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A CONCEPTUAL MODEL FOR ASSESSING THE IMPACT OF INTERNET-OF-THINGS TECHNOLOGIES FOR PEOPLE WITH REDUCED MOBILITY IN AIRPORTS

Juan José Herrera Martín[(a)], Iván Castilla Rodríguez[(b)]

[(a),(b)] Departamento de Ingeniería Informática y de Sistemas. Universidad de La Laguna

[(a)]jhmartin@ull.edu.es, [(b)]icasrod@ull.edu.es

ABSTRACT
The European Union has regulated by law the elimination of barriers to guarantee the right to free movement, freedom of choice and non-discrimination of people with reduced mobility (PRM). This regulation also affects air transport. More specifically, airports of the member states must offer a quality assistance service to PRM, with the adequate human and technical resources to guarantee their rights. The changing characteristics of the operation of an airport (delays, cancellations, breakdowns, etc.) add great complexity to the design and management of a PRM service. Internet of Things (IoT) technologies pose a unique opportunity to integrate new services and solutions to deal with these problems. This work focuses on the use of modeling and simulation techniques for the evaluation of the impact of the incorporation of new IoT-based elements (such as autonomous vehicles, smart devices and 5G-enabled systems), for the improvement of the PRM service.

Keywords: workstation People with reduced mobility, Internet-of-Things, airports, simulation model.

1. INTRODUCTION

In the European Union, as stated in Regulation (EC) 1107/2006 of the Parliament European Union (European Parlament 2006), in force since July 26, 2008, "disabled persons and persons with reduced mobility, whether caused by disability, age or any other factor, should have opportunities for air travel comparable to those of other citizens. Disabled persons and persons with reduced mobility have the same right as all other citizens to free movement, freedom of choice and non-discrimination. This applies to air travel as to other areas of life". Moreover, "in order to give disabled persons and persons with reduced mobility opportunities for air travel comparable to those of other citizens, assistance to meet their particular needs should be provided at the airport as well as on board aircraft, by employing the necessary staff and equipment. In the interests of social inclusion, the persons concerned should receive this assistance without additional charge.".

Since the entry into force of the op cited regulation, the service of attention to people with reduced mobility (PRM) in European airports has reported a significant increase in the number of attendances. Taking Spanish airports as a reference, about 1 million attendances were made, representing 0.53% of total passengers (Aena 2009), whereas in 2017, more than 1.5 million attendances were performed (0.61% of total passengers) (Aena 2017),. Around 1% of the passengers that transit through an airport require assistance from the PRM service. Large European airports record, on average, more than 500 attendances per day. For example, the London Gatwick airport transported more than 32 million passengers in 2009, and registered an average of 900 attendances per day (Reinhardt, Clausen, and Pisinger 2013),. At the Canary Islands, Tenerife Sur Airport offers assistance to approximately 1% of the 11 million passengers it serves, recording days in which more than 700 attendances were made.
The PRM service at European airports can be classified according to the passenger's flight phase in the following three types of assistance: departure, arrival and transit.

- Assistance at the airport of departure: assistance starts at one of the airport meeting points intended for this purpose. Some of the tasks of assistance to the PRM are: support in billing tasks, assistance in the displacement of carry-on luggage, support for security checks, escort to the pre-boarding area, boarding the aircraft and moving to the seat assigned
- Assistance at the arrival airport: assistance starts on the aircraft itself with the displacement from the seat to the door of the aircraft. In addition, the tasks of assisting the PRM include the disembarkation of the aircraft, travel to the baggage hall, support in security controls and accompaniment to a meeting point.
- At transit airports or connections: assistance includes all the necessary tasks to carry out with successful transit or connection of the PRM, including if necessary boarding

maneuvers, disembarkation, terminal transfer, etc.

In relation to financing, Regulation (EC) 1107/2006 of the European Parliament (European Parlament 2006), states that "Assistance should be financed in such a way as to spread the burden equitably among all passengers using an airport and to avoid disincentives to the carriage of disabled persons and persons with reduced mobility. A charge levied on each air carrier using an airport, proportionate to the number of passengers it carries to or from the airport, appears to be the most effective way of funding." Therefore, the optimization of PRM service costs becomes more relevant since it affects air transport rates in general.

Starting from the hypothesis that the management and development of the assistance service to PRM in European airports will continue to increase its complexity due to the annual increase in attendance and the higher level of punctuality and comfort of airport services. We also consider that, due to European regulation, the cost of the PRM assistance service has an impact on air transport rates in general. And moreover, taking into account that the planning of the operation of an airport can be affected by cancellations, deviations and large flight delays, as well as by many other causes such as adverse meteorological conditions, system failures, security alerts, among others.

The main objective of this research is the study of a conceptual model that allows, by means of simulation techniques, analyzing the introduction of Internet-of-Things (IoT) enabled services for the assistance to PRM in airports.

2. LITERATURE REVIEW

There is a limited amount of published papers that deal with modeling and simulation of PRMs in airports. Reinhardt, Clausen, and Pisinger (2013) present a heuristic algorithm based on simulated annealing for the planning of the assistance service for PRMs. The objective of the algorithm is finding solutions that attend to the greatest number of passengers in an optimal time. Reindhardt et al. treat this problem as a Dial-A-Ride Problem (DARP) problem, which is a generalization of the Pickup and Delivery Problem (PDP). The proposed technique is applied to an airport that employs 120 workers who perform a range between 300 and 500 attendances a day which should receive a solution in 2 minutes. The authors aim at offering fast solutions to reprogramming the PRM assistance, since there are many changing conditions of the operations of the airport due to unforeseen situations such as delays and cancellations of flights, unforeseen assistance, breakdowns, etc.

Yorukoglu and Kayakutlu (2011) present a model based on Bayesian networks of a civil aviation ground operations system, which aims to serve as a tool for making decisions that minimize delays and reduce the number of complaints of PRMs. The authors propose the use of Bayesian networks to determine the influence of the causes of delays coded by the International Air Transport Association (IATA) with the complaints factors of PRMs and vice versa.

Arcidiacono, Giorgetti, and Pugliese (2015) analyze the flow of PRMs who enter, exit and transit through a passenger terminal by means of axiomatic design techniques. They take as a reference the service assistance for PRM at an Italian tourist airport consisting of 4 terminals, as well as an additional one (T5) dedicated to the departure of particularly sensitive flights due to the risk of a terrorist attack.

Most of the found papers deal with boarding and disembarking PRMs, since these processes have a notable impact on delays and claims. Holloway et al. (2015) compare the strength and time required for two methods of boarding passengers in wheelchairs. They focus on the maneuver of boarding the wheelchair and do not include the processes of transferring the passenger to and from the wheelchair. Schultz (2017), and Molenaar, Gabrielli and Pudlo (2015) analyze different boarding strategies, with special emphasis on PRMs. While Molenaar, Gabrielli and Pudlo (2015) carry out a study of the cost of the different strategies, Schultz (2017) incorporate the use of the Side-Slip Seat technology into these strategies. This technology allows the reconfiguration of the seats of an aircraft in such a way that the width of the aisle or of some seats can be extended, thus facilitating the PRM boarding. Finally, although more generic in his approach, Schultz (2018) includes PRMs in his stochastic model of the passenger boarding process presents.

3. CONCEPTUAL MODEL FOR THE PRM ASSISTANCE SERVICE

None of the found contributions focus on assessing how PRMs can benefit from new technologies. Hence, a conceptual model that allows for the incorporation of such technologies into the PRM flows is required.

Of the possible passenger flows of the PRM assistance service at airports, five main flows stand out: departure, arrival, remote boarding, remote disembarking and transit. These passenger flows are related to each other, since they share service resources (assistants, ambulifts, among others) and the incidences of a workflow can affect the rest. However, for the sake of simplicity, it is advisable to divide the problem and study each of the flows separately to later integrate them in a global solution.

Passengers who need assistance, such as PRM, must make a prior booking both in the departure and the arrival flows. Requests without prior booking are attended anyway, but add uncertainty and complexity to the planning of the resources of the service.

The departure flow begins with the arrival of the passenger at one of the meeting points of the airport, at the time scheduled in the reservation. Then, an assistant takes the PRM to perform the check-in tasks. Subsequently, the assistant supports the PRM to pass the security controls. Depending on the type of flight, the PRM may require to pass the passport control process. Next, the assistant takes the PRM to the pre-boarding area. Finally, if the aircraf is parking in remote stand, the remote boarding flow is applied; but nevertheless if the boarding uses a finger the boarding process is performed. In the boarding process, one or more assistands (depend on the PRM) transfer the PRM from the boarding area prior to their assigned seat. In addition, it must be borne in mind that between the phases of arrival of the passenger and the pre-boarding there may be interruptions. “Interruptions” are moments in which the service is suspended at the request of the PRM to perform actions without assistance such as going to the toilet, buy or eat, among others. Figure 1 presents an outline of the departure flow.

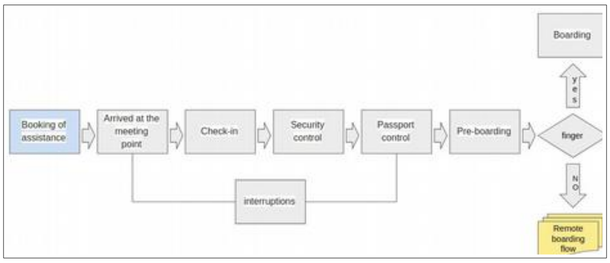

Figure 1: Departure flow

The arrival flow begins with the disembarkation process. In the case of a flight being disembarkation by finger, the disembarkation process consists of one or more attendants (depend on the PRM) moving to the PRM from the aircraft to the terminal airport. However, if the finger is not used, the remote disembarkation flow is performed. In the next step of the arrival flow, and if the flight requires it, the assistant takes the PRM to passport control. Then, the PRM should arrive at the baggage claim area. Finally, the assistant accompanies the PRM to the departure point of the airport, which may include, among others, the seat of a taxi, or a meeting point with a family member or friend who picks it up. We must emphasize that, as in the outflow, in the arrival flow there may be interruptions between the arrival phase to the terminal until it leaves the airport. Figure 2 presents a diagram of the arrival flow.

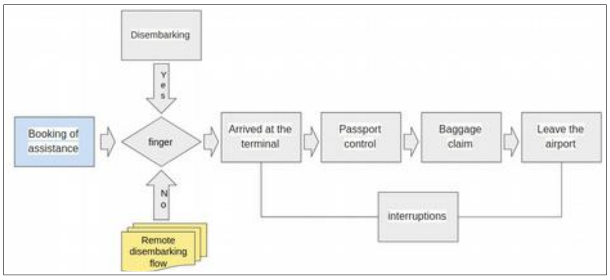

Figure 2: Arrival flow

In the remote boarding and disembarking flows, special vehicles called ambulifts facilitate the transport of the PRM to the aircraft door. The management and planning of the use of ambulifts is a key element in the optimization of the service associated with flights stationed remotely.

The remote loading flows begin at the ambulift loading docks, where the assistants ride the PRMs in an ambulift. The ambulift transport the PRMs and the assistants to the remote location where the aircraft is placed. Subsequently, Airport staff connects the ambulift to the plane and the assistant accomodates the PRM at his/her seat. Figure 3 presents a scheme of the remote approach flow.

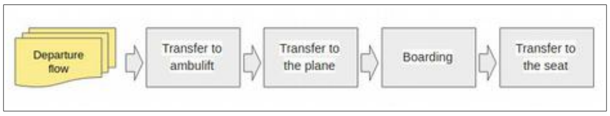

Figure 3: Remote boarding flow

In the case of remote disembarking, the flow starts with the PRM seated in the aircraft cabin. First, one or several assistants (depend on the PRM) move the PRM from his/her seat to the ambulift, then the ambulift makes the transport to the terminal building, and the assistants get the PRMs out from the ambulift to the terminal building. Figure 4 presents a diagram of the remote disembarking flow.

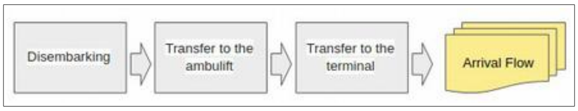

Figure 4: Remote disembarking flow


Figure 5: Ambulift

For in-transit PRMs, the basic flow begins with the disembarking process. An assistant transfers the PRM to the pre-boarding area of their departure flight and the flow terminates with the boarding. It must be borne in mind that between the phases of passenger arrival and the pre-boarding, as well as in the flows of arrivals and departures, there may be interruptions and the process of boarding and disembarking could be remote or through fingers. Figure 6 presents an outline of the basic transit flow.

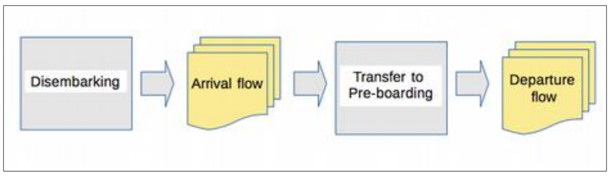

Figure 6: Basic transit flow

In the case of the in-transit PRMs, there are characteristics of the flight or the airport that may modify the basic flow of the passenger. Considering the characteristics of the airport, the flow may be modified if different terminals are available between incoming and outgoing flights for in-transit PRMs. With regards to the type of flight, transits between national and international flights require passing the passport control process. Besides, if the PRM is carrying out a link with different airlines, he/she will require the luggage collection and the check-in process, similarly to performing a combined arrival and departure flows.
The integration of arrival and departure flows requires considering that the aircraft that make a flight arriving at the airport also have a departure flight associated, unless the flight sleeps at the airport and performs the departure flight another day. The integration of arrival and departure flows requires considering that the aircraft that make a flight arriving at the airport also have a departure flight associated, unless the flight sleeps at the airport and performs the departure flight another day.
Figure 7 presents a model proposal for the airport PRM assistance service that integrates the five flows discussed above. In the model diagram, the flows of departures, arrivals and transit are differentiated, while the flows of remote boarding and disembarkation are represented as processes of the departure or arrival flows in the case of a flight associated with an aircraft with remote stand.

4. IOT TECHNOLOGIES IN THE AIRPORT

The proposed simulation model will serve to assess the impact of new technologies that should improve the assistance of PRM. The proposal of a technological framework for the management of the service of assistance to PRM in airports is based mainly on three technologies: 5G, Internet of Things (IoT) and autonomous wheelchairs.

Current services of IoT sacrifice performance to make the most of the existing wireless technologies (3G, 4G, WiFi, Bluetooth, Zigbee, etc.). Conversely, 5G networks are designed to achieve the level of performance needed by massive IoT, and to create the perception of a completely ubiquitous and connected world. Consequently, 5G is expected to become a great impulse for this technology. The 5G standard features are expected to become a great impulse for IoT since they offer low latency (1 millisecond), increased bandwidth (10 to 100x improvement over 4G), high coverage and availability (even indoors) and low power consumption (European Telecommunications Standards Institute 2018). IoT offers the possibility of creating a fully connected "things" ecosystem that will improve the user experience of passengers. At the same time, it allows the interconnection between the different stakeholders of the airport operations, facilitating the best management of the resources. In relation to the PRM assistance service, IoT techniques can be developed in different areas such as: the geolocation of PRMs, the use of autonomous wheelchairs, and the custom signage, among others.
Recently, several papers have been published to evaluate IoT platforms and their technical features. Mineraud et al. (2016) present a comprehensive gap analysis of 39 platforms and define gaps and recommendations that providers should follow to enhance the platform performance. Da Cruz et al. (2018) provide a performance evaluation of five opensource IoT platforms. Ismail, Hamza and Kotb (2018) presents an overview and comparison between the ThingsBoard (ThingsBoard Inc 2019), and SiteWhere (SiteWhere LLC 2019), platforms.
With regard to wheelchairs, there is an opportunity to have mixed fleet of manual and autonomous chairs, all of them connected through IoT to the service management framework. One of the objectives of the research is the valuation of the impact of the use of

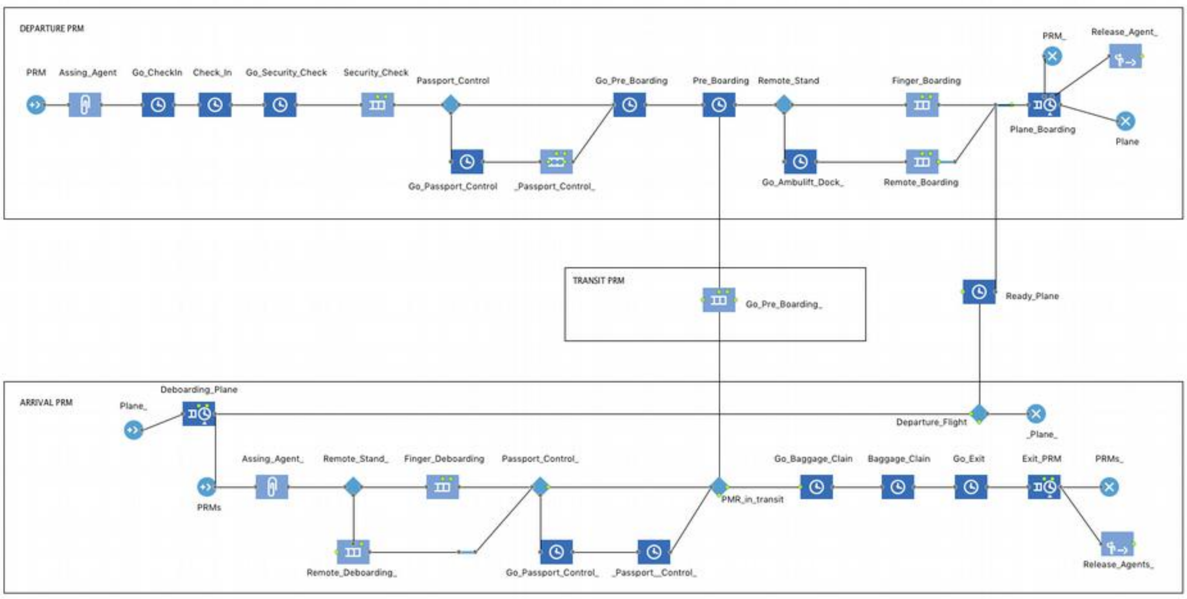

Figure 7: Model for the PRM assistance service

autonomous chairs through simulation, as well as quantifying the optimal implantation percentage with respect to the total number of wheelchairs.

Figure 8 shows a diagram of the proposed technological framework. In this proposal, the main actors and resources of the PRM assistance service (PRM, assistants, wheelchairs and ambulifts) would be connected to the IoT platform through 5G communications and an IoT gateway. In the case of wheelchairs and ambulifts, IoT devices would be installed; the attendees would connect through a mobile application since everyone has a cell phone to carry out their work, while PRMs could be connected through a mobile application or by means of an IoT device in smart card format.

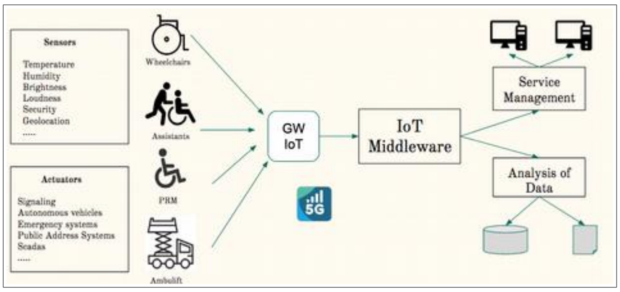

Figure 8: Proposal of technological framework

The IoT platform is responsible for organizing and processing all the data obtained from the actors and resources of the service (PRM, assistants, wheelchairs and ambulifts), and offering the information to the service management applications and data analysis systems.

This technological framework proposal will allow incorporating the management of other systems of an airport such as: parking, video surveillance, air conditioning, heating, among others. The sensors and actuators of these systems would be connected to the framework through IoT devices, which would use the IoT gateway to communicate with the IoT platform. In this way, the gateway and the IoT platform would be shared by all airport management systems and, in turn, data from a sensor or actuator could be reused in different management systems.

5. CONCLUSIONS

Airports are moving faster to adopt the latest technologies in order to improve their customer services. However, and despite the fact that current regulations highlight their importance, PRMs have not received enough attention in the design of such services. We have presented a conceptual model that will serve as a framework to assess, by means of modeling and simulation, the impact of 5G, IoT and automated wheelchairs on the assistance service of PRMs. We have also sketched the main features of a technological framework that will act as a central hub for these improvements.

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AUTHORS BIOGRAPHY

Juan José Herrera Martín received his B. Sc. and M. Sc. in Computer Engineering from Universidad de La Laguna, Spain, in 2004. He worked for AENA during five years, and he is now progressing towards his PhD by trying to develop new solutions that help improving the airport processes.

Iván Castilla-Rodríguez received his B. Sc. and M. Sc. in Computer Engineering from Universidad de La Laguna, Spain, in 2004. He obtained his PhD on Modeling and Simulation from the same university in 2010. He worked as Health Economic Modeler until 2015, when he returned to Universidad de La Laguna as Assistant Professor. His research fields include applying modeling, simulation and soft computing techniques to solve problems in any area but, especially, in health care.