SafeTRIP: A Bi-directional Communication System Operating in S-band for Road Safety and Incident Prevention

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Abstract— **SafeTRIP is a project in progress partially financed by the Seventh Framework Programme's (FP7) European research and development activities in the subtheme of Sustainable Surface Transportation. SafeTRIP intends to implement a demonstrator of an integrated system, from data collection to service provision, that aims at optimising the use of road transport infrastructures. In this paper a general overview of the SafeTRIP architecture is presented. A detailed analysis and description of the functionalities characterizing the main elements of the system and a brief description of infomobility services such as alerting, disaster recovery and dynamic traffic data is given. A relevant part of this architecture is the Satellite Communication System which operates through the W2A Geostationary Satellite. To have an idea of the potentialities of the proposed system, a summary of functional requirements and performances relating to different types of services implemented is reported.**

Index Terms— **Road safety, Infomobility, S-Band, W2A, Satellite, System Architecture.**

I. INTRODUCTION

Over recent years, the transport industry has changed its features under the impact of the internal market and of globalisation. Today the transport sector is a high-technology industry, making research and innovation crucial to its further development and conducive to worldwide competitiveness, environmental and social agendas.

Research and innovation have a fundamental role to maintain and increase the efficiency of different transport modes as well as their interaction and to foster progress. Technological progress, the organisation of transport and understanding the supply and demand factors are key elements in carrying out the international policies of transport research and innovation.

The big challenge in this field is to make growth and sustainability compatible, by decoupling environmental impacts from economic growth, while assuring the competitiveness and innovative character of the European transport industry.

The surface transport system is one of the main areas where research is focusing its studies. The aim is to address and resolve many of the problems that the transport system has to face, starting from the road safety one.

In 2001 the European Union set itself the ambitious objective of halving the number of fatalities on European roads by 2010 (from 50 000 to 25 000). Although some progress has been made and despite the clear increase in activities to support the development and use of preventive and assistance systems for road safety, in 2009 road accidents on EU roads, have still caused more than 35.000 deaths and more than 1.5 million of injured [1]. This large number of accident related deaths and injured causes high costs to society.

Among the activities launched up by European Commission against this weighty problem there is the eSafety initiative [2] which brings together the European Commission, industry, public authorities and other stakeholders to accelerate the development, deployment and use of Intelligent Vehicle Safety Systems that use ICTs in order to increase road safety.

Another EC initiative led to the definition of a Intelligent Transport System (ITS) Action Plan [3] that was adopted on December 16, 2008 by the European Commission. This Action Plan aims to accelerate and coordinate the deployment of ITS in road transport, including the interfaces with other modes of transport. In this context innovative technologies such as Radio Frequency Identification Devices (RFID) or EGNOS/Galileo should be used for the realisation of specific applications, notably for the tracking and tracing of freight along its journey and across modes of transport.

According to the above mentioned EC policies and in the context of FP7-SST.2008.4.1.3. (Integral system solutions for safety) research area, the SafeTRIP project [4] was submitted to EC by a consortium involving 20 partners from seven European countries, in response to the FP7-SST-2008-RTD-1 Call on Sustainable Surface Transport (SST) systems, whose general objective was to improve the use of road transport infrastructures as well as to improve the alert chain (information / prevention / intervention) in case of incidents by offering an integrated system able to cope with a set of tasks which span from data collection to service provision. The

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SafeTRIP project is co-funded by the EC, started in 2009, is still in progress and will end at the begin of 2013, intends to contribute to the achievement of the EC objectives regarding road transport safety and road mortality reduction.

In particular, in this paper, after providing a more detailed description of the objectives of the SafeTRIP project (section II) and reporting specific information concerning the W2A geostationary satellite, on which the communication section of SafeTRIP system is based (section III), in section IV is detailed the system architecture [5], describing the SafeTRIP Gateway and the user terminal functionalities. Section V presents a brief overview of the services that will be made available by the system and finally, in section VI, some concluding remarks.

II. Objective of the SafeTRIP Project

SafeTRIP is probably one of the most innovative projects of the last decades thanks to its horizontal and holistic approach: infrastructure / vehicle / drivers. The main stake of this project is to contribute to the achievement of the European Commission (EC) objectives regarding road transport safety (reduction of the number of the road mortality, exchange of information concerning traffic, vehicle status, ecc..) by the development of an integrated system based on a two-way satellite communications system.

As above mentioned SafeTRIP general objective is to offer a reference architecture (see fig. 1) as well as to implement a demonstrator of an integrated system, from data collection to service provision, that aims at optimising the use of road transport infrastructures, reducing the waiting-time and improving the alert chain (information / prevention / intervention) in case of an incident or accident.

SafeTRIP benefits from a new satellite technology, the S-band (detailed in the next section), which opens new perspectives for European telecommunications. This new satellite technology gives the opportunity to progress beyond the state of art, allowing communications in both directions with mobile units (downlink and uplink). It presents determinant advantages including global and full coverage on the European scale, multicast data transmission, quick and easy deployment, ecologic energy (as the satellite operates through solar panels), so it allows the development and deployment of Mobile Satellite Services (MSS) systems.

The SafeTRIP project proposes the development and experimentation of several services in the road sector that could be tailor suited for all type of vehicles (car, bus, truck, train, boat…) and infrastructures (sea, road, rail).

III. W2A Geostationary Satellite and the S-band

The SafeTRIP exploits the EUTELSAT W2A satellite (figure 2), which was launched April 4th, 2009 at the Baikonur Cosmodrome (Russian), on a geosynchronous orbit at 10.0° East. It has been designed by Thales Alenia Space with a lifetime of more than 15 years, W2A has a maximum launch mass of 5.7 tonnes and will deliver 11 kW of payload power.

The main mission of the W2A satellite is to extend Ku-band capacity for video, broadband and telecommunications services in Europe, Africa and Middle East, and to boost the C-band capacity available through Eutelsat's fleet for services across Africa.

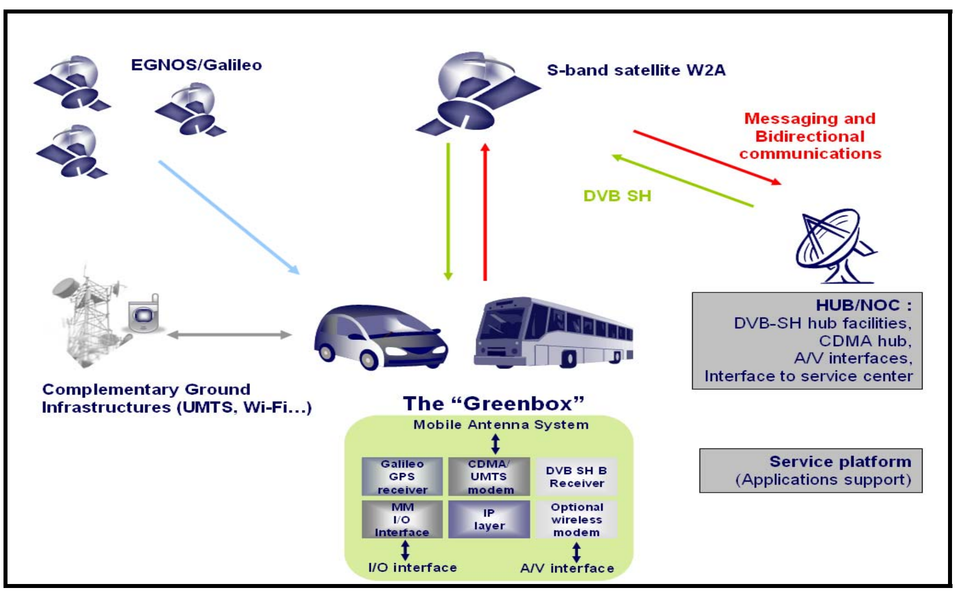

Figure 1. The SafeTRIP project approach

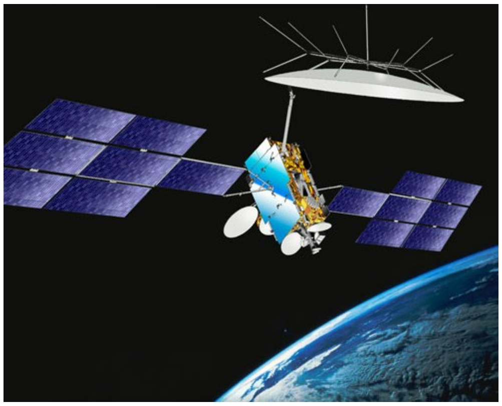

Figure 2. Synthetic view of the W2A

The W2A has 46 Ku-band transponders, 10 C-band Transponders, and S-band payload.

The S-band, that is defined by an IEEE standard for radio waves with frequencies that range from 2 to 4 GHz, opens new perspectives for European telecommunications in the context of the development of MSS.

In the European Union the EC Mandate to CEPT to study the harmonised technical conditions for the use of the 2 GHz bands for MSS resulted in the Decision ERC/DEC(97)04, where CEPT designates the 1980-2010 / 2170-2200 MHz bands for MSS use [6].

The importance of the MSS system has been well recognised by the EU. Such systems provide ubiquitous connectivity through widespread, international coverage, with simultaneous access to the satellite service at the time it starts to be available, in the entire footprint of the satellite. Moreover, the designation of the 2 GHz band to MSS systems, including the possibility to implement complementary ground components, will allow the development of a range of new markets and services [7], [8], [9].

In particular the S-band payload at 2.2 GHz on W2A satellite allows the delivery, in western Europe of mobile multimedia broadcast services, such as mobile TV and digital radio (DVB-SH), through the use of small omni-directional antennas integrated in the mobile unit. In its current configuration it delivers coverage across much of the EU landmass from two operational beams. Each beam, operating on its own is capable of providing 5MHz of bandwidth capacity, complementing additional bandwidth on the ground and each beam operates in opposite circular polarisation (LHCP & RHCP).

The S-band is also optimized for content delivery and two-way communications for vehicles on-board units interoperable with Galileo and UMTS systems.

W2A satellite allows the building of hybrid infrastructure over Europe, combining satellite and terrestrial networks, providing both universal coverage and indoor penetration for Mobile TV services. Moreover, it also enables direct satellite communications, useful in case of transmissions security or crisis management.

IV. Architecture of SafeTRIP system

The SafeTRIP system architecture mainly consists of two subsystems:

the Greenbox or On-Board Unit that is a device, installed in a vehicle, which interacts with the user and allows him to access some specific user services;

the SafeTRIP Gateway that is a ground station capable of communicating, through the S-band Satellite and/or the Complementary Ground Components, with the S-band terminal. It is devoted to the management and operation of all network resources so that communication services are provided properly.

Figure 3 shows the overall SafeTRIP system architecture detailing the functional blocks for each component of two subsystems.

In the following a more detailed analysis of the components constituting the above-mentioned sub-systems is reported.

SafeTRIP Gateway sub-system

The *SafeTRIP Gateway* section consists of three components: (1) Hub, that is capable of communicating with the S-band terminal and is responsible of managing and operating all network resources necessary to provide the communication services; (2) SEP (Service Enabling Platform), an entity attached to the SafeTRIP Gateway Segment that acts as an abstract layer through which the end users are able to access broadcast, messaging and real-time bidirectional services, and (3) Service Providers.

Hub component is divided into three sub-sections that are Physical Layer, Convergence Layer and Hub controller. The Physical and Convergence layers are responsible of decode and demodulate data stream from E-SSA (Enhanced Spread Aloha Access) [10] and QS-CDMA (Quasi Synchronous Code Division Modulation Access) [11] channels, encode and modulate data stream to DVB-SH channel and perform some specific functions for the E-SSA, QS-CDMA and DVB-SH channels such as header compression / decompression, encryption / decryption, encapsulation, packet and priority schedulers. On the other hand, the Hub controller, is responsible to perform resource, mobility, signaling and network management functions, performs terminal authentication functions and manages the system registers (HLR and VLR) containing user profile data.

The SEP is the transaction gateway of all service segments as access broadcast, messaging and real-time bidirectional services, depending on the class of terminal employed, between the end users and the corresponding Service Providers. SEP represents a distributed middleware which is adaptable to different hardware and software nodes.

The Service Enabling Platform implements the following functions:

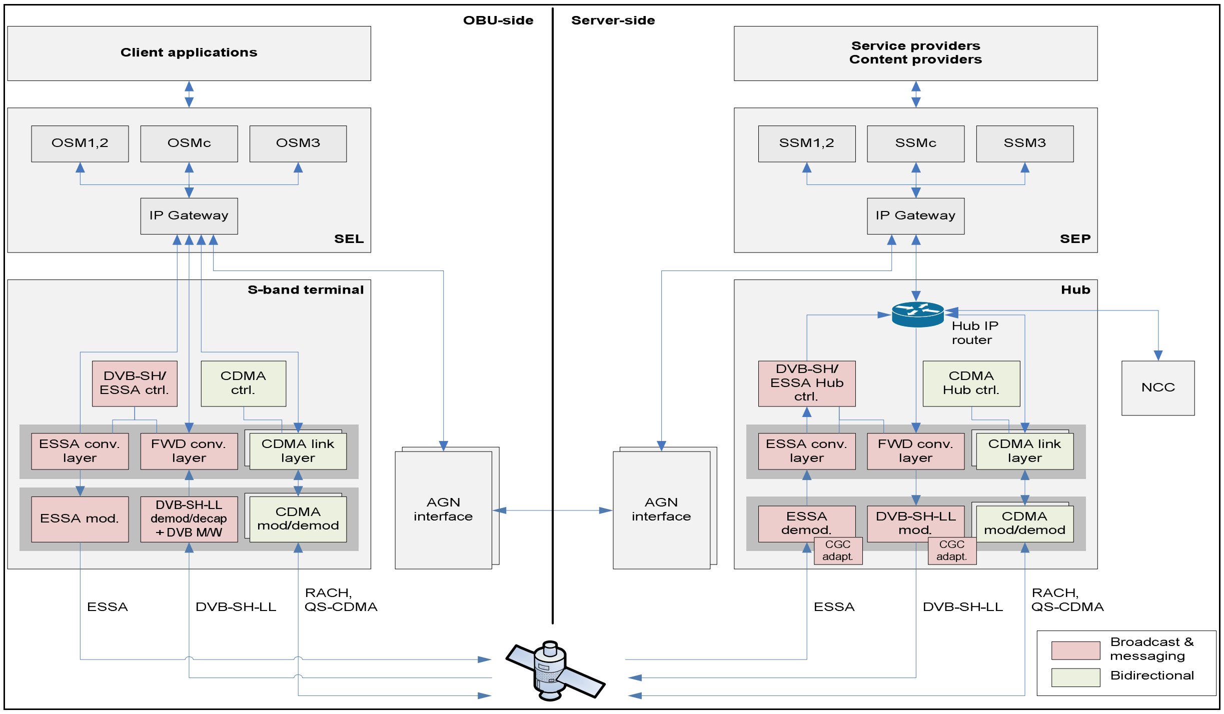

Figure 3. SafeTRIP system Architecture

- IP gateway: functions common to all kind of services;
- SSM 1/2 (Server-Side Middleware 1/2): specific functions for broadcast and messaging services;
- SSM 3 (Server-Side Middleware 3): specific functions for real-time bidirectional services.

As previously mentioned, the SafeTRIP project provides interoperability between satellite and terrestrial networks Thus the AGN Interface works in parallel with the Hub to allow the interoperability with alternative ground networks such as UMTS.

User Terminal (GreenBox) sub-system

The functional architecture of the *On-board Unit* (OBU) is divided in three components: the S-Band Terminal, the Service Enabling Layer (SEL) and the Applications Layer.

The S-Band terminal encompasses the forward and return link processing, including the E-SSA and QS-CDMA modulation for the messaging and bi-directional return link respectively.

The SEL is a middleware that interacts with the Service Enabling Platform in order to provide users with access to various kinds of services (broadcast, messaging and real-time bidirectional services). The main goal of the SEL (as well as of the SEP) is to simplify the access to those services and hide the complexity of the underlying access network(s). The SEL processes the IP requests from the application layer performing the authentication, authorization and accounting tasks. Besides, the SEL receives and processes the positioning information from the GNSS terminal (EGNOS/Galileo) [12] as well as the AGN interface (3G technology).

- SEL functions are grouped as follows:
- IP Gateway: functions common to all kind of services;
- OSM1/2 (OBU-Side Middleware 1/2): specific functions for broadcast and messaging services;
- OSM3 (OBU-Side Middleware 3): specific functions for real-time bidirectional services.

OSM 3 implements two different terminals for real-time bidirectional services: Professional Terminal (PT) that is an emergency terminal with the capacity of providing access to satellite services to a number of dependent terminals, for which it operates as a gateway, and Consumer Terminal (CT) that is a simpler terminal with no dependent terminals, i.e. it transmits over the satellite channel only the traffic generated by itself.

The application layer interacts with the user and transforms his petitions into IP requests. The main functions of this block can be summarized as:

- Friendly presentation of data to the user.
- Process user requests by generating the corresponding IP requests.
- Process all the information about the positioning of the receiver as well as the nearby traffic and presents it to the user.

As stated before, the positioning functionalities in the user terminal, will be carried out by the GALILEO system, but due to its unavailability until 2015, the SafeTRIP demonstrator will use the GPS system.

The GALILEO constellation consist of 30 satellites (27 operational and 3 active spares), supported by a worldwide network of ground stations. The large number of satellites, together with the optimization of the constellation, and the availability of the three active spare satellites, will ensure that the loss of one satellite has no discernible effect on the user.

V. SERVICES IMPLEMENTED AND SYSTEM PERFORMANCE

As we have pointed out in the previous sections, SafeTRIP platform has been developed to provide a variety services such as positioning, tracking, emergency calls, video and audio services to end-users on vehicles, increasing a level of road safety and making the trip more comfortable.

In this section functionalities and performances of the following communication services will be briefly analyzed:

- Broadcast services;
- Real time bidirectional services;
- Messaging services.

Broadcast Services

Broadcast services require an intensive use of the forward link capacity, for the delivery of video and audio streaming and data distribution services. This type of services include reception of TV programs, reception of radio programs, reception of data carousels and alerts, reception of an electronic service guide. Table I shows the defined throughput for broadcast services in SafeTRIP.

TABLE I - REQUIRED THROUGHPUT FOR BROADCAST SERVICES

Broadcast Services	Minimum throughput (kbps)	Maximum throughput (kbps)
Video	290	384
Audio	40	128
Electronic Service Guide	300	--

Bidirectional Services

The SafeTRIP System shall provide bidirectional data communications services (bidirectional data links) between a number of Service Centres and a population of users equipped with compatible terminals (Professional Terminals only).

Real time bidirectional services support voice, data and video, including *emergency call* and *two way IP connection*.

In table II are reported some required performances for bidirectional services in the SafeTRIP system.

Messaging Services

Messaging services are for handhelds and vehicular terminals, available for millions of end-users. They include vehicle telemetry, anti-theft services, traffic monitoring and distress beacon.

TABLE II – SOME REQUIRED PERFORMANCES FOR BIDIRECTIONAL SERVICES

Bidirectional services	Value
Standard data link rates	16 to 64 kbps
Video call frame rate	≥ 5 frame/sec
Video call resolution	≥ QVGA (320x240 pixs)
Data services – availability	≥ 99.8%
Voice quality: conversational MOS (PT)	≥ 3.6

The SafeTRIP System shall support message generation in the following modes:

- Automatic: messages can be generated automatically by either the Service Centre (e.g. traffic alerts) or the terminal (e.g. location messages in support of an emergency call);
- Manual: messages can be generated manually by either side;
- Upon request: messages can be generated by either side upon request from the other side.

Table III summarizes some performance requirements fixed the for SafeTRIP platform.

TABLE III – SUMMARY OF MESSAGING SERVICES PERFORMANCES

Messaging services	Value
Message loss ratio	Normal messages: ≤ 5% Emergency messages: ≤ 2%
Message loss delay	Normal messages: ≤ 10.5 s Emergency messages: ≤ 1.5 s
Messaging services – capacity	Telemetry: ≥2·10^6 messages/day (forward link, 40 bytes/msg), ≥48·10^6 messages/day (return link, 140 bytes/msg) Anti-theft: ≥48 messages/day (forward link, ~30 bytes/msg), 4800 messages/day (return link, ~30 bytes/msg) Fleet management: ≥1·10^6 messages/day (forward link, 30 bytes/msg), ≥60·10^6 messages/day (return link, 26 bytes/msg) Traffic monitoring: ≥ 400·10^3 messages/day (forward link, 30 bytes/msg), ≥1.6·10^6 messages/day (return link, 26 bytes/msg) Distress beacon: ≥29 messages/day (return link, 26 bytes/msg)

VI. CONCLUSIONS

On the basis of functional features described in this paper is evident that the solution proposed by the SafeTRIP Consortium to the EU in the context of the FP7 R&D activities is probably one of the most innovative of the last decades thanks to its innovative approach integrating infrastructure/vehicle/drivers.

SAFETRIP benefits from a new satellite technology. The S-band supported by the W2A satellite, opens up new perspectives for European telecommunications and this is even more true when one considers that it will be interoperable with Galileo and UMTS systems.

As we have seen SAFETRIP project's general objective is to improve the use of road transport infrastructures and to improve the alert chain (information/prevention/intervention) in case of incidents by offering an integrated system from data collection to service provision contributing to the achievement of the EC objectives regarding road transport safety and road mortality reduction.

To do that, low price on-board-units will be installed in vehicles to provide customized services such as emergency calls and a set of key messages (traffic alerts, incident/accident warning, etc.), addressed to vehicle drivers as well as road operators, that will be essential for road safety and incident prevention.

Currently the project is at a good stage of development and the system will soon be tested in the field by the French and Spanish road operators and road users.

VII. Acknowledgment

The authors of this paper would like to thank the partners of the SafeTRIP consortium and the DENISE [13] project. They are in particular thankful to the FP7 and the European Commission for funding the SafeTRIP project."

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