Combined Use of Italsat and Globalstar Satellite Systems for Monitoring and Disaster Recovery Purposes•

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Abstract

A primary requirement for Disaster Relief Organization, in terms of telecommunications capability, is the independence from the terrestrial networks, whose infrastructures are too liable to failure in case of occurrence of a disaster event. In this scenario, satellite-based systems are surely the most appropriate solution due to their intrinsic terrestrial independent architectures and to their typical flexibility. In this paper a satellite hybrid architecture is proposed, based on the combined use of two satellite systems, operating at Ka-band (Italsat) and at L/C-band (Globalstar), in order to provide both high data rate and low data rate services for emergency communications and environmental monitoring, respectively. The paper describes the architecture and the optimal network solutions, along with terminal characteristics and capability.

1. Introduction

The provision of telecommunications services for Disaster Relief Organizations requires the availability of two main kinds of highly reliable and survivable applications: emergency communications and environmental monitoring. For this reason, especially in areas affected by disasters, the use of alternative systems, independent from terrestrial infrastructures, is strongly required. Satellite systems can be very useful to this aim, because they are not affected by ground infrastructure failures and outages. Several operational satellite systems are able to meet such requirements. These systems mainly use L, C or Ku bands and are mainly dedicated to voice, messaging and localization services. The utilization of Ka band systems can offer larger bandwidths and an enhanced set of services, in conjunction with the utilization of IP common platforms, with simple and easily deployable user terminals. The scope of the present paper is to point out feasibility and advantages of a combined Italsat-Globalstar configuration and its applicability within the context of emergency communication and environmental monitoring services.

1.1 Italsat Global Beam Characteristics

ITALSAT is a satellite based telecommunication system developed by the Italian Space Agency (ASI). Two flight units compose it. The flight 1 was successfully launched in January 1991, while the flight 2 was successfully launched in August 1996. On board there are two Ka payloads for point-point and point-multipoint communications in Ka-band (20/30 GHz) with Italian coverage. The former, having 0,9 Gbit/s capacity, provides a multiple-spot coverage (6

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spot) utilizing multiple-beam antennas. The latter Ka-band communication payload is more traditional, with three (36 MHz) transparent transponders and a global coverage antenna.
For the first payload the satellite access is SS TDMA at 147 Mbit/s with QPSK modulation and regeneration on board. The total capacity is 12000 32 kbit/s circuits (2000 for each spot). The main services offered are voice and data communications.
The second payload provides the global national coverage and offers emergency connections, as proposed in this paper, with disaster-hit areas and TV signal broadcasting. Different types of access and modulation can be utilized with Global Beam GB transponders: TDMA, SCPC or FDMA as far as digital access and QPSK or 8PSK for the modulation scheme. Particularly the 8PSK modulation is well suited for high bit rate transmission operating at 45 Mbit /s (for instance Digital Cinema applications). This payload utilizes the frequency bands 29.5-30 GHz for the up-link and 19.7-20.2 GHz for the downlink. The Italsat F1/F2 Global Beam coverages for G/T and Downlink EIRP are shown in Figure 1 and Figure 2 respectively. These figures are given in terms of 1 dB decrements in respect of 9 or 10.5 dB/K G/T (F1 and F2 respectively) and 50 or 52 dBW EIRP (F1 and F2 respectively) respect to the center beam.

1.2 Globalstar Data Transmission Modes

The Globalstar data terminal can allow two data transmission modes:
- Asynchronous
- Packet Data

The active antenna provided with the Globalstar data terminal is omni directional and it does not depend on the particular outdoor location where the data terminal is located.
In asynchronous mode, the link is established from the Globalstar Modem to a Standard PSTN Modem or to a Remote Access Server located in the MCC; the gateway routes the call on the PSTN to reach the other end, using the switch installed in the gateway itself. This solution is based on the usage of a single satellite modem, ensuring a gross throughput of 9.6 kbit/s and a net throughput of ~7.2 kbit/s.
The alternative to the Asynchronous Mode is to use the Globalstar Modem in Packet Data Mode. In Packet Data Mode the connection is established between the Globalstar Modem and the terrestrial Gateway using a particular connection code. The Gateway has an Interworking Function that is able to establish an IP session assigning an IP address to the modem (in a Static or Dynamic way depending on the application), which can send Traffic Data using protocols determined by the application (TCP or UDP or FTP, etc.). Packets generated at the application level are transmitted to the Gateway and routed on to the MCC via the data link set on PDN or dedicated line. The gross Data Rate is 9.6 kbit/s while the net Data Rate is around 7.5 kbit/s. In Packet Data Mode it is possible to use several Globalstar modems to reach the desired throughput for new generation of Digital Sensors able to transmit 19.2 kbit/s or higher bit rates up to 64 kbit/s.

2 Network Requirements

The proposed communications network consists of four main parts:
- Space segment (Italsat [1] and Globalstar [2]);
- Network Control Center (NCC). It represents the heart of the entire network, handling control and management functions for all terminals involved. The NCC graphical user interface (GUI) is represented by the Network Management System (NMS);
- Communication Control Center (CCC). It manages either the operation of communication services for preventive monitoring or the deployment of emergency communications in case of a disaster;
- Remote Terminals for Emergency Communications. These are composed of fixed or deployable antennas, outdoor units (ODUs) and indoor units (IDUs);

- Remote Terminals for Environmental Monitoring and Risk Prevention. Globalstar Data terminals connected to volcanic and seismic sensors constitute these.

Our reference system architecture is shown in Figure 3.

2.1 Emergency Communication Network Requirements

The main objective for an emergency communication network is to provide basic services during emergencies: voice, localization information, as well as real-time data services and video transmissions at low bit rates. Voice and data compression are performed to make the most effective usage of the satellite power and bandwidth resources. No-real-time data services (e-mail, FTP file transfer, WWW) are virtually provided via the Internet Protocol. Also 2.4-9.6 kbit/s group 3 fax service can be provided, directly connecting terminals to standard fax machines. Videoconference and telemedicine are other potential applications that deserve a particular regard, bringing a new dimension to first aid. All the above services can be easily achieved through the satellite segment.

2.1.1 Service requirements classification

Table 1 shows the set of services and corresponding applications identified, together with the main quality parameters. Service requirements have been defined in terms of::

- Offered bit rate requirements;
- Delivery delay requirements.

BER values are dependent on the particular service and span from 10^{-3} to 10^{-6}. One way end-to-end delay, instead, is fixed for most time-sensitive services, voice and interactive video, belonging to real time classes.

Service	Type	Applications	BER	Max End-to-End Delay
Voice	Delay sensitive	Telephony	10^{-3}	400 ms
Data	No Delay sensitive	Internet Access, Electronic mail, Facsimile, Multicast Video	10^{-5}-10^{-6}	-
Video	Delay sensitive	Tele-medicine, interactive Video	10^{-6}	400 ms

Table 1: Service Requirements

2.1.2 Terminal types and bandwidth requirements

Four different kinds of terminals can be envisaged, one for each specific Disaster Relief body involved during emergency situations:

- Network Control Center (NCC) Master Station;
- Communication Control Center (CCC) fixed terminal;
- Local Office (LO) fixed terminal;
- Operational Teams (OT) transportable and deployable terminal.

The Master station, equipped with a Ka-band antenna of 3.8 m, is the heart of the network for the main control functions relevant to the terminal management, traffic routing and bandwidth assignment. Both CCC and LO sites can be equipped with fixed Ka-band antennas, with a diameter of about 1.5 and 1.2 m, respectively, in order to build up the coordination backbone of the Communication Network. These terminals, due to the Ka-band high gain antennas, can provide data rate up to 2 Mbit/s. Operational Teams OT are equipped with easy transportable and fast deployable Ka band terminals (antenna dish 90 cm) to keep national and regional disaster relief departments constantly updated about the actual environmental status. This terminal must assure a quick set-up time, also for not skilled people.

In consideration that the CCC must be able to coordinate overall disaster recovery operations and to manage all the information for the decision-making process, it must have the highest bandwidth requirement. It has been assumed that at least ten voice circuits, two high-speed data (e-mail, Internet access, Video broadcast/multicast) and four medium-quality video interactive (i.e. H.263) channels should be provided at the CCC site.

The LO's need to be in contact either with the CCC headquarter or with the rescue personnel if a disaster event occurs within its jurisdiction. To this aim, less severe communication requirements can be envisaged: specifically, two voice channels, intermediate-rate data service and two video interactive channels should be sufficient.

Finally the OT flyaway deployable terminals must guarantee at least the provision of six voice channels, moderate-rate data service and one medium-quality video interactive channel.

These requirements are summarized in Table 2, in terms of the minimum data rate each kind of terminal must be able to guarantee.

Terminal type	Voice	Data	Video
CCC	256	512	1024
LO	128	256	512
OT	64	64	64

Table 2: Bit rate requirements (kbit/s)

All the terminals are provided with a common IP interface in order to carry out multiple-service communications interfacing different typologies of user terminal. VoIP PBX carries out voice services compliant with ITU standards H323 and G.723/G.728. OT terminals must be equipped with laptop computer with installed videoconference and media players applications in order to provide unicast and multicast transmission respectively (i.e. H.263 for video interactive sessions and MPEG-4 for multicast video transmission). As the traffic growth exceeds the initial sizing during disaster events, additional carriers can be easily added under the NCC control.

2.2 Environmental Monitoring Network Requirements

The main scenario for Environmental Monitoring is to control the risky areas in order to prevent emergency situations. In fact, it is important to provide connections between the sensors network and the Disaster Relief Organization MCC (Monitoring Control Center) at variable bit rate in order to analyze all the history before and after disastrous events.

A second scenario for Disaster Relief Organizations is to directly monitor areas involved in the disaster, using mobile deployable sensors. In this case stationary sensors are able to calculate approximate position of the event (an earthquake for example).

The obtained data for both scenarios can be sent in real time using the Globalstar system. In particular data features offered by Globalstar can be used to interface either old generation of sensors at low data rate (9.6 kbit/s) or new generation of Digital Triaxial Sensors reaching higher data rates (19.2 kbit/s) as described in Para 1.2.

3 Network and system architecture

In this section the proposed solution for Emergency Communications and Monitoring Network are provided.

3.1 Emergency Communication Architecture

A mixed star/mesh network architecture is recommended considering that the access to the terrestrial communication infrastructure can be achieved through the NCC Master Station and CCC while the transportable and deployable terminals can be rapidly set in the area affected by a disaster. The Network Control Center NCC must be linked with the Communication Control Center CCC managed by the Disaster Relief Organization headquarters. The CCC has to handle the set of services required for the specific emergency situation.

The control network architecture is based on, bandwidth assignment and terminal management capabilities performed by the NCC. In addition to this feature, the star/mesh network capability allows the CCC to be connected to the operational teams (OT) as well as to the Local Office (LO) terminals, responsible for the affected area. This architecture allows an independency from terrestrial infrastructure between the CCC and the NCC resulting in a more affordable and reliable network. For redundancy routing terrestrial connection between CCC and NCC shall be also considered.

Furthermore to achieve fault protection, a redundant satellite network configuration has been considered, as shown in Figure 4. The NCC links all traffic terminals of the network through the Master Station (MS), which must reside at the same site of the network control center. Both can be backed up with the utilization of an Alternate Master Station (AMS) and another NCC in a locally or geographically redundant configuration, illustrated in Figure 5. The former envisages a back up at RF subsystem level, without the need for further master stations, while the latter consists in a more reliable and expensive back up at antenna level.

The Italsat communication system is proposed to operate with its Global Beam at nx2 Mbit/s in order to provide, on a common IP interface, multiple communication services (Figure 6). The proposed emergency communication system makes use of bandwidth-on-demand technologies (BoD) and TDMA/DAMA access, to optimize the required space segment.

3.1.1 Network Control Center (NCC)/Network Management System (NMS) administrative features

The main NCC/NMS management functions are:

- Configuration management
- Capacity/Bandwidth management
- Acquisition/Synchronization control
- Performance management
- Alarm management
- Security management
- Billing - Accounting

The NCC functionality can be pre-assigned to every TDMA/DAMA station involved in the overall network. Once its appropriate site has been chosen, a Master Station (MS) is co-located there to monitor all of the traffic terminals in the system. MS is directly connected to the NCC through an Ethernet link. This primary station is provided with a large Ka antenna (approximately 3.8m-diameter).

A local back-up facility, as shown in Figure 7, is certainly preferable to a geographically redundancy. This choice has the drawback of requiring the implementation of an appropriate communication link between the NCC itself and the Disaster Relief Organization headquarter, where all the network and communication information are conveyed into the CCC.

3.1.2 Ka band system dimensioning

The link calculations provided in this paragraph consider the Italsat Global beam utilization even though the next generation satellites (early 2002) with onboard Ka-band payloads can provide efficient alternatives to the Italsat system. Based on these characteristics, similar to the future satellite generation with Ka payload onboard, link budget calculations have been carried out based on the following assumptions:

- NCC Master antenna: 3.8 m diameter;
- Satellite Access: TDMA/DAMA;
- Fixed terminal (LO) antenna: 1.5 m diameter;
- Flyaway Deployable Terminal (OT): 90 cm diameter antenna, SSPA 3 Watts;
- TDMA bit rate: up to 2048 kbit/s;

- Network topology: Star/Mesh;
- Link Availability: 99,97 % with a BER better than 10^{-7}.

The link calculations between the NCC Master Antenna and an OT deployable terminal operating at 1024 kbit/s TDMA carrier are shown in Table 3.

3.2 Environmental Monitoring Architecture

The general architecture using Globalstar is shown in Figure 8. The data generated from remote sensors are sent to the Monitoring Control Center (MCC), passing through the Globalstar Gateway. This architecture contains the following subsystems:

- The Sensors and the Globalstar data modems used as DCE;
- The Globalstar System;
- Data Link;
- The MCC.

The MCC receives the data revealed by remote sensors and analyses these data for Natural Disasters prevention. Signals are plotted directly on thermal paper, or displayed on LCD screens. The Data Link is used to transport information from the Gateway to the MCC. This link can be set in two different manners depending on the data transmission mode used. In case of asynchronous mode, the data link can be set via the PSTN (Public Switched Telephone Network), while for Packet mode the PDN (Packet Data Network) is used.

4 Terminals

The NCC Ka Antenna (courtesy of Vertex) and a typical Ka flyaway deployable terminal (courtesy of Swe Dish) are shown respectively in Figure 9 and Figure 10. In Figure 11 the multi channel Globalstar modem and its omni directional antenna are shown.

5 Conclusions

To meet both disaster recovery and environmental monitoring requirements in terms of telecommunication needs a satellite-based architecture is surely a very robust solution. In this paper we proposed innovative system architecture based on the combined use of two different satellite systems to satisfy different data rates and service requirements.

References

[1] F. Marconicchio, G. Morelli, F. Valdoni, *ITALSAT, an Advanced on Board Processing Satellite Communication System*, 14th AIAA, Washington, DC, Mar. 1992, pp. 832-841.

[2] R. A. Wiedeman, A. J. Viterbi, *The Globalstar Mobile Satellite System for worldwide Personal Communications*, Proc. of 3rd Int. Mobile Satellite Conference (IMSC '93), June 1993, pp. 285-290.

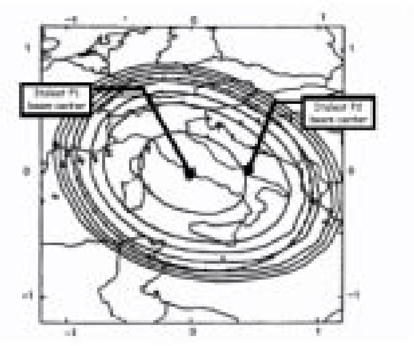

Figure 1: Italsat up link coverage (G/T)

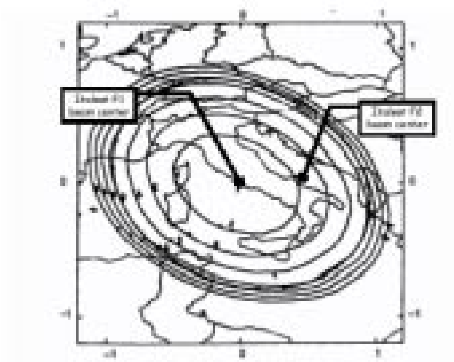

Figure 2: Italsat down link coverage (EIRP)

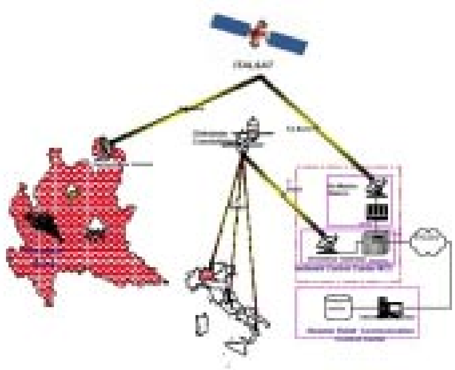

Figure 3: Overall Architecture

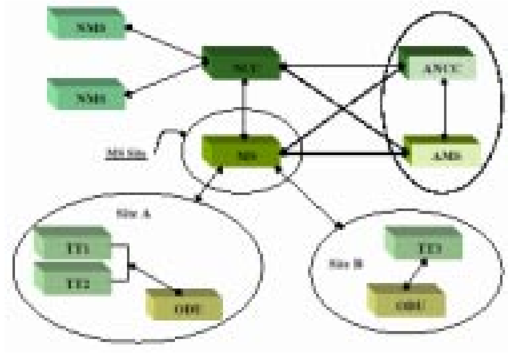

Figure 4: Redundant network configuration

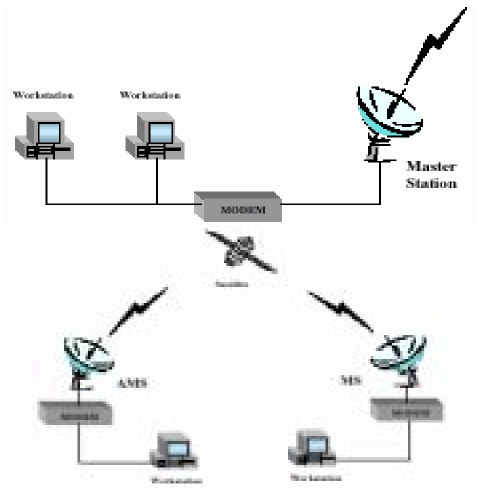

Figure 5: Locally and Geographically Redundant Configuration

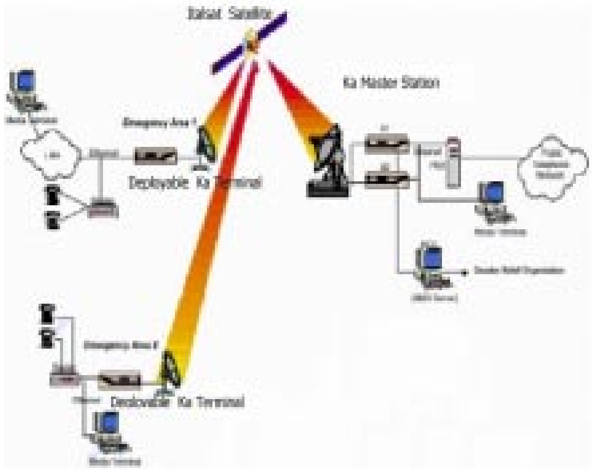

Figure 6: Ka band Communication Network

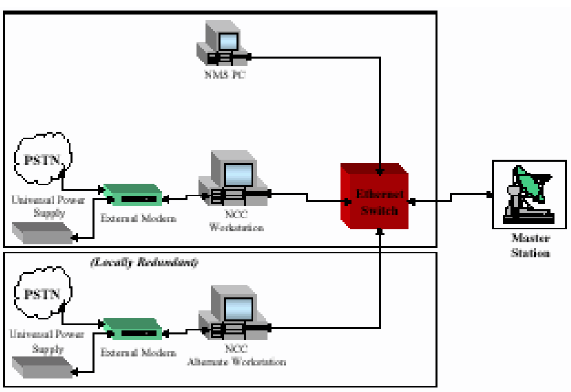

Figure 7: Locally back-up facility

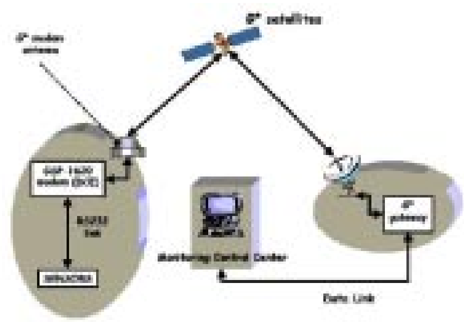

Figure 8: Environmental Monitoring Architecture

Figure 9: NCC Ka Antenna 3.8 m (courtesy of Vertex)

Figure 10: Ka Flyaway Terminal (courtesy of Swe Dish)

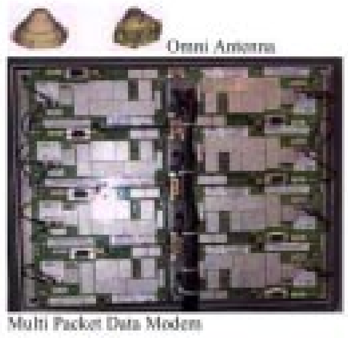

Figure 11: Globalstar Multi Channel PDM and Omni Antenna

Link Characteristics	**Ka Master>Ka VSAT**		**Ka VSAT>Ka Master**	
Up-link Free Space Loss	213.50	dB	213.57	dB
Down-link Free Space Loss	210.05	dB	209.98	dB
Up-link Atmospheric Loss	0.4	dB	0.4	dB
Down-link Atmospheric Loss	0.2	dB	0.2	dB
Up-link Rain Attenuation	0.0	dB	7.7	dB
Down-link Rain Attenuation	3.2	dB	0.0	dB
Source Bit Rate	**1.024E+06**	**bit/s**	**1.024E+06**	**bit/s**
Convolutional Coding Rate	1/2		1/2	
Reed Solomon rate	236/216		236/216	
Coded Bit Rate	**2.238E+06**	**bit/s**	**2.238E+06**	**bit/s**
Symbol Rate	**1.119E+06**	**Baud/s**	**1.12E+06**	**Baud/s**
Channel Bandwidth	**1,566.341**	**Hz**	**1,566.341**	**Hz**
Uplink Characteristics	**Ka Master>Ka VSAT**		**Ka VSAT>Ka Master**	
Carrier Tx Power	**0.2**	**Watt**	**3.00**	**Watt**
Carrier Tx Power dBW	-6.99	dBW	4.77	dBW
HPA Feed Losses	2	dB	1	dB
Earth Station Total Output Back-Off	6.0	dB	0.5	dB
Antenna Efficiency	0.70		0.65	
Antenna Diameter	**3.8**	**m**	**0.9**	**m**
Antenna Gain	59.99	dBi	47.16	dBi
EIRP per channel	**51**	**dBW**	**50.93**	**dBW**
Satellite Characteristics	**Ka Master>Ka VSAT**		**Ka VSAT>Ka Master**	
Satellite G/T	10.5	dB/K	10.5	dB/K
Satellite EIRP towards E/S	52.0	dBW	52.0	dBW
Transponder bandwidth	36	MHz	36	MHz
EIRP per channel	34,6	dBW	26.8	dBW
Equivalent bandwidth	1641.21	KHz	1566.34	KHz
Allocated Bandwidth	**1,641**	**KHz**	**1,566**	**KHz**
Downlink Characteristics	**Ka Master>Ka VSAT**		**Ka VSAT>Ka Master**	
System Noise Temperature (dark sky)	489	K	304	K
Antenna Efficiency	0.65		0.70	
Antenna Gain	43.6	dBi	56.5	dBi
G/T (dark sky)	16.2	dB/K	31.1	dB/K
Feed/LNA losses	0.5	dB	0.5	dB
Link Budget Results	**Ka Master>Ka VSAT**		**Ka VSAT>Ka Master**	
(C/No) Up-link	75.7	dBHz	66.0	dBHz
(C/No) Down-link	65.8	dBHz	75.9	dBHz
(C/Io) Satellite	91.9	dBHz	91.9	dBHz
(C/I) Satellite	30.0	dB	30.0	dB
(C/No) Total	65.4	dBHz	65.5	dBHz
(C/N) Total	3.4	dB	3.6	dB
Eb/No	5.2	dB	5.4	dB
Required Eb/No (BER 1E-06)	4.2	dB	4.2	dB
System Margin	**1**	**dB**	**1.2**	**dB**

Table 3: 90 cm/1024 kbit/s terminal link calculation