Multiple Alert Message Encapsulation Protocol: Standardization and Experimental Activities

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ABSTRACT

When a disaster occurs, the delivery of alerts to the population is a key element to prevent the loss of life and property and to increase the efficiency of precautionary measures. Advanced information and communication technologies enable new channels to reach people (e.g. mobile phones, Internet connected devices, smart TVs). Satellite systems represent an unique and efficient solution for delivering one-to-many messages, but in order to reach the maximum number of people in the target area with a reliable information service, a specific technical solution is needed. This paper gives an overview of an on-going ETSI standardization activity devoted to the definition of a Multiple Alert Message Encapsulation protocol over Satellite (MAMES) for the delivery of alerts to the population in the case of a disaster. Moreover, an experimental activity (the SatAlert experiment) for testing and validating the MAMES applicability to Low Earth Orbit (LEO) satellites is presented.

Keywords

Satellite, Emergency Communications, Encapsulation Protocol, Experimental Activity, Standardization, ETSI.

INTRODUCTION

The provision of an effective alerting service relies on the timely and reliable distribution of alert messages to the intended audience of the incident affected area. Both the integration of already existing alerting systems/technologies and an efficient transport of different alert message formats need to be considered in the provisioning of an alerting service.

Focusing on the resilience of satellite systems to terrestrial disasters and on their intrinsic capabilities of distributing information over a large area, a growing number of different standardization activities [1] [2] and research projects addresses the topic of emergency services provided by satellite systems [3] [4]. Particular attention is devoted to the development of integrated alerting systems and the exploitation of different communication channels, including global satellite navigation systems [5][6].

Starting from these considerations and from a review of the large variety of current alerting technologies and of the capabilities and limitations of satellite communication and navigation systems [7], the ETSI Specialist Task Force 473 (proposed by the SES-SatEC Working Group in accordance with [8]) has been developing a multiple alert message encapsulation protocol for transporting alert messages over satellite links (MAMES). Moreover, an experimental activity which involves the framing and transmission (on the alerter side) and reception and de-framing (on the user side) of a MAMES Message, will be carried out in the framework of the D-SAT Mission (led by D-Orbit) with the aim to evaluate and demonstrate MAMES capabilities in the context of LEO satellites.

The paper is organized as follows. After a brief overview of the MAMES objectives and operations, two main sections follow: The first one is dedicated to the MAMES protocol definition, including MAMES frame description and MAMES integration into Satcom/SatNav systems; the second one presents the SatAlert experiment. Finally, conclusions are drawn.

MAMES OVERVIEW: OBJECTIVE AND OPERATION

Taking into account the heterogeneity of Alerting Systems and the need for providing a flexible encapsulation scheme for different alert messages, the MAMES main objective is the definition of an extensible multiple alert message encapsulation protocol for alert messages transport over satellite links. In detail MAMES aims to:

- provide the means for encapsulating one or more differently formatted alert messages (e.g. CAP [Common Alert Protocol] [9], unstructured text, image, paging protocols, etc.);
- define additional (optional) functions for service extension, enabling the adaption towards a large variety of situations (including network resources limited context);
- integrate the defined protocol with the main telecommunication satellite architectures (Galileo Services, DVB-Suite, any IP-based satellite access, etc.) and with already existing terrestrial networks.

The MAMES basic alerting operation modes are shown in Figure 1, where the main involved entities and exchanged messages are highlighted. Focusing on the MAMES Network, the entities responsible for initiating and terminating the MAMES Protocol are the MAMES Alert Provider and the MAMES Alert Receiver. Moreover two MAMES operative modes are defined:

- *Direct MAMES Alerting.* The MAMES Alert Receiver is inside the satellite user segment and directly receives MAMES Messages.
- *Indirect MAMES Alerting.* The MAMES Alert Receiver is outside the satellite user segment and therefore MAMES Messages have to be forwarded to the MAMES Alert Receiver to be decoded.

As depicted in Figure 1, an Alert Protocol Message is sent by the Alert Issuer to the MAMES Alert Provider, an entity that is in charge of encapsulating the received Alert Protocol Message and distributing the generated MAMES Message using its associated satellite communication/navigation network. In the Direct MAMES Alerting case, the MAMES Message is directly received by the satellite terminal co-located with the MAMES Receiver, while in the Indirect MAMES Alerting case the satellite terminal receives the MAMES Message and forwards it to the MAMES Receiver. In both cases the MAMES Receiver decapsulates the MAMES Message and sends it to the Alerting Device for Alert Protocol Message content interpretation and rendering.

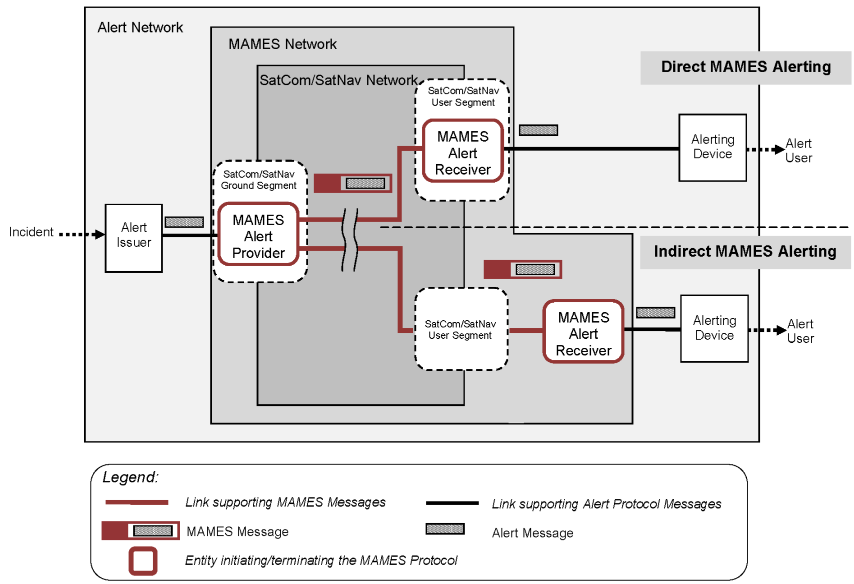

Figure 1. Overview of MAMES Operation

STANDARDIZATION ACTIVITY: MAMES PROTOCOL

MAMES Messages Design

In order to achieve the previously described MAMES objectives, MAMES Messages are characterized by an extensible structure for the encapsulation of multiple alert messages and the adaptation to specific crisis situations.

Figure 2 depicts the general structure of a MAMES Frame and the adopted notation. A MAMES Frame is composed of:

- a set of MAMES Headers (Mandatory Header (MH), Extension Headers (EHs) and Alert Message Headers (AMHs));
- a MAMES Payload, comprising a concatenation of Alert Protocol Messages (zero, one or multiple Alert Protocol Messages).

An Alert Protocol Message, or simply Alert Message (AM), can be represented by a message formatted according to an advanced Alert Protocol (e.g. CAP, with several dedicated message types), or a simple message conforming to an arbitrary Internet Media Type.

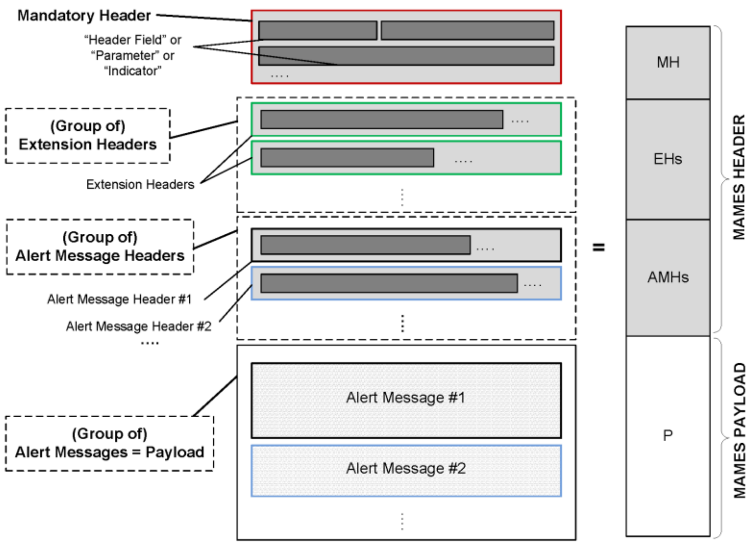

Figure 2. MAMES Frame Structure

The main features of the MAMES Headers are reported in Table 1.

MAMES Header	Main Features
Mandatory Header (MH)	▪ mandatory; ▪ fixed length; ▪ pertains to the entire MAMES Message.
Extension Headers (EHs)	▪ optional ▪ enhance the MAMES Frame by adding additional features (e.g. a validity window, integrity protection, authentication, etc.); ▪ pertain to the entire MAMES Message.
Alert Message Headers (AMHs)	▪ each AMH pertains only to a corresponding Alert Message contained in the MAMES Payload and specifies the type, language and length of the AM it refers to.

Table 1. MAMES Message Headers

Five types of MAMES Messages are defined:

- MAMES ALERT - enables the encapsulation of a single or multiple Alert Protocol Messages that need to be delivered to the Alerting Device.
- Ultra-short MAMES ALERT - represents the shortest MAMES Message defined for the transmission of MAMES Messages over narrowband satellite channels (e.g. MAMES over GNSS systems).
- MAMES UPDATE - contains updated information for a previously transmitted MAMES Message.
- MAMES CANCEL - declares a previously transmitted MAMES Message as obsolete, handling MAMES errors.
- MAMES ACK – provides an acknowledgement at MAMES level for a correctly received MAMES Message.

Upon reception of an Alert Message issued by an Alert Issuer, the MAMES Alert Provider generates a MAMES ALERT Frame, taking into account the Alert Issuer‘s indications, the type of Alert Protocol according to which the Alert Message is formatted and the available network resources for the transmission of MAMES Messages.

The MAMES ALERT represents the primary MAMES Message used for the encapsulation of different Alert Messages, including all specific message types that an advanced Alert Protocol may support (e.g. CAP update/cancellation/error messages). Additionally, if the Alert Protocol does not support such (update/cancellation) messages, the MAMES UPDATE message can be used to update or cancel a previously sent MAMES Message.

The flexibility of the MAMES Frame structure (Figure 2) and the different MAMES Frame types enable the MAMES Alert Provider to dynamically adapt the MAMES Message composition to the available bandwidth of the communication network used for the distribution of MAMES Messages.

In detail, as better described in the following, particular attention is also devoted to the possibility of transmitting MAMES Messages in networks with very limited resources, such as the satellite navigation systems (e.g. by employing certain Galileo navigation message types). This is achieved by using the Ultra-short MAMES ALERT, which can be seen as a radical solution that allows the alert notification (only essential information is carried) even in critical network conditions and in exceptional cases.

While the Ultra-short MAMES ALERT is only 13-Byte long, the size of a MAMES ALERT (or UPDATE) depends on the included EHs and the size of the AMs encapsulated in the payload. Since the protocol relies on fragmentation mechanisms provided by the underlying layers, the maximum size of the overall frame is conditioned by the constraints of the technologies used for MAMES Messages distribution. Moreover, both forward error control and ACK congestion control mechanisms of underlying layers are considered to avoid the reception of corrupted MAMES Messages and MAMES ACK congestion on the return link.

MAMES integration into SatCom/SatNav Entities

MAMES has been designed to operate over arbitrary telecommunications networks, including terrestrial fixed and mobile networks that provide at least appropriate OSI Layer 1 and Layer 2 technologies. Since the focus of this work is mainly on satellite-based networks, MAMES integration into the following types of networks was considered in detail: (1) Broadcast fixed and mobile satellite systems; (2) Bidirectional fixed and mobile satellite systems; and (3) Satellite-based navigation systems. To illustrate the principles of MAMES integration, one representative example is discussed here, see Figure 3.

The figure shows how MAMES is to be integrated into a broadcast fixed satellite system. The regular, i.e. non-alert related service domain (denoted "Broadcast Service") is depicted in the upper half of the figure, while the alert/MAMES related domain is depicted in the lower half. As can be seen, the MAMES Provider is considered to be part of the Ground Segment, while the MAMES Receiver may be inside (Scenario A) or outside (Scenario B) the User Segment. In the latter case, the MAMES Receiver is connected to the Fixed Satellite Terminal via a network, called the Alert Intermediary System. Furthermore, as can also be seen in the figure, the Alerting Device may either be directly attached to the MAMES Receiver (sub-scenarios A1 and B1) or also interconnected via an Alert Intermediary System (sub-scenarios A2 and B2).

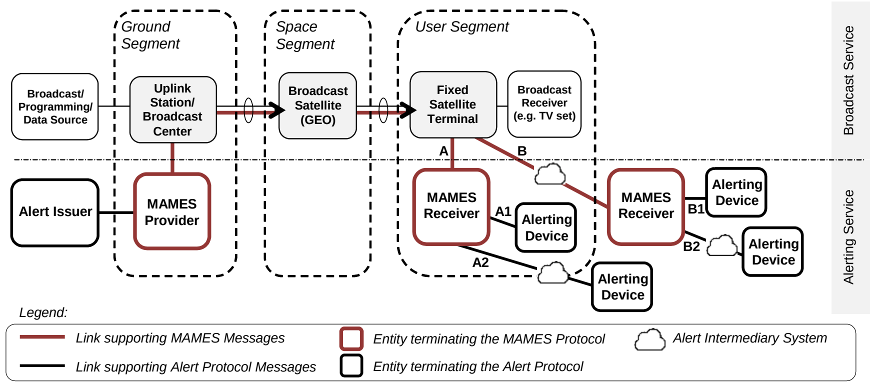

Figure 3: MAMES integration into a broadcast fixed satellite system

As regards the integration of MAMES into the other types of networks mentioned earlier in this section, analogous principles apply. For example, when considering the integration of MAMES into broadcast mobile satellite networks, the SatCom network entities in the User Segment of Figure 3 need to be replaced by the appropriate mobile entities (mobile satellite terminal and display/output module); the other SatCom entities remain unchanged. (Note, however, that different transmission technologies are of course involved in the two systems). The alert and MAMES-specific entities and their interconnections (lower portion in the figure) also remain unchanged.

Similarly, when considering the integration of MAMES into bidirectional (fixed or mobile) satellite networks, only the SatCom-specific entities (upper portion) will change accordingly, while the alert and MAMES-specific entities and their interconnections will again remain unchanged. The important difference between bidirectional and broadcast systems lies in the availability of a return channel in the latter systems, which can be used to carry MAMES ACK messages.

As regards the integration of MAMES into SatNav systems (Galileo and EGNOS were considered in the present work), the configuration of the alert and MAMES-specific entities will again be the same as presented above. The MAMES Provider will interconnect to the appropriate SatNav ground segment facility, which may be the facility that generates the (regular) navigation message, or the respective uplink station. In the User Segment, the MAMES Receiver is interconnected to the SatNav Receiver, again in analogy to the SatCom case.

Based on the considered satellite systems and the *Direct* or *Indirect MAMES Alerting* operative modes, the Alerting Devices range from simple devices such as sirens, to advanced devices such as smartphones; Alerting Devices may also be traditional TV sets, radio and multimedia receivers, VSAT terminals, and mobile satellite and terrestrial terminals. Focusing on sub-scenarios A1 and B1, to enable the different types of Alerting Devices to consume MAMES Messages, a MAMES Agent is required. This is represented by a software module that executes the MAMES Protocol (parsing of the received MAMES Frame, including decapsulation of the contained AMs). It can be directly integrated in the considered Alerting Device or implemented in a dedicated HW directly attached to the Alerting Device.

An application example is provided in the following: A Broadcast Fixed Satellite System is used to distribute MAMES Messages containing a CAP-encoded severe-storm and high-tide alert for a certain coastal region. The transmission is received by MAMES-capable satellite TV receivers installed on the roofs of shopping malls, large office buildings, government buildings and in some restaurants. Since the receiver-side equipment understands CAP, the alert content is immediately presented on the connected TV screens and (large) public displays of the Notification Area, allowing viewers to act accordingly.

EXPERIMENTAL ACTIVITY: SATALERT EXPERIMENT

SatAlert Experiment Objectives

During the second semester of 2015, CNIT will carry out, in the framework of the D-SAT Mission, a scientific experiment, named “SatAlert”, on a 3U cubesat thanks to the support of the D-Orbit company. The experiment’s main objectives are:

- to prove the applicability of direct LEO satellite reception of MAMES messages by satellite terminals;
- to validate the MAMES mandatory features and some of the optional features provided by the MAMES Extension Headers;
- to evaluate the on-board processing load on the ARM-based host processor for the capture, processing and relaying of MAMES alert envelopes;
- to provide a demonstrated proof-of-concept of a low-cost on-demand satellite alerting system.

SatAlert Experiment Description

The SatAlert experiment aims to verify the transmission setup of MAMES messages from the MAMES Alert Provider to the MAMES Alert Receiver. The experiment consists in the generation and transmission of a MAMES ALERT message, from an Earth station to satellite, which will process and broadcast the received message back to Earth. In order to validate the process, two separate Earth stations for satellite beacon tracking will be implemented. The main ground station will be located in Lomazzo (Italy) at D-Orbit’s premises and it will be responsible for the generation and transmission of the MAMES Messages and also for their reception and decapsulation; while a second ground station located in Florence (Italy) will only receive and decapsulate MAMES messages (Figure 4).

Satellite transmission will be carried out by an isotropic antenna at 437,5 MHz with a 100 kHz bandwidth. According to the international agreements on non-interference regulated by no. 4.4 of the ITU (International Telecommunication Union) Radio Regulations [10], MAMES broadcast transmission will be activated only during the available visibility windows in order not to cause harmful interference to other satellite and terrestrial services.

The satellite will cover an orbital trajectory similar to the one of the International Space Station (ISS), with the following specifications:

- Visibility windows/day: 3 or 4, depending on the specific day
- Visibility period: 480 s
- Transmission sessions: 8

- Session transmission period: 10 s
- Session idle period: 50 s

In the SatAlert experiment, data transmission will be possible both in uplink (Earth-to-Satellite) and downlink (Satellite-to-Earth), as follows:

1. Earth-to-Satellite link: during the visibility period, the Earth station sends to the satellite a MAMES message (maximum size of 4 kB) that will be stored in the satellite On-Board Computer memory.
2. Satellite-to-Earth link: the MAMES message, previously stored on the satellite, will be broadcast by the satellite upon reception of a proper trigger command sent by the Earth station.

In addition to this, an on-board processing of the uploaded messages will be carried out in order to verify the messages' validity and priority before their eventual transmission.

It is worth highlighting that the maximum size of 4 kB depends on the resources allocated for the SatAlert experiment in the framework of the D-SAT Mission. However this size allows the transmission of different types of MAMES Messages, including Ultra-short MAMES ALERTs and MAMES ALERTs encapsulating a short CAP and a short text.

In order to improve the validation level of the SatAlert experiment, amateur radio communities will be involved in the reception and decapsulation of the MAMES message.

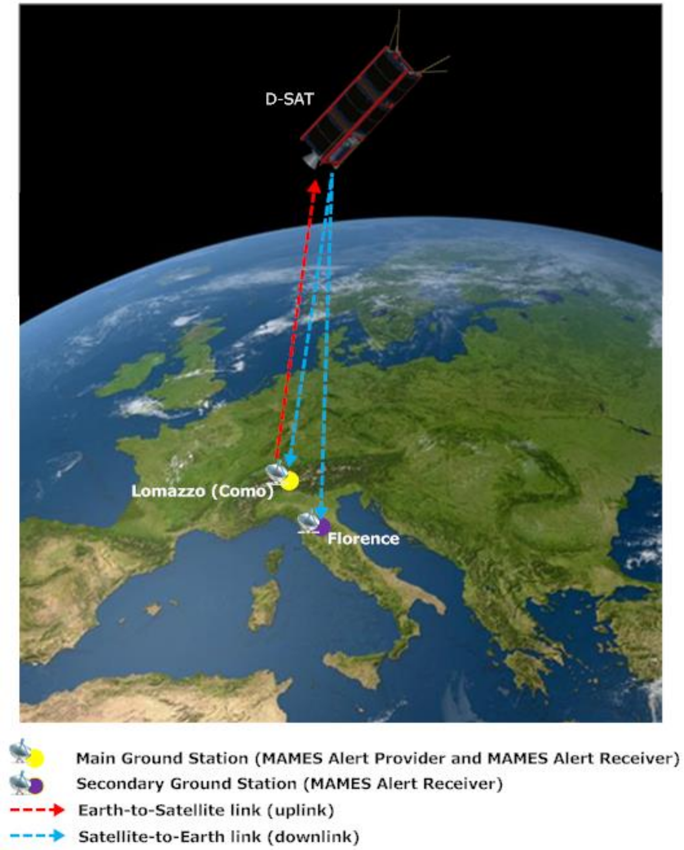

Figure 4: SatAlert Experiment Overview

Overview of the HW and SW components

Satellite component: D-SAT

The platform for the in-orbit validation of the MAMES Protocol will be provided by D-Orbit. D-Orbit is designing and manufacturing D-SAT, a 3-Unit cubesat that will be launched in the fourth quarter of 2015, and will be released into LEO from the ISS (International Space Station). D-Sat will be composed of a satellite platform, fitted in a 1-Unit envelope, to function as the hosting satellite, and by an independent 2-Unit Decommissioning Device, featuring a fully-functional propulsive stage with all the safety provisions required by the international standards for safety.

D-Sat's satellite platform is equipped with a complete telecommunication subsystem in order to provide a solid and dependable basis for the SatAlert Experiment. This is composed by a turnstile omnidirectional antenna and a UHF (Ultra High Frequency) transceiver module. The transceiver uses a GMSK (Gaussian Minimum-Shift Keying) modulation at a baud rate of 4800 bps: this guarantees a sufficient bandwidth for both telemetry and the service data link. The data are coded with a Reed-Solomon coding to reduce the probability of error and therefore increasing the reliability of the communication link. The transmitted power is 1 Watt, which is more than enough for guaranteeing a stable reception using a YAGI antenna on ground with 12 dBi gain, as depicted in link budget in Table 2.

D-SAT Link Budget		
Link Budget Parameters	**Value**	**Unit**
Satellite Range	768,63	km
Elevation Angle	30	deg
Frequency	437	MHz
Transmission Rate	4800	b/s
Band width	10000	Hz
Spacecraft:		
Output Power$_{TRX}$	1	W
Antenna Gain$_{TRX}$	1,4	dBi
Line Losses$_{TRX}$	-1,18	dB
Spacecraft Pointing Loss$_{TRX}$	-1	dB
Downlink Path:		
PathLoss	-142,97	dB
Polarization Loss	-3	dB
Atmospheric Losses	-2,2	dB
Ground Station:		
Antenna Gain $_{RX}$	12	dBi
LNA Gain $_{RX}$	16	dB
In-Line Losses $_{RX}$	-3,1	dB
System Noise Temperature	309,97	K
Figure of Merit, (G/T) $_{RX}$	-12,91	dB/K
Link Budget Results	**Value**	**Unit**
Received Isotropic Power	-118,95	dBm
C/N	19,18	dB
Required C/N	15	dB
Margin C/N	4.18	dB
Eb/No	22,37	dB
Required Eb/No (BER = 10^{-5})	13.5	dB
Margin Eb/No	8.87	dB

Table 2. Example of D-SAT Downlink Budget

The telecommunication subsystem is supported by the satellite on-board computer, which runs a real-time operating system with a high degree of reliability. Among the different functions of the operating system there are the SatAlert Experiment task (SAE) and the Interface SatAlert Experiment task (ISAE), which are better described in the following subsection.

In addition to the telecommunication subsystem and the on-board computer, the satellite is equipped with an electrical power system, an attitude determination and control system, a satellite navigation system, and with a solid rocket motor including a safe ignition system. This latter subsystem, referred as D-Orbit Decommissioning Device, will demonstrate in orbit D-Orbit's technology capabilities. After two months of D-Sat's operations and validation of the MAMES Protocol, the D-Orbit Decommissioning Device will be activated, thus removing D-Sat from its operational orbit and disposing it into the atmosphere where it will burn over an uninhabited region of the Earth. D-Sat will be the first satellite ever to be actively de-orbited in a quick, safe, reliable and controlled way.

SAE, the onboard SatAlert SW components

The previously mentioned ISAE manages the software-hardware interaction between the transceiver and the on-board computer guaranteeing the independency of the experiment from the rest of the mission, while SAE implements the nominal functions of the MAMES communication protocol. SAE is invoked by the onboard operating system only in the case of an upload of a new MAMES message or a transmission trigger command from the main ground station. When invoked, SAE receives through the ISAE interface information about the uploaded MAMES message, the onboard time and the last MAMES message stored in the transmission queue. Thus SAE is responsible for MAMES message validation that involves the following actions:

- In case of transmission trigger command, if MAMES message previously stored in the transmission queue is still valid.
- In case of an upload of a new MAMES message, SAE parses the received message in order to compare priority and validity of the new uploaded message with the previously stored message.

On the basis of these conditions, SAE decides which messages have to be broadcast or deleted from the transmission queue, providing this information to the ISAE interface.

CONCLUSION

This paper focuses on the new specific technical solutions to be developed for the delivery of alert messages to the population in case of a disaster. In particular, an overview of the ongoing ETSI standardization activity for the definition of a multiple alert message encapsulation protocol to transport alert messages over satellite links (MAMES) is provided, highlighting the MAMES Message definition and the MAMES integration into SatCom/SatNav entities. The related experimental activity (SatAlert experiment) for the demonstration of MAMES applicability to LEO satellites is presented, describing the SatAlert experiment objectives, the satellite component and the onboard software modules.

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