A Wifi Network for Surveillance of Airport Mobiles

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***Abstract*—Due to the continuous increase of airport traffic, there is the need to improve the safety of vehicle ground movements in the different airport areas and to improve also the efficiency of airport operations: several tens to hundreds of ground vehicles are sharing areas with the normal air traffic. The CLESTA project contributes to the solution of this problem by developing a new low-cost and modular platform with three components, namely, on-board system, communication network and ground system. The paper presents the platform architecture focussing into its innovative characteristics to provide, in an airport environment, the surveillance, control and guidance services for the airport main actors. This project led by M3 Systems, in partnership with TeSA and ENAC laboratories, and Intuilab company, aims at designing and deploying a positioning system for airport ground vehicles with service messages transmitted via a Wireless Network (Wifi, WiMax, ...) deployed outside in the airport area. In this context, technical objectives of the project consist in developing the software required for transmitting and processing of the service messages.**

***Index Terms*—Wi-Fi, Satellite Radionavigation, Geographical information systems, Airport traffic control.**

I. Introduction

THE continuous growth of air traffic leads to an escalating number of accidents and incidents on airport surface movements. In case of bad meteorological conditions or low visibility, since the surveillance and control of movements are mainly based on the ”see and be seen” principle, airport operators have little or no knowledge of ground surface traffic, thus leading to ground movement hazards. The safety of vehicles in the airport area and the efficiency of their movements are therefore seen as major issues by airport operators as the air traffic growth implies an increase of the number of vehicles that provide services to aircraft on stand/ gate or parking. The CLESTA (Local Complement for Airport Traffic Surveillance and Alerting) project, presently supported by the DRIRE (Regional Headship of Industry, Research and Environment) of the Midi-Pyrénées Region (France) under the VANS call for projects (Valuation of Satellite Navigation Applications), contributes to the solution of this problem. Its main objectives are to improve airport users safety on all the areas of the airport and to improve the efficiency of operations. These objectives are achieved by providing reliable and essential information obtained from the vehicles location to the airport operators. It requires the development of a low-cost platform for the surveillance, control and management of the airport vehicles, which implements the recommendations of Eurocontrol for Advanced Surface Movement Guidance and Control Systems (A-SMGCS). The platform relies on the GPS/EGNOS satellite navigation system for providing the position of the vehicles and on innovative communication technologies for an airport environment. The platform has three main components, namely, an on-board system in each vehicle, a central ground system and wireless communication network. The on-board system has a human-machine interface (HMI) to interact with the driver and capabilities to communicate with the ground system. The ground system runs the appropriate software to supply the relevant geographical, surveillance and alerting information to the operators via a HMI. The wireless communication network is a key element in the platform, as it allows the integration of the on-board systems and the ground system in the CLESTA platform. CLESTA will be deployed for validation at the Toulouse/Blagnac airport in France, which, by international standards, is a medium-size airport. Section 2 of the paper will present the description of the general architecture of the system, describing the architecture of the on-board and ground systems and will be followed in section 3 by the description of the CLESTA services. Section 4 will present the deployment of the Wi-Fi network in the airport area and some conclusions will be drawn in section 5.

II. General architecture of the platform

The CLESTA platform consists of three main components: on-board system, ground system and communication network. A diagram depicting the general architecture of the CLESTA platform is shown in figure 1. The on-board system, which is deployed in each vehicle, includes the GPS/EGNOS position sensor and the vehicle driver HMI. It interfaces to the CLESTA communication network and manages the software applications, which provide the CLESTA services. The ground system consists of a processing server to evaluate the overall situation and manage the services, a ground HMI to interface with the ground actors (air traffic controller, airport operation officer and ground handling) and a communication server to manage the communication links to the on-board systems. The communication network allows the exchange of data between vehicles and ground system, covering both the manoeuvering area and the apron area. The network will be based on the Wi-Fi technology, demonstrating the ability of exploiting innovative networks.

The on-board system block diagram consists of a Communication and Navigation Unit (CNU), a display system, an EGNOS receiver and a Wi-Fi network transponder. The CNU is an embedded processing system based on an electronic board, which is a modular box capable of being easily installed in the vehicle. It runs the appropriate software modules to provide traffic information, traffic context, conflicts/ infringements detection and service monitoring services. The CNU drives the display system, which provides the vehicle driver with information about the situation awareness and the vehicle position in the airport and gives alerts in hazardous situations.

The ground system has a communication server managing the communication with the vehicles through Wi-Fi transponders. The core of the ground system is the Processing Server linked to the Ground HMI System (see figure 1). The latter runs the following software modules: provide traffic information, provide traffic context, conflicts/ infringements detection and service monitoring. These modules together with a GPS/EGNOS receiver (for GPS time synchronization) constitute the core components of the Ground Processing System. The Ground HMI System receives inputs from the Ground Processing System modules, including the updated mobiles (vehicles and aircrafts) positions over time. The traffic information module provides the traffic information (position, speed and identity of the mobiles). The traffic context module is in charge of providing the traffic context (airport configuration, runways status). The conflicts/infringements module considers traffic information and traffic context information as input data, and generates C/I alert when a pre-defined Conflict/Infringement situation is detected according to predefined scenarios. The service monitoring module monitors the quality of service of CLESTA system (equipment status, performances, operational failures, etc.) and generates an alert when the CLESTA system must not be used for the intended operation.

III. CLESTA services

From the ground surface movements point of view, an airport layout can be broken down into the three following segments: manoeuvring area, apron area and public area. The manoeuvring area is composed by runways and taxiways. It is under control of the Air Traffic Control (ATC) authorities. A limited number of vehicles, together with aircraft, are operating in this area, and ground control ensures safety by maintaining adequate separation between the mobiles. The apron area is mainly composed by parking areas. It is under the joint responsibility of airport operators and ATC authorities. A large number of vehicles are operating around the aircraft to support various activities, such as passengers transfer, goods handling, aircraft servicing and security. The public area corresponds to the arrival and departure halls. It is the interface of the airport with a variety of ground transportation means. The CLESTA actors are the air traffic controller, the airport operation officer, the ground handling manager and the vehicle drivers. The CLESTA services aim to improve safety for the airport movements of vehicles and aircrafts on the manoeuvring and apron areas (see figure 2).

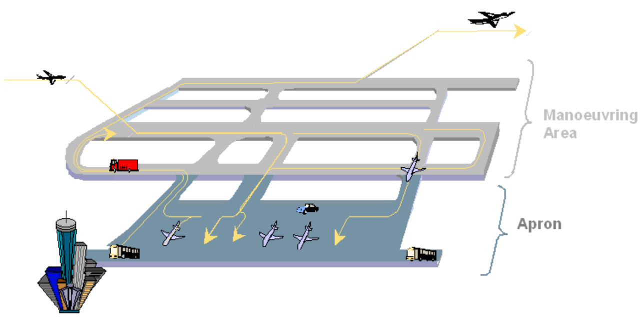

Fig. 2. Airport responsibilities sharing.

For this purpose three different services are provided by CLESTA: surveillance service, control ser-

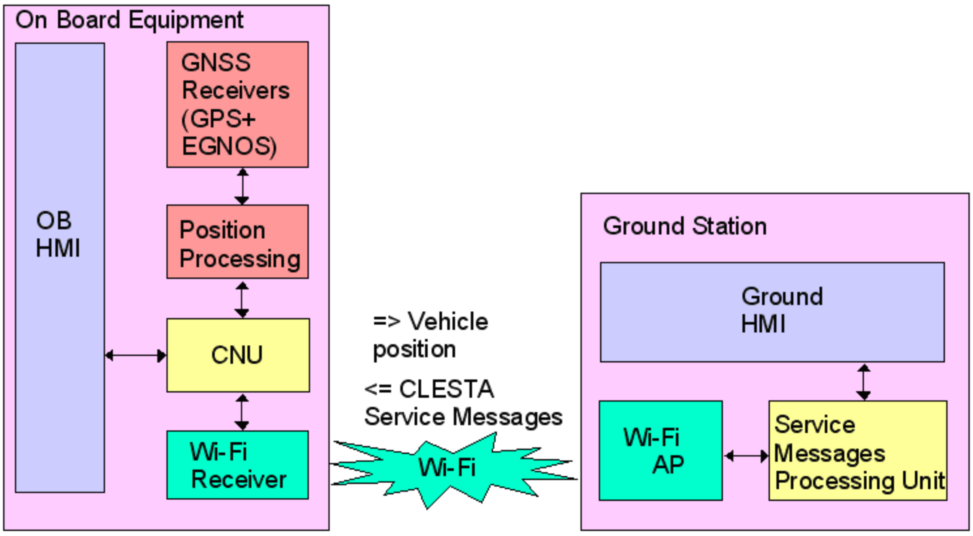

Fig. 1. General architecture of the CLESTA platform.

vice and guidance service. The surveillance service aims to provide continuous surveillance of the traffic situation for the air traffic controller. The surveillance service includes traffic information (mobiles position and identity) and traffic context (airport map representation). The traffic data needs to be provided with an adequate accuracy and update rate in order to support the decision-making process. The control service provides conflict/ infringement alerts to the air traffic controller. For example, a driver of an airport vehicle, during a runway inspection is first "visually identified" by the control service on the vehicle HMI and, later on, is "soundly identified" if an aircraft is approaching and the vehicle is still on runway. The guidance service aims to provide navigation information for all the areas of the airport. This service intends to reduce navigation errors, which might occur in reduced visibility conditions or with non-experienced drivers. The guidance service allows vehicle drivers to visualize their own positions on a moving map of the airport. For all the services the objective is to improve the safety and the efficiency of aircraft and ground vehicles movements.

IV. Wi-Fi network deployment

A. Generalities

Several governmental organisms legislate in their countries to set available frequency ranges for public applications and their associated maximum EIRP (Effective Isotropic Radiated Power). These limitations come from reserved military frequency bands and public health reasons. In France, the ARCEP (Autorité de Régulation des Communications Electroniques et des Postes, see [2]) allows the use of 2.4 GHz signals (802.11b/g norms) outside with a maximum EIRP of 100 mW. 5.8 GHz signals (802.11a) are prohibited whatever be the EIRP. Actually, EIRP is the apparent power transmitted towards the receiver, if it is assumed that the signal is radiated equally in all directions, such as a spherical wave emanating from a source point, in other words, the arithmetic product of the power supplied to an antenna and its gain.
In the CLESTA project, Wi-Fi server and client hardware has been chosen to be compliant with the 3 physical norms (802.11 a,b and g) because the system will be deployed in airports of different countries.

B. Link budget and EIRP specifications adherence

The maximum emitted power of the chosen AP is 19 dBm (relative unit in decibels related to the milliwatt) following the product specifications and can be converted to Watts using (1).

$$dBm = 10 \log \left(\frac{P_{max}}{0.001} \right). \tag{1}$$

This corresponds to a maximal emitted power $P_{max} = 0.0794W$. Knowing the emitted power P and the total gain G_T (antenna gain minus cable and connectors losses), the EIRP is obtained using (2):

$$EIRP = P.10^{\frac{G_T}{10}}. \tag{2}$$

In order to respect the authorized EIRP of $100mW$, the emitted power must limited to $P = 0.0524W$ as shown in table 1. The theoretical link budget is the modeling of the whole transmission chain which means, for a transmission without obstacle:

- `Emission [dBm]: emitter [dBm] - cable loss [dB] + antenna gain [dBi].`

TABLE I

EIRP DERIVATION.

`AP output power`	$P = 0.0524W$
`Antenna gain`	$G = 6dB$
`Cable loss`	$A_1 = 2dB$
`Connectors loss`	$A_2 = 1.2dB$ ($0.6dB$ `by connector`)
`Total loss`	$A = A_1 + A_2 = 3.2dB$
`Total gain`	$G_T = G - A = 2.8dB$
`EIRP`	$EIRP = P.10^{\frac{G_T}{10}} = 0.0998W$

- `Propagation [dB]: free space loss [dB].`
- `Reception [dBm]: antenna gain [dBi] - cable loss [dB] - receive sensitivity [dB].`

The Friis formula (3) is used to derive the free space loss for a given distance and emitted power and frequency:

$$P_r = P_e G_e \left(\frac{\lambda}{4\pi d}\right)^2 G_r \qquad (3)$$

with P_r: received power at observation point (W), G_e: emission antenna linear gain, $\lambda = \frac{C}{f}$ (wavelength in meters) with $C = 3.10^8 m/s$ and $f = 2.5 \times 10^9$ Hz, d: distance between emitter and receptor (m) and G_r: receptor linear gain. The free space loss $A = \left(\frac{\lambda}{4\pi d}\right)^2$ can be expressed in dB as in (4)

$$A(dB) = 10 \log \left(\frac{\lambda}{4\pi d}\right)^2 = -40.4 - 20 \log(d). \qquad (4)$$

This represents a loss of -80.4 dB for a distance $d = 100$ m. The total `Emission + Propagation + Reception` must be greater than zero for the system to work. The remaining will give the security margin necessary to guarantee working despite interferers (other WLAN networks, bluetooth), the industrial noise (microwave ovens) damaging Signal to Noire Ration (SNR), atmospheric losses (humidity, dispersion, refraction) and badly orientated antennas. An important security margin is necessary for long distance transmissions.

The link budget presented table 2 ensures a good security margin of approximatively 35 dB.

C. Covered area

The typical airport area to be covered by the Wi-Fi network is a 50 meters by 100 meters area depicted in figure 3. It has been chosen to place 2 APs (Access Points) antennas along the wall, even if a single one would *a priori* be enough to cover the whole area, for several reasons:

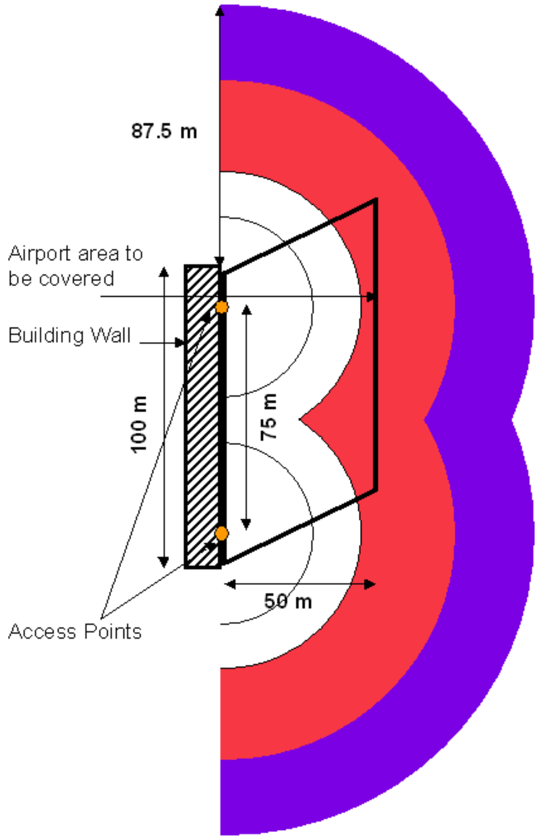

Fig. 3. Wi-Fi network coverage.

- Some vehicles can mask other ones being situated between them and the AP.
- Security problems requiring an over-coverage of the area with APs (better detection of rogue APs and redundancy useful in case of hardware failure).
- Automatic adjustment of APs radiated power requiring at least 2 APs in view (an AP tests the other one by radio sweeps to estimate current free space loss knowing the distance between the 2 antennas).
- Bad weather conditions (rain, snow, etc...) can reduce transmitted radio power. According to [1], 2.4 GHz signals may be attenuated by up to 0.05 dB/km by torrential rain (10 cm/hour) and thick fog produces up to 0.02 dB/km attenuation respectively 0.5 dB/km and 0.07 dB/km for 5.8 GHz signals). Even though rain itself does not cause major propagation problems, rain will collect on the top of obstacles and will produce attenuation until it evaporates.

This use of several APs raises the problem of the commutation of a mobile client when leaving an AP cov-

TABLE II

LINK BUDGET.

Emission	Emitter output power	17.193 dBm
	Cable losses	−3.2 dB
	Antenna gain	6 dBi
Propagation	Free space loss	−80.4 dB
Reception	Antenna gain	6 dBi
	Cable losses	−4.4 dB
	Receptor sensitivity	−94 dBm
Total	Remaining margin	35.193

erage area to enter in an other one (*roaming*). This problem is addressed by the 802.11f recommendation [3] introducing Inter Access Point Protocol (IAPP). This document is only a draft and these recommendations are not yet integrated by the different hardware manufacturers. As a consequence, the only way to ensure a working roaming functionality is to use server hardware and software from a single manufacturer (base station software, Wi-Fi switch and APs) integrating proprietary solutions. In most cases the client hardware can be chosen freely as IAPP protocol only concerns the transmission of client credentials between APs.
As shown in section IV-B, an important margin in the link budget calculation (35 dB) and the use of 2 APs with a working roaming functionality will ensure a satisfactory coverage of all the area.

V. CONCLUSIONS

This paper presented the CLESTA project, with its general and detailed architecture (on-board and ground systems) and the services it provides for localization of mobiles in an airport area. The two main original points of the project are the use of EGNOS satellite system to provide corrections to GPS positions and integrity measures and the use of a Wi-Fi network deployed outside in the airport to transmit CLESTA service messages. In the future, the use of Wi-Max technology (802.16 xx norms, [4]) with a data rate going up to 40-50 Mbps and a range of several kilometers is envisaged when it is available.

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Prof. Francis Castanié has got his Ph. D and its Doctorate of Sciences degree from National Polytechnics Institute of Toulouse (INPT) respectively in 1971 and 1977. He teaches essentially Signal Processing at the undergraduate and graduate level. He gives several doctoral courses in the following topics: Time-Frequency and Wavelet Analysis, Parametric Signal and Time Series Modeling, Digital Signal Processing. Prof. Castanié is the Director of the Research Laboratory Telecommunications for Space and Aeronautics (TeSA). Together with this activity in TeSA, he joined the CNRS Institut de Recherche en Informatique de Toulouse (IRIT) in 2002, where he had been heading the Signal and Communication Group to the end of 2005. He has several responsibilities in research societies at the national level (SEE) and at the international level: he had been Chairman of the French Chapter of Signal Processing of the IEEE, from 1992 to 2002. He serves as an expert in various European research programs, in particular of the 6th FP. He authored or co-authored more than 52 papers (among which an International First Prize and a Best Paper Award), and more than 240 communications in international conferences. He has 7 international patents, and has co-authored around 99 industrial contracts reports. During his 35 years of career, he has been the advisor of more than 60 Ph. D. students.