RFID for Real Time Passenger Monitoring

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Abstract: - This article discuss the advantages of using Radio Frequency Identification (RFID) technology embedded on smart card to obtain relevant information about the movement of people who use public transport and thus extend the possibilities of seeking greater efficiency in operation of buses and permit to improve the services to meet the real necessities of passengers. The proposed scenario will permit to have proactive manage operations increasing bus comfort and transportation services reliability for users and allow the development of applications that will give for uses real time information about the bus comfort conditions (capacity) thus gathering information for planning and deciding travel options.

Key-Words: - Public Transportation, Planning, RFID, Passenger, Auto-identification, Smart Card

1 Introduction

The city of São Paulo is one of the largest urban agglomerations in the world and, as such, has problems related to the complex concentration and distribution of people, products, jobs, services, recreation and culture. The state of the art published references discusses changes that occur in urban spatial configurations in recent decades, and points out that the origins of different needs of people displacements change patterns, standards and the ways its population do their trips. Thus describes Taschner and Bogus (2001) on "the pattern of clustering on around the industrial concentration (Fordist accumulation) that has been affected by great economic transformations. The impact of the restructuring process, the global financing aspects and the formation of large markets have influenced the cities ". In fact, in São Paulo, the reduction of industrial activity in favor to the growth of service activities related, the timid decentralization of local jobs and expertise of local housing and moreover, public policies related to urban mobility, define the recent daily movements of people.

Improvements in public transport is one of the pillars for assuring adequate conditions of accessibility and mobility required by sustainable cities (MINISTRY OF CITIES, 2009). In this sense, within an appropriate accessibility and mobility plan, deployment and use of infrastructure and the implementation of public services closer to constantly seek (or necessary) requirements imposed by the urban transformations to meet the need for movement of people.
SERVICES OF PUBLIC TRANSPORTATION OF PASSENGERS

The city of São Paulo has a network of public transport (subway, trains and buses) that has been consolidated over the past years. On the bus system operated by Municipal Public Service, there are 1,350 lines and their routes are operated by distributed 15,000 buses in a road network of 4,500 km. These buses operate 190,000 daily trips linking origins and destinations of lines and through three million km per day, serving 3.7 million people on 9.5 million daily trips.

To meet the standards of public policy development in the city of São Paulo, the public management of the transportation sector bases the strategic level the planning of future transport network based on origin and destination data survey. The “Origin and Destination Survey”, or simply O/D survey, is held since 1967 in São Paulo metropolitan region, every ten years surveying trips made by the population of the metropolis in a typical work day. This represents the main trip information, serving as the main basis for transport studies planning (METRO, 2007). This information, added by demand forecast models, serve as a reference for the structural planning of the public transport system of the city. VAZ (1994) states that "governments generally solve the periodic crisis that involve some sectors of the population who depend on public transportation through superficial actions using new bus routes or modifying the existing routes." A strategic plan is needed promoting the reduction in the number of trips and the time of travel, the reduction in the use of personal transport and providing attractiveness to public transport, and improving the way how the transport system is used and operated. At the tactical level, according to BODMER & SEABRA (1995), "the traditional models of demand forecasting can provide a generic information, but are not suitable for operations planning."

Therefore, the use of the infrastructure available for the distribution of services of each route are planned according to demand and attraction points and are scheduled taking into account the distances to be traveled, vehicle service displacement times and the number of passengers to be transported. Already at the operational level, despite the complexity assigned by events such as heavy traffic, bad weather, public events, etc., managing its resources is broadly supported by ITS - Intelligent Transportation Systems. The buses that provide transportation service in the city have on-board equipment for data collection and operations control based on data from electronic ticketing AFC (Automatic Fare Collection) and vehicle locators and transmitters alerts from AVL (Automatic Vehicle Location). These devices enable online monitoring of operations and systematic analysis of the fleet, the distances and schedules achieved.

However, the automated data collection processing information on the vehicle occupancy of vehicles and measurements on origins and destinations of passengers are not yet available. Based on the need or desire to perform displacements, ANTP (1997) "highlights the need to know these information in order to development of plans and actions of transport and traffic." FERRAZ and TORRES (2004) states that "it is important to have updated frequently data in order to make a proper operational programming."

To overcome deficiencies, São Paulo Transporte SA - SPTrans, the city government company responsible for the management of bus public transportation, calls for specialized engineering services for the characterization and diagnosis of specific aspects of municipal bus services. Generally, these services are based on field research for important information for transportation planning (SPTRANS, 2010) such as:

a) Passengers boarding and alighting on bus stops: gather data on bus stops and diagnose the reasons for buses unable to board passengers at bus stops.

b) Frequency of buses and passengers in a route: diagnose the attendance of passengers on a given bus line through data collection at both ends of this route (initial and final) in a given period of time, recording schedules of buses, number of passengers boarding and alighting, and passengers with denied boarding. Also bus turnstile data should be recorded for each trip.

c) Password boarding and alighting: identify the highest passenger loads sectors of a given route, recording the bus stop where each passenger board or alight. A password is given to each passenger at boarding and alighting stops.

d) Origin and Destination: diagnose how a bus line attends passenger movement needs associating both trip and passengers origins and destinations. Data is obtained interviewing passengers on the their trip origins and destinations, and may include...
other bus lines or transportation modes used, frequency, times and reasons, etc.

e) User’s waiting times: verifies service levels based on waiting times at bus stops, including terminals.

Implementation of these surveys are financially costly and highly complex to organize.

Successive editions, amplitude and disaggregation of data: Detailing: obtained by disaggregation of information to enable the identification, particularize and play scenarios; Comprehensiveness: information to include the entire operation of the line, in both directions of travel during the course of service; Periodicity: the city is dynamic and creates, modifies and extinguishes need to travel at high frequency. The research needs constant updating.

SPTrans information technology group studies various technologies that can be applied to the solution of transportation problems. In these studies, they test communication systems, hardware and software that can be used in solving passenger identification and control problems, especially on using concepts and products of Auto-ID (Figure 1) that are being applied in different systems around the world.

Figure 1 - Overview of the most important procedures self-ID (RFID Handbook: Fundamentals and Applications in Contactless Smart Cards and Identification)

Among the opportunities presented, this article discusses a low cost RFID (Radio Frequency Identification) based solution associated to a smart card, that can remove deficiencies and difficulties in order to overcome the lack of important information on the displacement of passengers in the city, essential to transportation services tactical and operational management.

3 RFID Technology

RFID technology has been widely discussed in the technical community, and there are many works related to its description and application. It became relevant within sectors of the industry, trade, services and government, being widely used in a variety of applications: supply chain control (logistics), product tracking, tracing and authentication, access control, biometric identification, anti-theft systems, personal identification (passports), electronic payment cards and smartphones (NFC).

Briefly, it is based on the use of miniaturized components consisting of coils in the form of labels (TAG) or microchip transponders, reader or transceiver antennas and middleware modules. The use of this technology allows for objects to be located and identified through radiofrequency waves. The way of energizing the transponder can be classified as active, passive or semi active (or semi-passive). The focus of this article is the passive transponder (receiver), which uses radiofrequency waves emitted by antennas to activate it. From this moment on, the transponder will be able to initiate transactions with the reader. The frequency bands used are the LF – low frequency (125kHz) and HF – high frequency (13.56MHz) both used in contactless smart cards and proximity neighborhood, and UHF – ultra high frequency (860MHz - 960MHz ) applied on the EPC (Electronic Product Code) systems. Microwave (2.45 GHz) are also used in some applications.

Since 2004, the public transport fare payment in São Paulo is made through smart cards called "Bilhete Único" (Single Ticket). This card is quite popular among users of the city's transportation system and allows for fare payment on buses and subway trains. Seven million people daily use these cards to make their daily movements, and on the bus system, only 6% of the passenger demand eventually pays services in cash.

Facing the possible use of automatic RFID in smart cards, SPTrans invited the NXP Semiconductors, the company who owns of the technology used in the MIFARE “Bilhete Único” for a partnership in order the develop and test an effective solution.

MIFARE is a family cards for contactless electronic transaction (1KByte standard, standard and 4Kbyte UltraLigth) under the patent NXP Semiconductors.

3 Methodology

The proposal is based on having a RFID tag in the “Bilhete Único” smart card (Figure 2), thus
making it possible to read it and identify it at distances larger than one meter.

In the experiment – using an N-bit transponder, read only type – the microchip of each label (TAG) stores in its memory an unique sequential number associated with its “Bilhete Único” card number, thus allowing that, at the time of TAG reading, it conveys the transportation-identifying information to the reader. Thus, records obtained are associated only to the “Bilhete Único” which contains the TAG. Once processed, recordings collected by equipment installed in the buses will allow the identification of each passenger boarding and alighting locations.

Additionally, buses stops will also receive specific tags with an unique identification, thus allowing also for the identification of the infrastructure (route) used by each bus carrying a that activates the bus stop tag. Information on passenger card tags (“Bilhete Único”) collected at bus stops and not identified in the bus on route, will also allow estimating the number amount of users in bus stops and the average times for bus waiting.

The experiment using this technology will be carried out in three steps. The first will test the efficiency of the recovery of the identification tag inside and outside the vehicle environment, according to the scope of the spectrum. At this stage the location and positioning of antennas within the bus framework will be defined. In this process, on board ITS technologies will be associated with the operation of this new application, since they will depend on the provision of auxiliary data to compose main information such as time (day, hour, minute, second) and location (longitude and latitude) obtained both from the bus AVL and electronic fare payment transactions through the use of the smart card in the AFC reader. Considering possible systems and hardware interferences and restrictions, standards and settings for hardware location and operation within the bus will be achieved through testing.

Internally, the bus has installed a reader device capable of managing a number of data collection antennas. The number of antennas depends on the size of the vehicle and the number of doors. Through the antennas, an RFID reader can transmit radiofrequency waves and perform about 600 IDs by TAGS per second. Records thus collected through smart card tags will allow identifying the passenger approaching the bus for boarding, during its trip in the bus, and when it alights the bus and moves away from it (Figure 3).

The second step is to put in real bus commercial operation the standards and settings obtained before. A number (between 100 and 200 units) of “Bilhete Único” smart cards of volunteer users will receive labels affixed on them, and a vehicle will be equipped with tag readers and its antennas. The labels distributed must be registered and associated with the sequential number of the card for verification. Furthermore, the bus must be equipped with sensors on doors for loading and unloading systems (APC – automatic performance control), also being tested by SPTrans for technology comparison.

The third stage of the experiment will be the definition of the computational model for treating and processing of data collected, as well as the modeling of systems and infrastructure for data integration (AVL x AFC x APC). The amount of
data from RFID tags on a bus commercial trip is high, but only user data associated with vehicle boarding and alighting—i.e., the passenger first and last detection—are relevant. In this case, data collected by the RFID system will be treated, automatically deleting unnecessary. This deletion is the main function of the middleware, which will consist primarily of communications infrastructure, a hardware hosting systems analysis (application server) focused on data selection, purging of unserviceable data, and data storage. It is noteworthy that the activities of this step can start just after the first stage of the experiment.

The distribution architecture of the middleware mechanisms will depend on the form in which the data will be used. In the option where data collected is utilized online, the middleware will be concentrated in a central processing. Otherwise, it may be distributed on the bus garages and retransmitted timely to SPTrans central processing.

In the option of having records availowed online, the data collected is to be sent constantly by the bus AVL through GPRS communication to a central processing center. While needing greater investment, the records received in this way can be used by information systems to inform users, allowing them to know, for example, the level of bus passenger loads before the vehicle reaches the boarding point where the user waits. Another opportunity to take advantage of the data transmitted online form are activities that allows for the regulating bus services: Operations Control Centre – OCC can make real time decisions adjusting bus dispatching as a result of information provided by a computer system algorithm based on such data.

Otherwise, if records are available off-line, the processed data will be useful for OCC actions based on the statistical records expectation of the passenger displacements.

The basic architecture of relationships with data collected online or offline is illustrated in Figure 4:

![Figure 4 - Basic architecture of data collected by RFID tagged based on payment cards of the tariff.](image)

It is expected that studies from the recent partnership between SPTrans and NXP Semiconductors will demonstrate, through tests, experiments and simulations, the rate of effectiveness of technology implementation of self-radiofrequency identification in related approach in this article.

### 4 Conclusion

Looking beyond the bus automatic counting of passenger buses (APC) systems, prospects for the use of RFID technology in order to obtain information on passenger boarding and alighting in municipal public transport in the city of São Paulo is expected to promote greater efficiency in activities related to the management of bus services, both in the planning and programming services, in controlling and regulation functions that will improve services to transport users. It will allow filling the gap of important information on the characteristics of displacement of public transport users carrying out their daily trips. In this new scenario, it will be possible to proactively manage operations, increasing bus comfort and transportation services reliability for users.

Additionally, it will allow for the development of applications (systems) that will give transportation services user access to real-time information on bus comfort conditions (capacity), thus gathering important information for planning and deciding travel options.

On the other hand, the systematic use of passenger identification technology should supply, improve and innovate ways to collect data and produce knowledge on the characteristics of the displacement of passengers in order to constantly providing and updating them accurately. This new information generated will allow for dynamic adjustments in programming services in order to get the best conditions for commercial buses operations. This should enhance savings on the use of resources and, consequently, providing the best service to users.

The possibility of associating the “Bilhete Único” smart card to the bus boarding and alighting with their geographic location will enable construction of passengers displacement matrices. This management tool is unique and innovative, and will lead to improvements in how to regulate bus operations bring additional important benefits to plan the structure, infrastructure and services of the public transportation system.
As a next step it is expected that these experiments resulting from the partnership between NXP Semiconductors and SPTrans improving smart card identification technology through the use of RFID will soon generate data that can be analyzed will prove, or not, the efficiency of these experiments, allowing recommendations on its commercial application.

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