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BUILDING A CENTRALIZED SMART CITY SYSTEM FOR URBAN MOBILITY MANAGEMENT AND SOLVING PROBLEMS RELATED TO PARKING AREAS, PUBLIC TRANSPORT AND ECO-TRANSPORT

PART 2 - ALGORITHMS FOR VALIDATION OF TRANSPORT DOCUMENTS IN SMART CITY SYSTEM - PUBLIC URBAN TRANSPORT[26]

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Abstract: *The focus of this article is to examine in detail all possible cases and their respective Validation Algorithms for the different types of Transport Documents from the Smart City Public Transport System. Two main scenarios will be considered. The first one investigates the case with availability of an Internet connection (ONLINE VALIDATION), i.e., when we have a connection through the REST API to the central servers. The second scenario presents the functionality in the absence of Internet connection (OFFLINE VALIDATION), when local validation must be performed from the available hardware in the vehicle. Also, all the principles set for structuring the data parameters in the Electronic PD (Transport Documents) and in the physical carriers for Subscription - Mifare plastic cards will be considered in detail, in which the basic information about the Subscription itself is recorded and read, namely number of trips, period of validity, accessible lines, subscription card holder/user.*

Keywords: *Smart City, smart solutions, public transport, eco transport, LoraWan network, API and central database, smartphone app, Android, iOS, Validators, Centralized system, Web applications, Servers, efficiency, GPS*

INTRODUCTION

The growing implementation of smart technologies in every area of the modern urban environment requires the invention of increasingly universal and "cunning" ways for reliable yet simple methods for accessing numerous services only with the help of the smartphone of the average user (Buehler, R., & Pucher, J., 2017). Also, these technologies, in addition to providing the end user with access to many different services in this unified urban environment, must also offer diverse and reliable methods to pay for these same services (ERTICO, 1998a), again through the systems that make up the overall Smart City environment. The basis of the data exchange through the transport

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protocols are the algorithms or in other words the conditional logic and the rules, according to which the accesses and the payment of the services from the Smart City system are validated, in particular with an application in the Public Urban Transport (ERTICO, 1998b).

EXPOSITION

As already mentioned, the focus of this article is on the algorithms for validation of Transport Documents (PD) in the Smart City system of Public Transport or generally speaking the rules, by which the use and payment of services in the system is being carried out. Two main scenarios for PD validation will be considered and the division of these two scenarios is based solely on the presence or the lack of a communication link with the centralized servers of the system.

When vehicles from the public transport network are equipped with the full range of hardware and software devices from the Smart City system (Validator, driver terminal, 4G router) and these devices, respectively, have a permanent connection to the central server, communicating via the **REST API** and exchanging necessary information according to system-specific protocols, on the Request/ Response principle is being carried out. In this case, the connection is initiated by the devices that are part of the **EXTERIOR** system components, which send their requests to the central server, which in turn responds with the corresponding responses, based on the the commands contained in the individual requests. In no case is a connection initiated from the server to any device from the **EXTERIOR**.

It should be noted that the priority should always be **ONLINE** validation, because it can compare many more parameters and the relevant criteria to make a reliable decision whether a PD (Transport Document) is valid or not. **OFFLINE** validation should be a backup version of the **ONLINE** validation, in cases, such as failure of the Internet connection to the server, failure of the central servers themselves, failure of the return of a valid response from the servers, etc.

For example, calls for validation of PDs through the **REST API** can be made at:

https://XXX.XXX.XXX.XXX/api/trip-validation

In order to simplify and unify the protocol for all four individual cases, only one universal structure of the JSON object can be transmitted. Depending on the specific case, certain parameters of this structure can be used, while other will remain without the corresponding values and thus will not be used.

The sample structure of the JSON object that will be used for the unified command in ONLINE VALIDATION mode is as follows:

Request: {"aid": 1, "vid": 124, "department_id": 7, "department": "A6", "route_id": 85, "course_id": 23644, "trip_type": 3, "trip_id": 734675, "trip_uuid": "", "latitude": " 43.826565", "longitude": "25.9460161", "altitude": "0.78", "accuracy": "15.805000305176", "speed": "23.56", "timestamp": "14523452345"}

As follows for the following parameters of this JSON structure, the values will be set:

From the current systems stored in the validator's memory after the last retrieval with the get-current-department command from the tablet:
"aid": 1, "vid": 124, "department_id": 7, "department": "A6", "route_id": 85, "course_id": 23644,

From the current GPS coordinates taken by the Validator at the time of the event:
"latitude": " 43.826565","longitude": "25.9460161","altitude": "0.78""accuracy": "15.805000305176", "speed": "23.56","timestamp": "14523452345"

From the above JSON structure, there are 3 parameters that are filled in depending on the 4 types of trips with PD validated on the Validator: **"trip_type": 3, "trip_id": 734675,"trip_uuid": "**

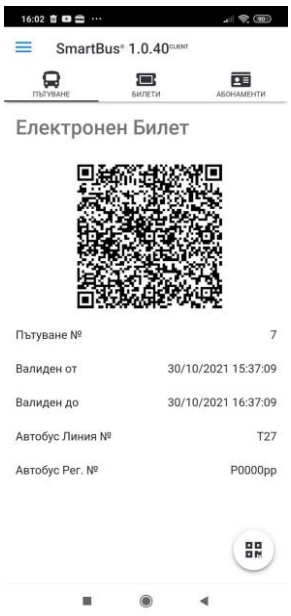

Fig. 1. Electronic Ticket

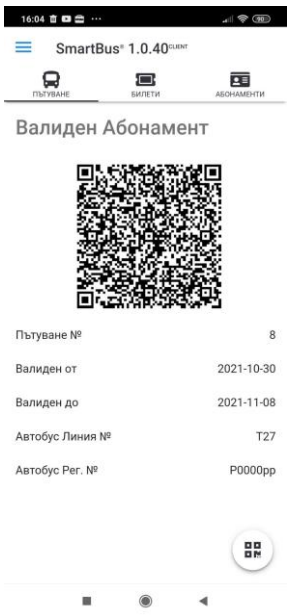

Fig. 2. Electronic Subscription

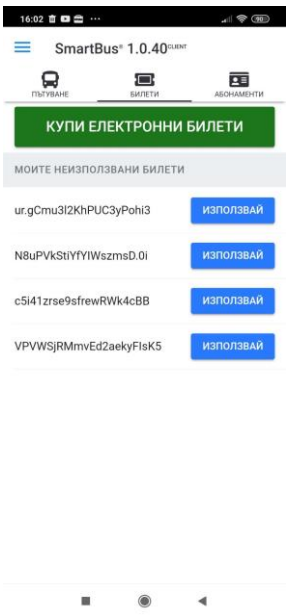

Fig. 3. Tickets Purchase

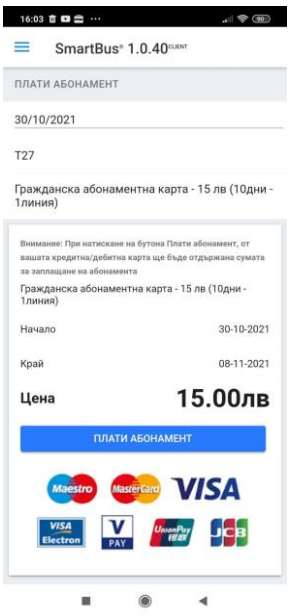

Fig. 4. My POS Payment Process

For cases (1 and 3) the QR code of the Validator generated by the client application (Android/ iOS) is scanned and the content of this QR code is a JSON object.

For the cases (2 and 4) when we have a physical medium Card Plastic / Paper Ticket and respectively the value read by the NFC reader / QR scanner is a serial number of a certain number of numbers and / or issued by a certain secret algorithm, the validity of which can be verified with checking the checksum.

1. Traveling with Electronic Subscription (trip_type = 1, Android App)

In this case (Fig. 2), the passenger has the client application from the Public Transport system installed on his smartphone and has accordingly purchased a Subscription Plan through it, or one is associated with its application, which was previously purchased through the ticket center. The corresponding QR CODE from the screen of the passenger's smartphone is scanned on the validator, as an example of the JSON object encoded in it is:

{"trip_type":1,"trip_id":"13", "subs_id":245, "from":"03/06/2021 06:58:26","to":"03/06/2021 07:58:26","line":"T24","plate_number":"P7777AP"}

The following items can be retrieved from this object: **"from": "03/06/2021 06:58:26", "to": "03/06/2021 07:58:26", "line": " T24 "** and respectively to check whether the current date falls between the period" from "and" to "and whether respectively the current line selected by the validator with the start of the change for the driver's day coincides with that extracted from the site. The subscription is valid, and in all other cases the subscription is invalid and the passenger should be fined.

As for the 3 parameters, the following are set from the read json object as follows:

"trip_type" = "trip_type", "trip_id" = "trip_id" (can be = 0, if the static code in the vehicle is not scanned in advance, but shows QR from its list of valid subscriptions) "trip_uuid" = "subs_id" - where subs_id is the ID of the electronic subscription in the system. The validation is performed by the

Central Server and the Response is returned, approving or rejecting the respective trip with this subscription, as this is displayed on the Validator / Driver Terminal screen with an appropriate message and an audible signal. If there is no **ONLINE** connection or no valid Response, the **OFFLINE** validation procedure is triggered, which is performed locally in the validator itself, only on the basis of the parameters read by the QR code.

2. Traveling with Plastic Card (trip_type = 2, Physical medium - Subscription)

The parameters stored in the Mifare card itself are read on the Validator and accordingly if there is an **ONLINE** connection a request is made to the server. Priority is given to the result returned by the server, if there is no **ONLINE** connection or no valid Response, the **OFFLINE** validation procedure is activated, which is performed locally in the validator itself, only based on the parameters read by the card itself. Similarly, in the plastic card we have information recorded for the Period of validity of the subscription, for the line or lines along the route for which it is valid and based on these criteria the trip will be accepted or rejected by the validator. In this case the type of subscription is also looked at and if it is limited by Number of trips, respectively through its NFC reader, the validator reads the system of the remaining number of trips, reduces it by 1 and writes the decremented system again in the card. This is an additional criterion for validity in case we have a plastic card with a Subscription, which is not of the Unlimited number of trips type.

Plastic card (Subscription) **Card Number** 248747867983
"trip_type" = 2, "trip_id" = 0 - submitted 0, "trip_uuid" = 248747867983 - submitted Card Number

3. Travel with Electronic Ticket (trip_type = 3, Android App)

Here we have 2 sub-cases depending on whether the passenger uses an electronic ticket generated by scanning a static QR code A) or uses a prepaid electronic ticket pre-purchased through Annex B)

A) Electronic ticket of scanned static QR code in the vehicle (Fig. 1)

In each vehicle, in addition to the availability of hardware and software, there are 1 or more static QR codes in the form of stickers affixed in the passenger compartment and are unique identifiers for the specific vehicle. This valid static QR code is scanned on the validator via the passenger's smartphone with Android App, which contains, for example, the following JSON:

{"aid":"1","vid":"24"}

which in itself identifies the system number and the vehicle number in that system and is a unique identifier for the vehicle itself. By scanning this static QR code, a request is made from the passenger's smartphone to the server, in which a combination of the parameters identifying the vehicle and respectively identifying the passenger through the parameters unique to his smartphone / application is submitted. In case the subscriber does not have an available subscription for the specific line and has a valid credit / debit card associated with its application, micropayment is automatically made through MyPOS (Fig. 4) for the value of 1 ticket (for example BGN 1.00) and immediately with confirmation of successful payment generates an electronic ticket. This e-ticket is displayed on the smartphone screen as a QR code, for example:

{"trip_type": 3, "trip_id": "11", "from": "03/06/2021 06:52:43", "to": "03/06/2021 07:52:43", " line ":" T24 "," plate_number ":" P7777AP "}

It should be noted that this case is possible not only for **ONLINE** validation and partly for **OFFLINE** VALIDATION (i.e., the validator is not connected to the central server for some reason), but at the same time the passenger's smartphone is connected through the application to the central

server to a valid e-ticket can be purchased and generated. Accordingly, when it is already visible on the Screen of the smartphone and is scanned on the Validator, the parameters "from" are extracted from it: "03/06/2021 06:52:43", "to": "03/06/2021 07: 52:43 "," line ":" T24 "and the validator offline decides to accept or reject this trip. The QR code from the passenger's phone Android App, which contains the following coded JSON object, is scanned on the Validator:

{"trip_type":3,"trip_id":"11","from":"03/06/2021 06:52:43","to":"03/06/2021 07:52:43","line":"T24", "plate_number":"P7777AP"}

B) Prepaid e-ticket (**Fig. 3)** - is the other case in which the passenger at some point in connection with a central server has purchased 1 or more e-tickets and they are available in the application of his smartphone and can use them at any time, respectively in this case can be fully used as in the **ONLINE** validation, as the parameters read for the electronic ticket are submitted to the server and it is now connected to a specific trip, line, route schedule and specific vehicle. It can also be used for **OFFLINE** validation**,** if possible, not only if the central server has failed for some reason or is stopped for maintenance, we have a situation in which the Validator and the client application of the passenger's smartphone do not communicate with the central server. ONLINE validation is again a priority. At the same time, the passenger from his application can choose from the list of pre-purchased tickets and use 1 electronic ticket. By selecting an e-ticket, it simultaneously disappears from this list and appears on the smartphone screen as a QR code, which is scanned on the Validator and the sample object to be read is:

{"trip_type": 3, "trip_id": 12, "from": "03/06/202106: 55: 37", "to": "03/06/2021 07:55:37", "line": "", "plate_number": ""}

Here from the object can be extracted the systems of **"from": "03/06/2021 06:58:26" "to": "03/06/2021 07:58:26"**. The JSON type objects have the same structure in both cases, but in B) there are no elements in the fields "line" and "plate_number", as it is an anonymous ticket at the time of purchase, respectively only the current date can be checked. falls between the period "from" and "to", while in sub-case A), a match on the current line is also checked. In both cases, each e-ticket is valid for 1 astronomical hour, and the beginning of this period (from) is set at the time of purchase (in case A) or the moment of choice of prepaid (in case B).

The QR code from the passenger's phone Android App, which contains the following coded JSON object, is scanned on the Validator:

{"trip_type":3,"trip_id":12,"from":"03/06/2021 06:55:37","to":"03/06/2021 07:55:37","line":"", "plate_number":""}

As for the 3 parameters, the following are set from the readed json object as follows:

"trip_type" = "trip_type", "trip_id" = "trip_id", "trip_uuid" = "" - left blank,
the system will automatically fill it in on the server with the UUID generated for this e-ticket which is something like:

W2CTm87wpEvcQfyrvyWQJsPB9nheh0g.A / E64

Unique hash string generated on the server according to a certain algorithm from the input data of the electronic ticket.

4. Travel with a Paper Ticket (trip_type = 4, Paper with QR code)

In this case we have a classic paper medium, which has a printed and small QR code in which its serial number is encoded, for example Paper ticket: 001000386001. This serial number should not be just a serial number of printings, but a number generated by a certain algorithm, which can be used to calculate the checksum.

When scanning the QR code of a paper ticket, a Request is made to the Central Server and there it is verified whether the ticket number is valid from the issued ones and whether it has no longer been used for re-travel in the system. This can only be checked in the **ONLINE** validation, otherwise in the **ONLINE** validation only the checksum will be checked, but not whether the ticket has already been used. Which at a later stage will only be registered as a violation.

Paper ticket № 001000386001

"trip_type" = 4, "trip_id" = 0 - submit 0, "trip_uuid" = 001000386001 - ticket number

5. We should provide here a 5 special case, which has nothing to do with all the others so far and this is in order to eventually replace the scanned QR codes containing JSON objects (Electronic subscriptions and electronic tickets from the client Android application) with encrypted string from kind of:

W2CTm87wpEvcQfyrvyWQJsPB9nheh0g.A / E64

This can be done at a later stage, in the presence of a reliable algorithm for encrypting and decrypting the server and, accordingly, to contain the necessary parameters. That is why it is good to anticipate and bet from now on in the Validator, in which case things will not be different from those with a Plastic Card (Subscription) or a Paper Ticket.

If a string of the type is extracted from the scanned QR code:

W2CTm87wpEvcQfyrvyWQJsPB9nheh0g.A / E64

it should set 3 parameters:

"trip_type" = 0 - 0 is passed
"trip_id" = 0 - 0 is passed
"trip_uuid" = "W2CTm87wpEvcQfyrvyWQJsPB9nheh0g.A / E64" - submit string

All the above cases are used in the case of ONLINE VALIDATION, forming the appropriate JSON structure as described above and sending to:

https://XXX.XXX.XXX.XXX/api/trip-validation

Response is returned from the centralized system for Valid or INVALID travel, respectively.

CONCLUSION

Even when designing a Smart City system in Public Urban Transport, in addition to emphasizing the reliability of hardware and communication protocols, special attention should be paid to the design of the Algorithms themselves, which implement all business logic in the system. The algorithms themselves must be both logical and as simple as possible, because if they are too complex, this reflects on the functionality and user interface of the final software products, which in turn makes it difficult for both end users and employees who work with the software in this system. Simplified Algorithms, in turn, will be more reliable in the operation of the system, and higher reliability leads to lower maintenance costs and increased efficiency.

Therefore, many different technologies are used in such a system, both software and hardware, and they must be carefully selected by design engineers at the design stage to ensure high reliability

and long life at a later stage for a period of operation at minimal cost for maintenance. Only under these conditions would the system be efficient and reliable and would have a high return on initial investment and therefore a profit. Therefore, from the very beginning of the design of the system, special attention should be paid to each aspect, be it from the point of view of hardware or software, be it from the point of view of communication protocols and technologies for implementation or from the point of view of business processes and user logic described by the Algorithms in the system.

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