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Optional Expansion of The Automated Fare Collection System in Public Transportation

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ABSTRACT

The subject of this research is the automated fare collection system and the possibility of its expansion. The purpose of the work is the optional expansion of the automated fare collection system in public transort of the city of Kharkiv to improve the transport network based on the use of GPS tracker. The following tasks are solved in the article: analysis of the existing automated fare collection system, construction of the structure of the automated system, construction of the data exchange model between the server and the devices validating the system, assessing the capabilities of the existing system, developing an extension for further improvement of the system. The following methods are used: process modeling using the IDEF0 charts. The following results were obtained: The article proposes an optional extension of the automated fare collection system for public transport in the city of Kharkiv to improve the transport network based on the use of GPS tracker. The analysis of the working system and its possibilities is carried out, namely: the analysis of data flow exchange in the existing system has been performed in order to identify the possibilities of its expansion; the structure of the existing system of automated payment of travel has been developed. The proposed expansion is characterized by minimal costs, since it is based on an already functioning system, which enables the provision of full dispatching and logistics of public transport in the city of Kharkiv using the subsystem of analysis and processing of information. The system is characterized by the ability to optimize the route network by collecting and analyzing the statistics of travel paid , passenger traffic and behavioral models of passengers, as well as information on road conditions and routes. Conclusions: The proposed expansion of the automated payment system for public transport in the city of Kharkiv can be applied without changing the hardware base of the system, and will also achieve results such as increasing road safety, reducing time and energy resources costs for travel, improving vehicle comfort, increasing the competitiveness of carriers , improving public transport image.

Key words: automated fare collection system, automatic payment systems, GPS, electronic travel document, IDEF0.

1. INTRODUCTION

Nowadays, the lives of most citizens of the world is closely connected with the use of information systems. Due to the significant advances in information technology, the transport sector is undergoing significant changes: from smart ticket payments to new initiatives multimodal mobility and autonomous vehicles.

There is a rapid increase in the popularity of cashless settlement [20]. At the time when most financial settlements can be made even without leaving home, it becomes obvious that the method of payment of travel in transport with the help of a paper ticket is completely outdated.

This article presents solutions for increasing the efficiency of the use of the existing automated fare collection system (AFC)..

1.1 Final Stage

A wide range of publications on this subject emphasizes the importance and relevance of this study The articles in different areas of improvement of the AFC were analyzed.Thus, the work of Carmelo R. Garcia and Ricardo

Perez [2] describes an automatic payment system based on various mobile communication and information support devices that reduces operating costs through the use of local communication infrastructures and general-purpose devices. On the other hand, A. Gusev's and V. Sergeev.'s approach is to supplement the existing concept with the components of internal control for autonomous elements [3].

The goals of the development of AFC are to increase road safety, reduce time and energy consumption for travel, increase the level of comfort of vehicles, improve the competitiveness of carriers, improve the image of public transport.

Nowadays, the global changes occurre in the services sector, which are expressed in the reorientation of the market towards the consumer. This also applies to the sphere of transport services. In this regard, the application of new managerial decisions in creating conditions for the provision of transport services and public transport organization becomes essential. In particular, the improvement of the existing automated fare collection system for public transport services by involving modern methods of distribution, collection and processing of information. Improvement of the system aims at bringing it to such a level that it will be able to respond flexibly to the change of any components: density of passenger traffic, road conditions, routes etc..

2. Main Material

Many industries use new technologies in an effort to increase efficiency and attract consumers to use innovations. Nowadays, most developed countries use an automated payment and checking system for public transport as an alternative to cash payments.

The automated fare collection system is intended for fare payment and control, sale and replenishment of electronic travel document on the basis of contactless technology Mifare Plus, as well as sales of one-time travel document.

AFC is a new stage in the development of passenger transportation. The automated fare collection system plays an important role in the production activities of transport companies. They allow to transfer payments for travel in non-cash form, increase the efficiency and control of financial activities of transport companies, improve the culture and quality of passenger services. The automated fare collection systems allow to effectively deal with the problem of unlisted travel, forgery of travel document, as well as to carry out the most accurate accounting of the number of passengers in public transport, to accumulate, store and analyze this data [8].

The advantages of using the automated fare collection system are:

- Creation of an economically attractive and convenient fare system for passengers using modern technology.
- Upgrading the convenience and culture of passenger service. Attraction of new passengers and social groups to public transport.
- Ability to provide additional services and integration with other modes of transport.
- Providing the possibility of non-cash payment.
- Ability to optimize the operation of the route network through the analysis of passenger traffic.

Nowadays, automatic payment systems are introduced in many countries of the world, including Ukraine. One of the leading companies in the world involved in the manufacturing of equipment for the automated fare collection is the Czech Microelectronics Company. Equipment under the brand "Microelectronics" daily serves 30 million passengers in 30 countries, especially in Europe and South America.

One of the latest projects where the hardware and software solutions of Microelectronics Company have been used, is the project "Eticket" in the city of Kharkiv. The system of the single electronic ticket of Kharkiv has an architecture similar to that implemented in the Czech Republic and other large cities of the world. The main components of the AFC are:

- Electronic travel document (ETD).
- Validation systems for contactless electronic cards.
- ETD replenishment systems.
- System of analysis and processing of information.

The structure of the automated fare collection is shown in Figure 1.

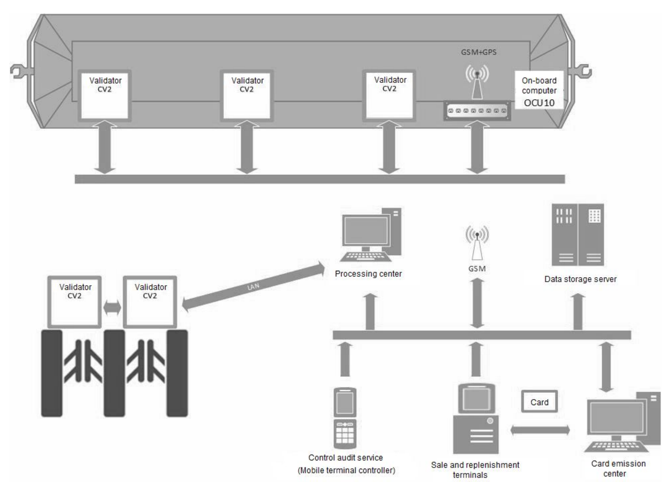

Figure 1: The structure of the automated payment system

2.1 The principle of the system

Ground transport is equipped with validators of contactless electronic cards. Systems use non-contact cards of the Mifare family. Contactless card Mifare PLUS is a plastic card, which works up to 10 cm away from the reader (card reader). The

PLUS card carries the UID, which is a unique identifier and additional memory that can be overwritten. The PLUS card provides standard security in smart card applications. The card can use the updated security level, the AES 128 algorithm for authentication, data integrity and encryption.

Information security of the validation system is provided using hardware SAM modules. They are equipped with devices that read contactless cards. The SAM module includes secure memory and supports cryptographic functions (encryption, electronic signature readout, authentication of electronic signatures, etc.) used to enhance the security of systems with contactless cards.

The keys are diversified, which means that each contactless card used in the system has its own unique key issued by the SAM module.

In addition, data stored on contactless cards has an electronic signature, and it is encrypted. The SAM module uses standard cryptographic algorithms for MAC signatures, for encoding 3DES and AES.

The system uses the FareOn control software. This software allows the system to continuously improve, optimize, adapt to changing conditions, and take full advantage of the new technologies potencial. FareOn effectively evaluates and uses the received operational data. Its high adaptability allows to program functions in accordance with the individual needs of the client. FareOn also provides the ability to import data from other systems and provides an efficient analysis of operational data. Openness of the system and the use of advanced standards facilitate the work with data (for example: XML), data exchange through web services, and integration with equipment subsystems such as payment terminals, information boards, etc.

On the ETD the required tariff is entered (full, preferential). In the future, the maps can be repeatedly replenished with the help of self-service devices.

In the public transport the passenger apply an ETD to the validator/turnstile. As a result, the fare is deducted or the availability of travel document is checked, payment information is recorded on the card and transmitted to the processing and issuing center. Also, the validator has the function of payment for another person (persons) and luggage.

The controller checks the payment on the card with a hand-held contactless electronic card reader. All information on sales statistics and the use of maps is collected automatically in the processing and issuing center and is displayed in the analytics system.

The cost-effectiveness of ASP is achieved by:
1. Downsizing of conductors.
2. Improving the effectiveness of control over travel fares.
3. Reduced costs for ticket products.

2.2 Analysis of communication channel load

To represent the transactions exchange process between the server and validation device, the model of data exchange between the server and validation device has been made, which is represented in notation IDEF0 (Figure 2). This model allows to understand how transactions occur in the system for further improvement.

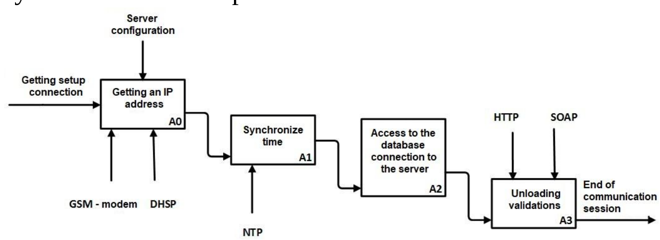

Figure 2 The model of data exchange between the server and validation device.

In such systems, for the provision of communication through GSM channels, the power of local telecommunications operators is used, which imposes certain restrictions on the volume, speed and data transmission volumes. Within this system, a tariff plan with a traffic restriction of 700 MB per month is used for each vehicle.

The current system analyzes the data exchange between the server and the validator for a complete 90-minute communication cycle.

The following main stages of data exchange can be distinguished:
1. Getting the IP address.
2. Time synchronization.
3. Access to the database connection.
4. Upload validation.

In this article, the loading of the communication channel at each stage will be analyzed.

At the first stage of obtaining an IP address, the network protocol DHCP is used. The device asks for an address to the server. The server, in return, receives the message of the device, defines the necessary configuration of the client in accordance with the initial settings and sends it to the device. At this stage, the device must select one of the configurations and send a request to the server. The server confirms the request and the device may apply the settings. In total, during the session, approximately 30 packets of a total volume of 9,000 bytes are transmitted.

The second step is to synchronize the current time with the server on the device for the correct transaction record. Time synchronization occurs immediately after receiving an IP address and then once per hour. The standard NTP protocol is used to synchronize time. This protocol provides high accuracy and reliability of the time synchronization service due to the availability of complex statistical algorithms and timing filtering.

One time synchronization session consists of 12 packets, 8 of which are directed to the server and 4 to the client. The total packet size in one session is 1080 bytes. Access to the database connection takes place once every 15 minutes.

Transmission of transactions to the server occurs every 90 minutes. Packet data transfer is used, namely the cross-platform SOAP protocol, which can be used in conjunction with other data transfer protocols. SOAP provides additional safeguards for the confidentiality and data integrity, and also offers built-in repetitive logic to offset unsuccessful data exchange attempts. One packet size is 1192 bytes.

The total amount of data uploaded to the server during one complete loop of communication is 150 kilobytes, and 70 kilobytes loaded on the device.

Thus, in order to ensure full functioning, the system uses only 220 kilobytes during one communication loop. Taking into account the dynamics of the growth in the number of transactions, one can predict that at a maximum load, the Internet traffic of one device will be about 500 megabytes. This provides the potential for the expansion of the functionality and additional download link.

To improve the system, it is suggested to introduce a navigation GPS system. The use of modern programmable controllers as part of the equipment makes the system unlimitedly flexible, opens up many opportunities for expansion of the system itself, as well as opportunities to provide it with additional functions. Existing hardware features allow to combine multiple systems into one software and hardware complex. The implementation of the GPS-tracking of the vehicles into the existing system is suggested [8]. This will make possible not only to track the movement of vehicles, but also to optimize the route network based on the analysis of paid trips, passenger traffic and passenger behavioral models.

Using the GPS module, it is planned to receive information about the location of the transport and transmit it to the processing center. Based on transport location information, bindings of statistics on the number of transactions to the transport route and its schedule can be utilized using certain algorithms to programmatically adjust the transport route, its traffic and idle time. Also, this system can be equipped with sensors for monitoring of transport resources, which will provide information on energy costs and the possibility of their usage optimisation.

The existing hardware of the AFC system has the necessary tools to obtain, store and process the necessary transaction information. Each unit of ground-based public transport is equipped with an on-board computer OCU-10. It, in return, is equipped with GPS and GSM antennas. GSM communicates with the processing center, where the recording of information processing in real time occurs.

After analyzing the capacity of the communication channel, it can be stated that this system has the ability to use a certain amount of traffic to transmit GPS coordinates from the device.
The transmission of one coordinates pair with system information takes 263 bytes. When sending GPS coordinates, every 10 seconds, in the current operating mode of vehicles, traffic consumption per month is about 50 megabytes. This is 9% of the total traffic, taking into account the transfer of GPS coordinates, and allows to use the system's functionality without changing the tariff plan.

To improve the software of an existing hardware base, the following features may be provided by the system:

1. Creation of a timetable for routes.
2. Operational control and management of vehicles on routes.
3. Control of the vehicles' availability in the section of each route in accordance with the approved schedule.
4. Availability of tools for detecting deviations from planned schedules on the line.
5. Traffic monitoring on the routes of controlled vehicles in real time.
6. Visualization of the location of all vehicles on the electronic plan of the area.
7. Control of driver's working time on the line.
8. Ability to load vector graphs of roads.
9. Storage and processing of navigation and telemetry data obtained from vehicles.
10. Receiving report data on the transport work performance.
11. View and analysis of the data in the archive, resolving controversial situations.

In future it is planned to expand the functionality of the system by introducing navigation for the driver, and an information board for passengers. Using the existing GPS tracker as the basis, passengers can be automatically notified about the route and its stops. For the driver it is planned to create a navigation program that will control the speed of transport and its route using data from traffic sensors and will provide guidance to the driver on optimal route decisions and speeds.

Referring to the information on the driver's working time on the line, it is possible to introduce a payroll system for employees in accordance with the data in the transport system. It can be achieved by improving the software, namely, by the implementation of algorithms that are based on the data from all routes for a certain period of time from the archive.

5. CONCLUSION

The existing automated fare payment system is flexible and has the ability to expand and align with other systems, using only its own hardware base, by improving the software. Implementation of the GPS navigation system will cause a 9% increase in channel traffic, which is entirely within the current system and will not require additional financial costs.

The use of additional functions based on GPS navigation will increase the competitiveness of the system and in the long run will allow to transfer the entire system of vehicles management and monitoring, as well as workers, into an electronic automated system.

Creation of the algorithm for a unified system of public transport monitoring includes:

1. Introduction of a single ticket system.
2. Creation of a program part of the GPS function.
3. Creation of software part for visual monitoring of public transport.
4. Creation of a program for statistical data accumulation and transactional bindings.
5. Dispatching of the transport.
6. Development of the program part of the payroll accounting function for public transport workers.

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