals to private and public networks, including the Internet. Orbcomm delivers information to and from virtually anywhere in the world on a nearly real-time basis to the Terrestrial Telecommunication Network (TTN). The Orbcomm ground segment and subscriber transmitters (Tx) that provide a continuous 4.8 to even 9.6 Kb/s stream of downlink packet data to the receivers (Rx), and viceversa.

1. Introduction.

The Orbcomm MSC network is a global satellite operator and provider of Internet of Things (IoT) and tracking solutions, announced the introduction of its next-generation analytics and reporting platform. The ground segment of MSC network offers advanced data insights and a dynamic user interface, to provide mobile and fixed users with a single, unified view of all their transportation asset types using a single sign-on. Thus, the new, cloud-based Orbcomm Platform (OP), which has the unrivaled capacity to support millions of subscribers, was built for the future to address the industry's evolving requirements for greater processing power, data bandwidth and scalability in a 5G IoT ecosystem.

The OP infrastructure offers the ability for different customers to track, monitor and control all of their transportation assets in one place – from reefers, dry trailers and trucks to chassis and dry and refrigerated shipping containers on the road, rail and at sea. The platform also includes a driver management component to enable workflow management, performance, communications and safety compliance with the Electronic Logging Device (ELD) Mandate, U.S. Federal Motor Carrier Society Administration (FMCSA) Hours of Service (HOS), and Canadian working hours rules. The scalable platform can accommodate any size of operation whether the customer has one or 100,000-plus assets. The OP system also integrates with sensors for fuel, doors, cargo, temperature, and more for unparalleled visibility.

Using Orbcomm flexible Application Programming Interface (API) and extensive integrations, the open platform can deliver rich asset data to customers' existing third-party or pro-

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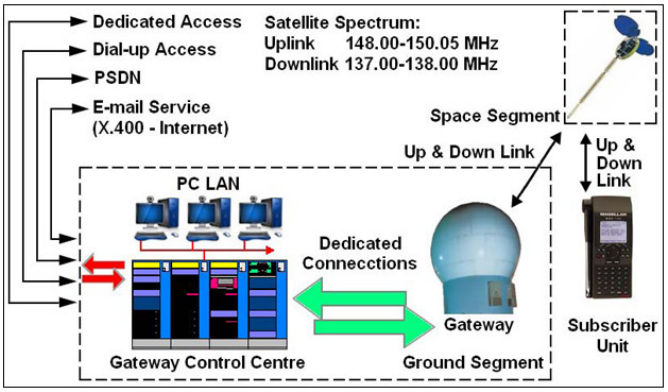
prietary enterprise systems to facilitate optimal fleet management. In addition, customers can access increased data and utilize the platform's advanced analytics to gain valuable insights about their mobile or fixed assets performance, including benchmarks, historic trends and comparisons among asset types, enabling faster, more informed business decisions.

The OP system supports multiple modes of communication with new capacity has been expanded to process more than 100,000 messages per second, which is an increase of over 1,000 times in message throughput over legacy systems. With the OP system increased processing capability, customers can continue to expand their deployments, access a higher level of visibility, and enable more sophisticated solutions in a 5G, sensor-enabled IoT ecosystem.

Figure 1: Orbcomm System Overview.



Source: Author.

2. Orbcomm MSC Network.

Orbcomm communication network consists in 36 operational satellites in little LEO orbit at about 825 km above the Earth's surface. Vital messages generated by a variety of space applications are collected and transmitted by an appropriate mobile or fixed SCU to the Orbcomm satellite. The satellite receives and relays these messages down to one of several GES. The GES then relays the message via certain satellite link or dedicated terrestrial line to the NCC. The NCC routes the message to the final addressee via Internet via E-mail to a personal computer, through terrestrial networks to a mobile subscriber unit or pager and to dedicated telephone or facsimile, which system see **Figure 1**. Messages originating outside the USA are routed through international GCC in the same way to its final destination. In reverse mode, messages and data sent to a remote SCU can be initiated from any PC onboard using common E-mail, Internet and X.400. The GCC or NCC then transmits the information via Orbcomm ground network.

Orbcomm serves customers with fixed and mobile units through distributors and so-called Value Added Resellers (VAR), which provides whole product solutions and customer support to the end-users. Thus, customers from around the world currently rely on Orbcomm for a wide range of mobile and fixed site data applications including:

1) Monitoring and controlling assets at remote or rural sites for oil and gas platforms, extraction and pipeline operations, meteorological centres, water stations, construction and agriculture, satellite SCADA (M2M) control, storage, custody transfer and electric power generation and distribution;

2) Messaging for truck and bus fleets anywhere, owner operators and remote workers;

3) Tracking and managing construction devices, locomotives, rail cars, trucks, trailers, containers, vessels, aircraft and locating and recovering stolen vehicles and cargo and

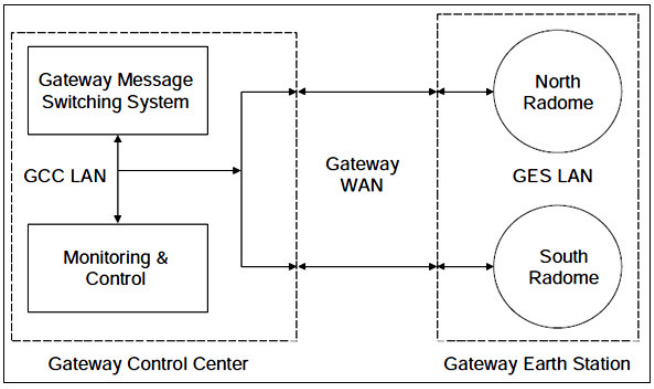
4) Weather data reports for general aviation and especially for small aircraft.

3. Orbcomm Ground Segment.

The Orbcomm ground segment, which has most of the intelligence of the Orbcomm entire system, comprises Gateway Earth Stations (GES), Control Centres and both mobile and fixed SCU user terminals worldwide. Otherwise, the Orbcomm space segment is controlled by one Satellite Control Centre (SCC).

The Gateway terminal, which include the GES, GCC and the NCC, are located at Orbcomm headquarters in Dulles. Within the USA, there are four GES located in Washington, Arizona, New York and Georgia. The several GES are located worldwide controlled by the US GCC managing the overall system. Orbcomm Gateways are connected to dial-up circuits, private dedicated lines, or the Internet. The SCU hand-held devices for personal messaging are fixed and mobile units for remote monitoring and tracking applications.

Figure 2: The ORBCOMM Gateway Architecture.



Source: Author.

3.1. Orbcomm Gateway Terminal.

An Orbcomm licensee requires a Gateway to connect to Orbcomm satellites in view of its service area. An Orbcomm Gateway consists of a GCC and one or more GES sites, as well as the network components that provide interfacility communications.

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 host for Orbcomm network subscribers, as well as providing the interface between the subscriber and the interconnected public and private data networks and the Public Switched Telephone Network (PSTN). In **Figure 2** is shown an elementary schematic of an ORBCOMM Gateway.

3.2. Gateway Control Centre (GCC).

The GCC terminal contains the GMSS and the Monitoring and Control (M&C) component. The M&C function allows GCC operators to manage hardware and software processes both within the GCC and at the remote GES sites, and to monitor the communications circuits between the sites. Each GES site contains two completely independent systems, each capable of communicating with one satellite. The Orbcomm network component (ORBNet) includes Local Area Networks (LAN) within the GCC and each Gateway Earth Station (GES), as well as the Wide Area Network (WAN) that provides interfacility communications.

The GCC terminals are located in a territory that is licensed to use the Orbcomm system and provide the following functions: locate wherever Orbcomm is licensed; link remote SCU with terrestrial-based placecountry-regionGeorgia systems; communicate via X.400, X.25, leased line, dial-up modem, public and private data networks and E-mail including the Internet. The Orbcomm GCC terminal efficiently integrates the Orbcomm infrastructure with new or existing customers and system providers. The GCC is the operations center for Orbcomm Gateway activities. Auxiliary systems such as the subscriber management and business support systems are typically located in the GCC.

3.3. Network Control Centre (NCC).

The NCC is responsible for managing the entire Orbcomm communications network, elements and the USA Gateways via satellite telemetry monitoring, commanding and mission system analysis. It provides network management of Orbcomm satellite constellation and is staffed 24 hours a day by Orbcomm-certified controllers and has the following main functions: monitors real-time and back-orbit telemetry from the Orbcomm satellites; sends the real-time and stored commands to the satellites; provides the tools and information to assist engineering with resolution of the satellite structure and ground anomalies; archives satellite and ground telemetry data for analysis; monitors the performance of GES terminals and so on.

The NCC manages and controls the entire Orbcomm satellite constellation, its processes and analyzes all satellite telemetry. The NCC is responsible for managing the Orbcomm system worldwide as well, which NCC is moved to new location in placeNorthern Virginia. In addition, through so call OrbNet, the NCC monitors message traffic for the entire Orbcomm system and manages all message traffic that passes through the US Gateway. The NCC is staffed 24 hours a day, 365 days a year and is located in placeCityDulles, StateVirginia, country-regionUSA. A backup NCC system was established in 2000, which permits the recovery of critical NCC functions in the event of an NCC site failure.

Figure 3: Orbcomm GES Radome Structure.

Source: Author.

3.4. Satellite Control Centre (SCC).

The SCC serves in a territory that is licensed to use the Orbcomm system and provides control of the Orbcomm satellite constellation. It means the facilities that process and display the telemetry data for the satellites monitor the operational status of the satellites and control the operation of the Satellites' power subsystems, attitude control subsystems and all other subsystems.

3.5. Satellite Communication Unit (SCU).

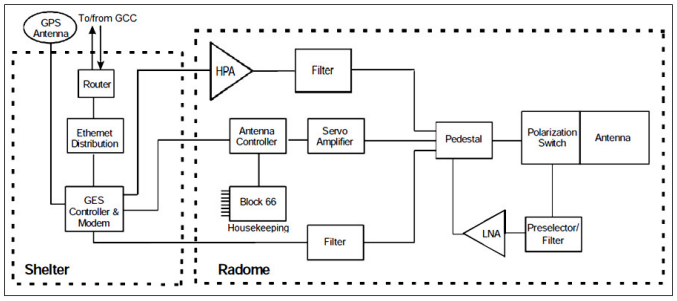
The SCU equipment is both mobile and fixed terminals used for connection to the Orbcomm satellite network through Gateway stations. The SCU terminal is a wireless VHF modem that transmits messages from a user to the Orbcomm system for delivery to an addressed recipient and receives messages from the Orbcomm system intended for a specific user. Manufacturers have different proprietary designs and each model must be approved by Orbcomm and adhere to the Orbcomm Air Interface Specification, Subscriber Communicator Specifications and Orbcomm Serial Interface Specification (if an RS-232 port is available).

4. Gateway Earth Station (GES) Terminal.

The mission of the GES is to provide a Radio Frequency (RF) communications link between the OMS and the satellite constellation. It consists of medium gain tracking antennas, RF and modem equipment, and communications hardware and software for sending and receiving data packets. The GES equipment and site are designed for unattended operation. The GES uses radome-enclosed, VHF full-motion antennas with approximately 17 dB of gain. Two fully independent antenna systems and associated RF and control equipment provide complete functional redundancy at a GES terminal. In **Figure 3** is illustrated one of two GES radome structure. The Orbcomm network is committed to continuing the deployment of additional regional GES to provide near-real-time service for all

major areas of the world, as well as developing and launching a new generation of satellites that will enhance and expand the current system?s capabilities. All Orbcomm GES terminals link the ground segment with the space segment and will be in multiple locations worldwide.

Figure 4: Generic GES Functional Block Diagram.



Source: Author.

The GES provides the following functions: acquires and tracks satellites based on orbital information from the GCC; links ground and space segments from multiple worldwide locations; transmits and receives all transmissions from satellites; transmits and receives signals from the GCC or NCC; monitors status of local GES hardware and software and monitors the satellite system level performance “connected” to the GCC or NCC terminals. However, an Orbcomm GES is typically remotely located to provide optimum coverage for the required service area, which functional block diagram of the GES terminal is shown in **Figure 4.**

The GES terminal is redundant and has two steerable high-gain VHF antennas that track the satellites as they cross the sky. The GES transmits to a satellite at a frequency centered at 149.61 MHz and 56.7 Kb/s with a nominal power of 200 W. The GES receives 3 W transmissions from the satellite at 137 to 138 MHz range. These up and downlink channels have a 50 KHz bandwidth.

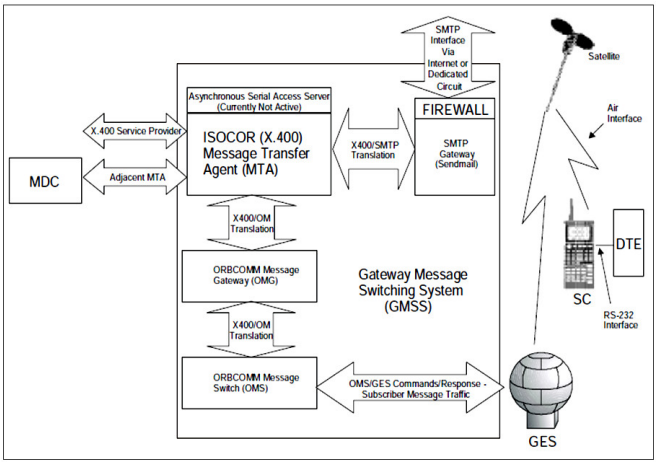
The mission of the GES is to provide an RF communications link between the ground and the satellite constellation. It consists in medium gain tracking antennas, RF and modem equipment and communications hardware and software for sending and receiving data packets from and to users. An Orbcomm licensee requires a Gateway to connect to Orbcomm satellites in view of its service area. Namely, the Gateway consists in a GCC and one or more GES sites, as well as the network components that provide interfacility communications.

The Orbcomm typical GES site plan is projected to provide minimum acceptable dimensions. Thus, specific site details and dimensions must be prepared for each GES installation, considering all local factors such as terrain, RF field-of-view, negative radiation hazard criteria, zoning, and other nosegay regulatory requirements. Two licensee-provided communications lines (one for each antenna), each with a capacity of at least 56 kbps, form the satelliteb link between each GES and the GCC terminal. These lines can use one or more dedicated telephone data circuits, the Integrated Services Digital Network (ISDN), microwave circuits, or Very Small Aperture Terminal (VSAT).

4.1. Gateway Message Switching System (GMSS).

The GMSS contains the software that performs the actual message processing, routing and conversion to and from X.400 and Simple Mail Transfer Protocol (SMTP). This software converts the proprietary protocol used for transmissions between the SC and the Orbcomm Message Switch (OMS) into traditional X.400 formats, processing by a commercial X.400 Message Transfer Agent (MTA). The portion of the ORBCOMM Gateway software that performs this conversion is called the ORBCOMM Message Gateway (OMG). This interface gives customer facilities equipped with an X.400 electronic mail system and access to public data networks a simple, standard connection to the ORBCOMM System. X.400 is a set of communication protocol standards defined by the International Telecommunications Union-Telecommunications Standardization Sector (ITU-T).

Figure 5: Gateway Message Switching System Functions.



Source: Author.

The GMSS configuration is based on the Open Systems Interconnect (OSI) model and describes the basic components and service elements required to exchange messages between systems and users. The GMSS also provides an SMTP interface, called the SMTP Message Gateway, for customer facilities connected either to the Internet or over dedicated circuits, which the GMSS functions are illustrated in **Figure 5**.

The GMSS hardware is based on two servers, one hosting the OMS, the X.400 MTA, the SMTP Message Gateway, and OMG, and the other serving as a hot standby. In the event of a server failure, all software packages are respawned on the standby server. By the way, it should be noted here, Hat the GMSS hardware is the responsibility of the ORBNet segment, and the functional description was included here for the sake of readability.

4.2. Message Distribution Center (MDC).

The optional MDC component provides message routing capability for all messages to and from SC terminals provisioned by an MDC Operator. An MDC connected to a GCC

provides an alternative means of message management at a cost significantly less than the cost of owning an additional GCC. By controlling and managing messages to and from its customers, an MDC Operator can provide the following:

1. Customer care developed specifically to meet the needs of the customers;
2. Secure access into the ORBCOMM network;
3. Visibility into the message delivery process of the local Internet service provider and/or the local X.400 service provider;
4. Specialized applications (POP3 mailboxes);
5. Statistical compilation and reporting of message traffic;
6. Visibility into message traffic profiles; and
7. Control over messages for regulatory purposes.

Messages to or from the SC are routed through the appropriate MDC based on originating X.400 and SMTP addresses. The MDC is a group of fault tolerant servers, routers, hubs, and Uninterruptable Power Supplies (UPS). All of the hardware and software components for the MDC component, with the exception of the MDC Transfer Module (MTM), are available as Commercial Off-The-Shelf (COTS) products. The Orbcomm role in developing the MDC is that of a systems developer and integrator. Otherwise, the GES available for use by an MDC may be located in sites that do not provide optimal coverage for those MDC remote SC terminals.

4.3. Monitoring & Control (M&C).

The Orbcomm M&C structure consists of the Network Management System (NMS) and a suite of core network monitoring tools. The NMS is a multi-user, distributed, fault- and event monitoring and performance management software system that tracks and manages the Orbcomm System. The NMS incorporates COTS tools and applications/enhancements developed by Orbcomm System.

Every NMS tool and utility is developed and integrated into Hewlett Packard OpenView Network Node Manager. The NMS system applications are developed as Graphical User Interfaces (GUI) consisting of OpenView and X_Windows/Motif screens. This gives the NMS a common GUI-based front end with a consistent look and feel.

Common NMS functions include the following:

1. A1. A visual display structure depicting the layout and status of the Orbcomm network and all system components in a standard and consistent graphical format;
2. An event filter and correlator;
3. Audio alarming for all critical system failures;
4. Collection and storage of system fault and performance data;
5. Web-based reports;
6. Graphical interfaces for most system administration tasks; and
7. Real-time displays of OMS and GES information.

As stated above, the GMSS and the M&C components are contained in the GCC structure. Therefore, the M&C function allows GCC operators to manage hardware and software processes both within the GCC and at the remote GES sites, and to monitor the communications circuits between the sites.

Conclusions.

The Orbcomm system allows mobile and fixed users to communicate, track, monitor, control and manage mobile and remote assets for purpose of SATFM, SCADA or M2M, command and logistics applications at sea, on the ground and in the air. These small devices are a very new satellite communications tools available for all professionals in transportation, business people, oil and gas, agriculture and remote environment to everyone who likes to have satellite messaging, tracking and logistics using Little LEO Orbcomm satellite systems everywhere.

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