The IntraCoastal Satellite Communicator System (ICSCS)

Nedo Celandroni, Erina Ferro, Francesco Potortì,
Giacomo Saviozzi^, Marco Boldrini *

Institute CNUCE of National Research Council (C.N.R.)
C.N.R. Research Area, 56010 Ghezzano (Pisa), Italy
E-mail: {nedo.celandroni, erina.ferro, f.potorti}@cnuce.cnr.it
Fax: +39-050-3138091/3138092
^ Synthema S.p.A., Lungarno Mediceo 40, Pisa, Italy
*Telespazio S.p.A., Via Tiburtina 965, Rome, Italy

Abstract

This paper describes an application of the ORBCOMM satellite system for helping pleasure-boat sailors to navigate. The IntraCoastal Satellite Communication System (ICSCS) is an improvement on the well established ChartPlotter made by Geonav 11E Navionix for bidirectional coastal communication. By using a terminal of the ORBCOMM system, ICSCS allows the sailors to access and retrieve information which has been coded ad-hoc on web sites. The paper briefly describes the software architecture of the system and presents the additional user facilities. The IntraCoastal Satellite Communicator System has been available on the market since beginning of year 2000, and has already been installed on many pleasure boats in Italy.

1. Introduction

In the IntraCoastal Satellite Communicator System (ICSCS) project we have used the ORBCOMM satellite system to solve the bidirectional communication problems of small boats equipped with a ChartPlotter, a device for controlling and aiding maritime navigation. On the ChartPlotter screen an electronic navigation chart is displayed, but it is read by a flash memory which is coded some months before and is thus not updated. The most up-to-date Chartplotters are already integrated with other board instruments (such as a compass, GPS, automatic pilot, etc.), but they do not provide bidirectional communication with the rest of the world. This bidirectional communication cannot be obtained neither by means of land mobile telephonic networks (GSM), because their coverage is limited to a few miles from the coast, nor by geostationary satellites, because usage costs are so high that only large navigation companies can afford them. The utilization of low earth orbit (LEO) satellites only is compatible with the characteristics of mobility of an insulated mini-system such as the boat is, and costs are affordable. Unfortunately, however, the LEO Iridium system has been a failure, and other complex LEO systems for multimedia communications are still not operative, a part from ORBCOMM which is a simple messaging system based on LEO satellites' technology. ICSCS is a software package which has been be included in the ChartPlotter installed on board of small boats in order to send/receive data via the ORBCOMM satellite system to allow the boats to access and retrieve information which has been coded ad-hoc on web sites. The software developed also includes the managing of the satellite channel, the display on the ChartPlotter screen of the information retrieved, and the maintenance of data at web sites. The hardware of the device for the satellite access included in the ChartPlotter (i.e. the communicator and a small antenna) was provided by Telespazio S.p.A., which is using this project as a testbed of the ORBCOMM technology. The software for the satellite communication channel, the information display, and the management of the web sites was developed in ANSI C, so that it could be easily installed on all the devices currently on the market.

The IntraCoastal device was tested by Synthema S.p.A (Italy), and then installed on many small boats in the harbor in Viareggio, Italy. The device is now available on the market.

2. The satellite link

The satellite link considered in this project is part of the ORBCOMM constellation of LEO satellites. ORBCOMM is a wide area, packet switched, two-way data messaging system. It allows the transfer of short messages between mobile user terminals, called *subscriber communicators* (SC), and fixed terrestrial sites, called *ORBCOMM gateways* (OG).

An ORBCOMM gateway consists of one *gateway control center* (GCC) – the facility that houses the computer hardware and software that manages and monitors the message traffic - and one or more *gateway earth stations* (GES). Each GES provides an RF (radio frequency) link between the satellite constellation and the ORBCOMM gateway. ORBCOMM gateways are connected to dial-up circuits, private dedicated lines or networks, such as the Internet and X.25. The main role of an ORBCOMM gateway is to provide message processing and subscriber management for a defined service area. This role includes serving as the "home" for ORBCOMM subscribers as well as providing the interface between the subscriber and the interconnected private and public data network and public switching telephone network. Communication between the subscriber communicators and the ORBCOMM gateways is achieved through a constellation of LEO satellites. Figure 1 shows the ORBCOMM system architecture.

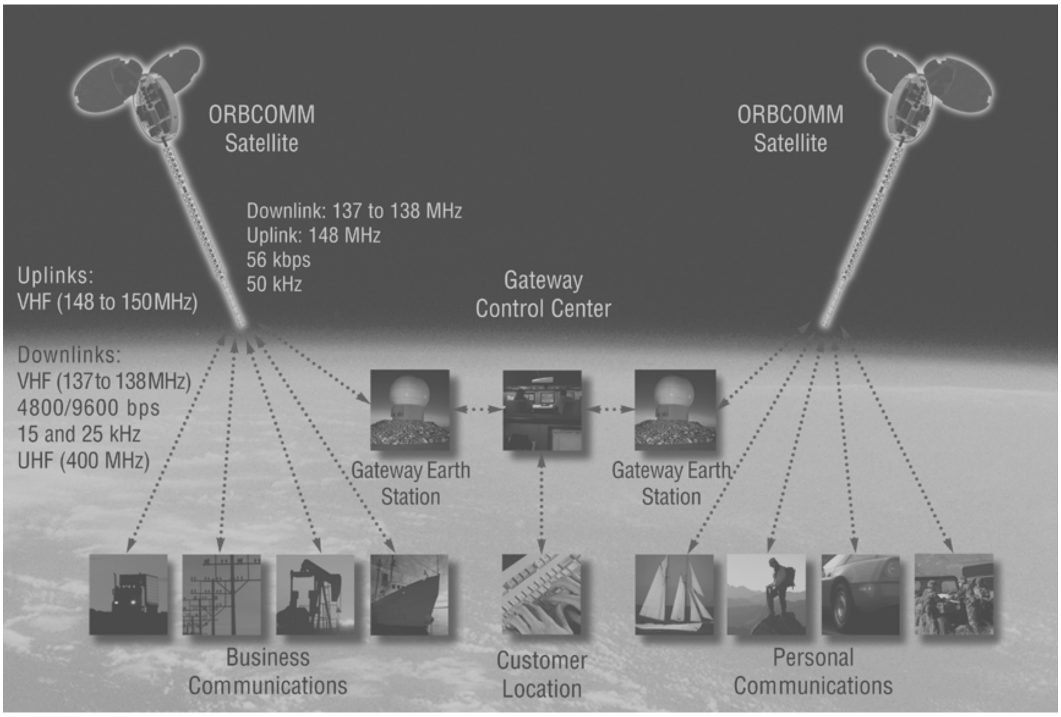

Fig. 1. The ORBCOMM system architecture

A subscriber communicator can send data to the ORBCOMM system when at least one satellite in the constellation is visible. The transfer happens in quasi real-time when a satellite can be seen simultaneously both by the subscriber communicator and by the ORBCOMM gateway, and in delayed time when a satellite is only visible to the subscriber communicator, but not to the gateway.

The ORBCOMM system consists of four operational segments: a) the space segment, which consists of 32 satellites; b) the ground segment, which consists of ORBCOMM gateways the main elements of which include earth stations that send and receive signals, and a message switching system that processes the message traffic; c) a control segment, to monitor and manage the flow of information through the ORBCOMM system; and d) a subscriber segment, which consists of communicators used by ORBCOMM system subscribers to transmit and receive information to/from LEO satellites.

In the ORBCOMM system there is also a *satellite control center* (SCC), which provides satellite operations, monitoring and control. The SCC is located in the *network control center* (NCC), which is responsible for the overall management of the ORBCOMM system and for the SCC management, as well as for controlling the gateway control center for the existing ORBCOMM gateways covering the USA and Canada. The European gateway control center is located in Lario (Italy) at Telespazio S.p.A.. It manages two gateway earth stations, the first one located in southern Italy (Matera) and the second in Maghreb (Morocco).

ORBCOMM provides customers with basic services: packet data transmission, positioning (GPS data) and messaging (email). The system combines both space-based and terrestrial network components, and radio spectrum and multiple access protocols. These support a wide array of wireless data messaging applications and solutions. Some important network characteristics include:

- packet-switching providing dependable, global coverage for point-to-point and point-to-multipoint messaging (unicast and multicast messaging)
- store-and-forward switching to ensure messages are delivered regardless of the user's location or status at the time the message is sent
- reliable access
- message retransmission protection, and acknowledgments
- power saving protocols to increase battery life in subscriber radio equipment.

These services are supported by the ORBCOMM system through four data transmission services: data reports, messages, globalgrams, and commands.

Data report is a basic service element where a subscriber communicator generates a short report that is transmitted via the random access protocol used to access the satellite. A data report may be generated as needed on a periodic basis. It may be sent on request (polled by the ORBCOMM system) or only when there is data to send.

Message is the basic service element whereby a longer sequence of data is transferred to and from a subscriber communicator. Message lengths are typically from 10 to 500 bytes, though longer messages can also be handled. To ensure reliable message transfer, messages are transferred via short packets over the satellite reservation channels, with all packets acknowledged or retransmitted. Messages are then accepted/delivered via public or private data networks. Messages from a subscriber communicator can be originated at the request of the subscriber (random access) or at the request of the network (polled). In both cases the transfer of the packets of a message is in reservation mode.

Globalgram is the basic service element whereby a subscriber communicator sends or receives a single, self-contained data packet from a satellite when that satellite has no access to an ORBCOMM gateway. For an *SC-terminated globalgram*, the relaying satellite stores the data packet and transmits it on request from the destination subscriber communicator. For an *SC-originated globalgram*, the satellite receives the globalgram from the subscriber communicator, acknowledges it, and archives it in the satellite memory until the destination ORBCOMM gateway establishes a contact with that satellite. This allows remote and oceanic areas to be served in “store and forward” mode.

Command is the basic service element whereby short messages consisting of one packet are transmitted to a subscriber communicator. Commands should be signals to initiate actions by devices attached to the subscriber communicator. Acknowledgements may or may not be required.

Communication from a subscriber communicator to the satellite constellation is shared between two different types of communication channels: random access channels and reservation/messaging channels. The network control center controls the number of satellite receivers assigned to these two communication segments. Information exchanged on the random access channels permits either short reports or control packets to be passed between the gateway message switching system (GSS) and the subscriber communicator, or permits the ORBCOMM system to assign a messaging channel to a subscriber communicator for transferring longer message packets.

The ORBCOMM system operates in the interference environment known to exist in the uplink band of 148-150.05 MHz. This band is shared on a worldwide basis with terrestrial communication services. The RF links that connect an ORBCOMM gateway earth station to the satellite use a single 57.6 Kbps uplink and downlink channel using a TDMA (Time Division Multiple Access) protocol. This protocol

permits simultaneous RF links between a single satellite and several gateway earth stations within the satellite footprint, and provides a virtually seamless handover of a satellite from one GES to another under the centralized control of the gateway message switching system. In addition, even large aperture antennas will have relatively wide beam widths at the VHF frequencies being used. This ensures satellite coverage by increasing the percentage of time two or more satellites will be in or near the main beam of the same gateway earth station antenna.
Gateway earth stations to gateway control center channels operate over 56 or 64 Kbps data lines. A typical installation consists of a CSU/DSU with a V.35 interface at both ends. TCP/IP IEEE 802.3 (Ethernet) packet routers, which provide link layer internetworking, connect these interfaces to the gateway control center and gateway earth station facilities. The gateway earth station process communicates with the process of the gateway message switching system by using TCP/IP UDP packets. Table I outlines some important features of the ORBCOMM system.

Optimal message length	from 6 to 1000 bytes
Max globalgram length (in store and forward mode on satellite)	190 bytes
Data rate from user terminal (SC) to satellite	2400 bps
Data rate from satellite to user terminal (SC)	4800 bps
Earth-satellite link frequency	148.00 - 149.90 MHz
Satellite-earth link frequency	137.00 - 138.00 MHz

TABLE I. ORBCOMM system features

3. An overwiev of the ICSCS system

The IntraCoastal Satellite Communication System project aims to develop additional software in a ChartPlotter in order to integrate it with a satellite communication system and to enable it to utilize the Internet facilities. Figure 2 gives an overview of how the system works.

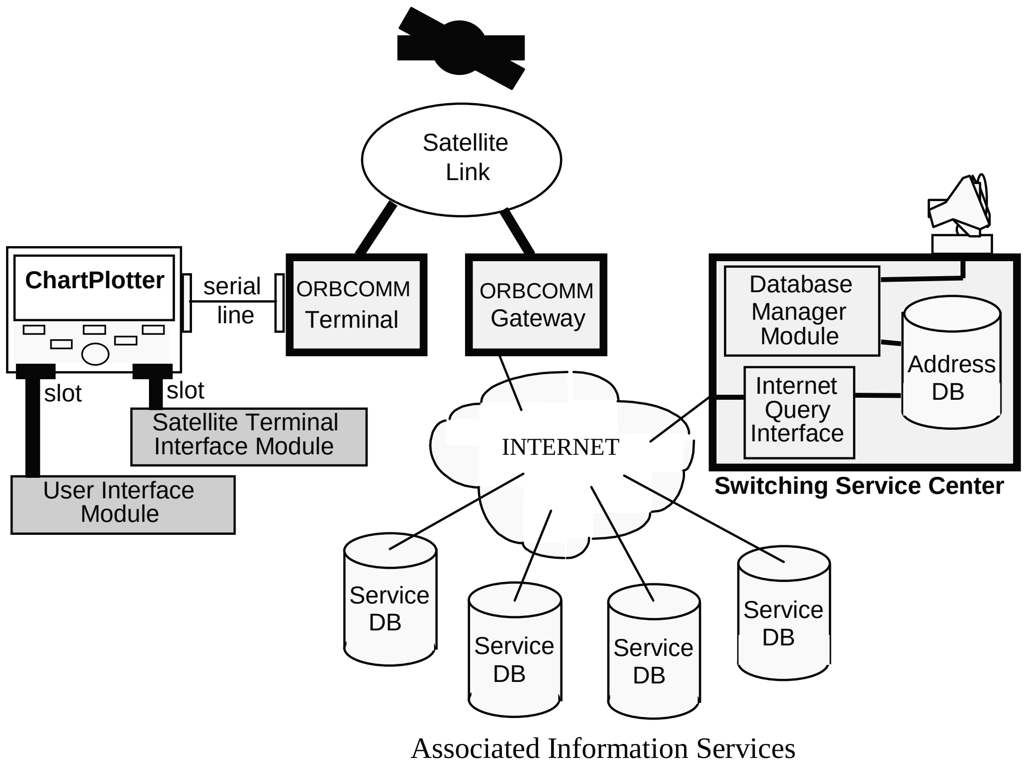

Fig. 2. Overview of the IntraCoastal System

Many Internet sites offer different types of information; for example, big companies already have at their disposal large up to date chart databases (Opera Multimedia, Touring Club Italia, Visula Gis Engineering, Microsoft Corporation, Carin navigation System, EGT NavTech, TELE ATLAS, etc) which they now market via CD-ROM. Complex, selected, and up to date information can now thus be transmitted at low costs even to mobile users on their boats. The overall architecture of the ICSCS is based on the idea of having many Satellite Client Units (SCU) and one Satellite Server Task Set (SSTS) communicating through logical channels and events. Figure 3 shows a black-box view of the system.

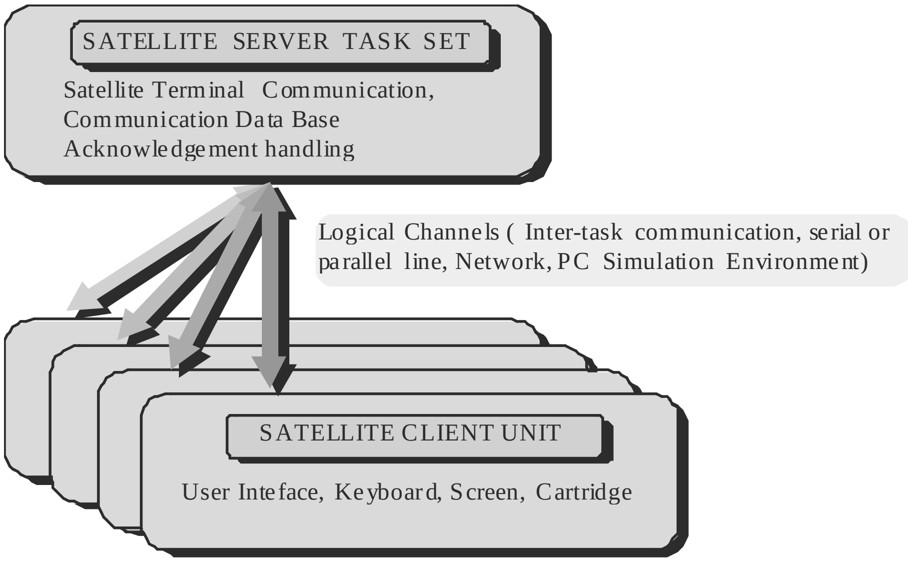

Figure 3. Satellite Server Task Set and Satellite Client Unit. The underlying idea.

The Satellite Server Task Set fully controls the communication of the whole system with the external Satellite Terminal and does not depend on the hosting ChartPlotter hardware and software characteristics. It also incorporates a *Communication Data Base* (CDB) to manage the externally exchanged data. SSTS is also envisaged as a service provider since it performs, on demand, the required acknowledgment operations and data retrieval on the Communication Data Base.

A Satellite Client Unit depends on the hosting ChartPlotter and performs user-defined operations. In the ChartPlotter a real-time kernel is responsible for managing several tasks that interact together. The User Interface Client Task (UICT), which manages the user interface, is the main part of an SCU. The UICT may contain its own Client Data Base to manage display data. It is also responsible for interfacing the hardware needed for the user interaction (LCD, Keyboard, Cartridge, etc.) and sends requests to the SSTS whenever a user action or a particular display operation needs data which is not available in the internal data base. Examples of satellite client units are the cooperating *User Interface Task* and the *Controller Task*, which make up the *UIClient* module of the ChartPlotter. The *User Interface Task* is responsible for the user interface, where most of the code is changed when a customized version is built. It is also the component that interacts with the cartridge reader; and it may have its own data base. The *Controller Task* is responsible for the satellite terminal configuration and maintenance.

A satellite client unit sends one command at a time and expects to receive the data from the SSTS, while taking care of the user interface and possible errors. The SSTS sends a message to an SCU on the basis of a previous command or in case an error has occurred in the system.

Tasks communicate via well defined interfaces, whose definition was part of the project development. The logical channel was implemented by using inter-task message exchange in the final software release, while files were used during the development and are still being used in the maintenance of the product.

Figure 4 describes the overall ICSCS system architecture. Details on the organization of the tasks and their peculiar functions can be found in [7].

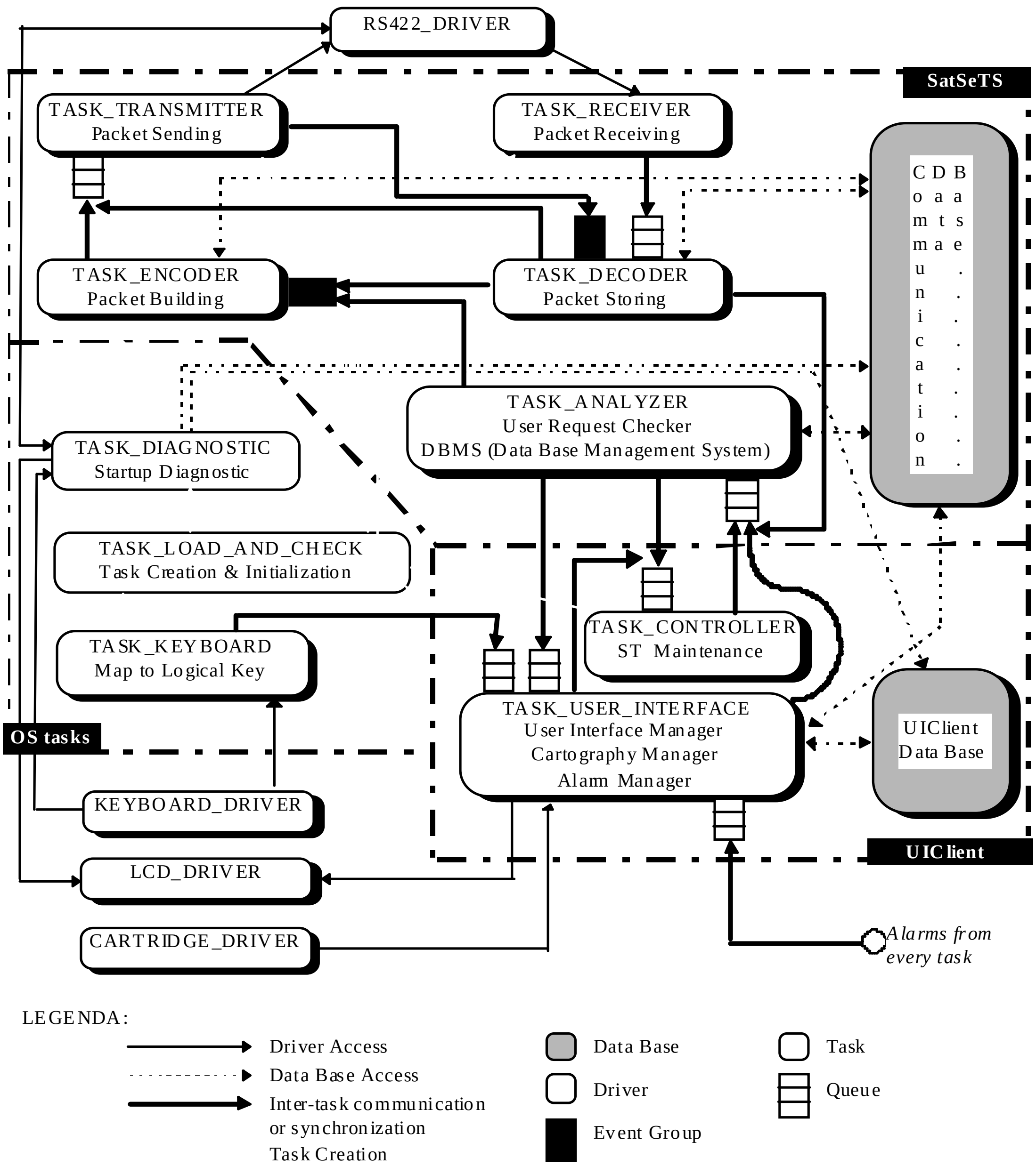

Fig. 4. The ICSCS system architecture

4. Main features of the ICSCS system

Thanks to the newly developed software for accessing the satellite, the ChartPlotter is interactively connected to the ORBCOMM terminal via a serial port. This allows sailors to:

- send and receive short messages to/from any GSM cellular phone;
- send and receive email by using an Internet mail address;
- send faxes;
- navigate in Internet in a filtered way, in order to receive information only through the Synthema web Center, and from other thematic sites, such as the Italian Teletext web pages.

While developing this project, we have set up some thematic web sites, such as a meteorological data base, we have made it possible to send data on requests, and we have created some specific web pages. Moreover, the system has been programmed to receive weather forecast data relevant to the area where the boat is positioned, or any area selected by the user. In fact, thanks to an agreement with the French Meteoconsult, it is possible to receive data from any of the areas shown in Figure 5.

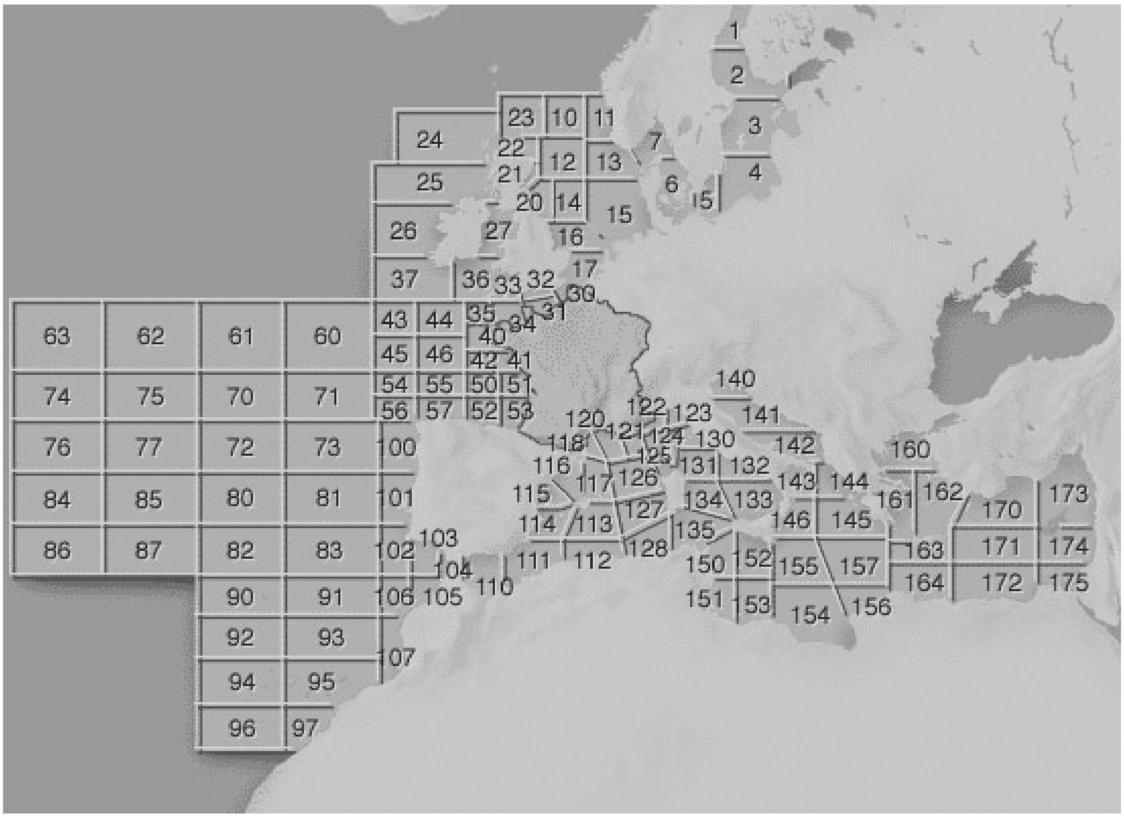

Fig. 5. The areas covered by the weather forecasting service via ICSCS

The forecasts (for a maximum of the following five days) are displayed in text form in a window positioned in the geographical area corresponding to the request. The data displayed are reported in Table II. Data refers to six-hour time intervals (00 – 06, 06 –12, 12 – 18, 18 – 24) for each day of forecasting, and they are updated at least twice in a 24 hour period. The data retrievable from Internet sites is compressed for transmission on satellite, and then decompressed at the ChartPlotter.

wind (direction, force, and gusts)	barometric pressure
sea conditions	sky conditions
waves (direction and height)	rainfall
temperature	reliability of forecasts
visibility	other remarks

TABLE II. Forecast information available

5. Conclusions

We have presented the IntraCoastal Satellite Communicator System which, once integrated with a ChartPlotter, allows a small pleasure boat to be in contact in an interactive way with the coast by means of the ORBCOMM satellite messaging system. It is important to underline that various customized versions of the ICSCS can be produced. Thus an important requirement of the system is software reusability. The architecture we have described is a good compromise between application constraints (i.e. performance and memory size), reusability, and, where possible and appropriate, portability. There are three main benefits from the communication by means of the satellite system: improvement in navigation security, utilization of up to date information, and a wider market for the

ChartPlotter. In fact, ChartPlotter is above all used on pleasure crafts, which means the market will widen even further when it has been integrated with the IntraCoastal Satellite Communication System.

<u>Acknowledgements</u>

The authors wish to thank Navionix S.p.A. for its collaboration during the development of this project.

REFERENCES

[1] ORBCOMM Global, L.P.
"ORBCOMM Application Developers HandBook"
TD-G1-013 Version 1.3 June 21, 1994.

[2] Navionics S.p.A
"ChartPlotter - General Technical Requirements", 1996.

[3] Navionics S.p.A
"CHARTLIB Cartography Library - Reference Manual", 1996.

[4] Advanced RISC Machines Ltd (ARM)
"ARM Software Development Toolkit Reference Manual", 1995.

[5] Navionics S.p.A.
"CLPS7110 – System Functions Reference", 1996.

[6] Navionics S.p.A
"ChartPlotter - General Technical Requirements", 1996.

[7] Nedo Celandroni, Erina Ferro, Francesco Potortì, Giacomo Saviozzi, Marco Boldrini:
"ICSCS: an application of the ORBCOMM satellite system to help the navigation", submitted to the IEEE Communications Magazine.