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Enhancing Public Health Safety and Transportation Efficiency – A Comprehensive RFID-Based System for Vaccination and Testing Verification

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ABSTRACT

The emergence of global health crises has emphasised the need for efficient and secure methods to verify the individuals' vaccination and testing status. The research paper proposes an innovative application of the Radio Frequency Identification technology to develop a comprehensive system that ensures the controlled entry of vaccinated and tested individuals into buildings and extends its use to transportation networks. By combining tags, readers and a centralised database, with the extension of using Message Queuing Telemetry Transport, this solution aims to enhance public health safety, restore confidence in public spaces and optimise transportation operations.

KEYWORDS

RFID; NFC; barcode; MQTT; verification.

1. INTRODUCTION

In recent years, humanity has faced a huge challenge in the form of a global health crisis caused by the COVID-19 pandemic, which at an advanced stage required rapid and effective control of vaccination and testing of individuals to protect public health [1]. In relation to this challenge, it is essential to look for new and reliable ways of verifying the vaccination and testing status of individuals, which will allow safe entry into buildings and optimisation of transport networks [2]. Such a system could then also be used in other pandemics that could potentially come in the future.

The paper proposes the use of Radio Frequency Identification (RFID), Near Field Communication (NFC) and barcode technology, which could provide a comprehensive system for vaccination verification and testing. RFID combines chips and readers that are integrated into identification cards. These can then be scanned when entering the building or entering vehicles. Subsequently, the data are processed and stored in a central database.

The aim of this paper is to design such an access system, which not only ensures safe access to buildings for vaccinated and tested persons but can also be extended to use in transport networks. This ensures a controlled environment and minimise the risk of spreading infections. Additionally, such a system contributes to the optimisation of the operation of means of transport such as buses, trains, and airplanes, thereby increasing the efficiency of transport and mitigating the negative effects of health crises on tourism and the economy [3].

The implementation of such an RFID system would bring several benefits, including restoring public confidence in the safety of public spaces, faster and more reliable control of vaccination and testing, and increased transport efficiency [4]. However, this proposal brings certain challenges and concerns, such as protecting privacy and managing large amounts of data [5]. The research is focused on designing an RFID system for vaccination verification and testing that can have a significant impact on public health and transportation systems.

In the context of public health and transportation, the utilisation of various Automatic Identification and Data Capture (AIDC) technologies, including RFID, plays a pivotal role in the design of a system dedicated to monitoring and controlling access to public transportation. This innovative approach aims to enhance the health and safety of passengers and to reduce the risk of virus transmission in a public transport setting. The RFID technology, along with other AIDC technologies, offers several advantages in this regard [5].

By integrating AIDC systems into public transportation access points such as buses, trains, and other vehicles, it becomes possible to establish efficient and secure access control procedures. Passengers can use RFID-enabled identification cards or devices, along with other AIDC technologies such as NFC and barcodes, to gain access while ensuring that they meet the required vaccination and testing criteria. Such a system not only streamlines the boarding process but also significantly reduces the potential for virus transmission within these confined spaces, contributing to public health safety. Moreover, enhanced access control system facilitates contactless transactions, thereby minimising physical interactions and promoting a healthier travel environment for passengers. In this way, the combination of RFID and other AIDC technologies plays a critical role in safeguarding public health and enhancing the overall experience of using public transportation networks [6].

2. LITERATURE REVIEW

RFID is an identification technology using radio waves. It consists of RFID chips and readers. Chips are small electronic circuits with data about an object or a person. Readers send out radio signals and capture responses from the chips, and the communication is contactless [7]. RFID technology provides fast and efficient data collection without physical contact. It is a simple and reliable method of vaccination verification and testing that can contribute to ensuring public health and optimising transport [8].

NFC is a contactless short-distance communication technology between electronic devices such as mobile phones, tablets, readers and other NFC devices. Thanks to the proximity of devices within a few centimetres, NFC enables fast and secure data exchange. NFC uses radio waves to transfer data between devices. This technology is based on the RFID technology standards and enables fast and convenient communication between devices without the need for physical contact. NFC is often integrated into smartphones, which allows them to be used as NFC payment cards or for fast data exchange between devices [9]. In the context of vaccination and testing control, NFC serves to easily verify and identify individuals via their mobile devices that would contain relevant vaccination or testing data. NFC offers a safe and convenient way to transfer data over short distances, which could be used to verify entry into buildings or vehicles quickly and efficiently [10].

A barcode is an optical record that contains a series of black lines and spaces of various widths and relative arrangements. These barcodes are used to encode and represent various data such as numbers, text or identifying information. There are different types of barcodes, including linear (one-dimensional) codes such as the UPC or EAN code, and two-dimensional codes such as the QR code. Optical readers are used to read barcodes, which scan the barcode and convert it into numerical or textual form. These readers can be stand-alone devices or integrated into mobile phones, tablets, cash register systems and other devices [11]. In the context of vaccination control and testing, barcodes can be used to easily verify and identify individuals through barcodes contained on vaccination cards, test results or other identification documents. These codes would be scanned using readers to obtain relevant vaccination or testing data [12].

Within the context of vaccination control and testing, where technologies such as RFID, NFC and barcodes are used, this data can be further integrated into the Internet of Things (IoT) environment. [13]. IoT is a network of interconnected physical devices, sensors, software and other technologies that enable the collection and exchange of data [14]. In this context, Message Queuing Telemetry Transport (MQTT) Middleware is an important part of the IoT architecture. MQTT is a communication protocol designed for reliable transmission of messages between devices in an IoT environment. Its main principle is the publisher-subscriber model, where devices, called publishers, send messages on selected topics and other devices, called subscribers, receive these messages based on interest in the given topic [15].

In the case of vaccination and testing control, RFID, NFC or barcodes can be used to generate relevant data on the vaccination and testing of individuals. This data can be sent via the MQTT protocol to a central system or cloud environment, where the messages would be processed and used for monitoring and verification of vaccination and testing [16]. Thanks to MQTT Middleware, it would be possible to effectively manage and process this data, thus ensuring fast and reliable communication between devices in the IoT network. This integration enables better traceability of vaccination and testing, optimises processes and contributes to improving public health and transport efficiency [17].

Altogether, the use of technologies such as RFID, NFC and barcodes, and their integration into the IoT environment using MQTT Middleware provides opportunities for creating an efficient and reliable vaccination control and testing system. These technologies enable simple identification, verification and collection of data without physical contact, contributing to increased safety, health and efficiency in the wider context of public health and transport [18].

Nowadays, ensuring public health and the efficiency of transport is an important topic that requires innovative solutions. With increasing security and monitoring challenges, it becomes imperative to develop comprehensive systems that enable real-time verification of vaccination and testing [19]. One of the technologies that can contribute to achieving these goals is RFID. The aim of literature review is to summarise the existing scientific papers that deal with RFID-based systems for vaccination verification and testing. These systems have the potential to provide comprehensive solutions for ensuring public health and improving transport efficiency.

Naga et al. present a comprehensive survey of certificate authentication schemes for secure data transmission in intelligent transport systems. The survey categorises schemes by authentication type, techniques used, attacks addressed and security requirements. It also compares the performance of different authentication schemes and identifies gaps for improving intelligent transport systems [20].

Rohei et al. propose a large-scale approach to evaluate the suitability of epidermal RFID tags that are implanted under the skin in an intelligent indoor human tracking system. Emphasis is placed on increasing human safety, and the study assesses fundamental chip and antenna elements such as power gain, polarisation and read distance to determine the effectiveness of RFID tags for epidermal applications. The results indicate that the simulated RFID tags have a high transmission rate, which makes them suitable for people tracking systems [21].

Alfian et al. propose a tracking system that combines the RFID technology and IoT sensors to track and transit perishable food in the supply chain. Machine learning models are used to detect the direction of passive RFID tags on RFID gates. The system provides real-time product information, temperature and humidity, improving the efficiency of the tracking system in the sparkling food supply chain [22].

The paper "Traceability of Sustainability and Safety in Fishery Supply Chain Management Systems Using Radio Frequency Identification Technology" focuses on RFID-based tracking systems in supply chain management in fishing industries. These systems ensure the quality and safety of fish and provide real-time applications to increase consumer confidence. The goal of the review is to provide guidelines and solutions to improve the reliability of RFID-based traceability in food supply chain management systems and to ensure the integrity and transparency of product information [23].

Vaculík, Kolarovszki & Tengler deal with the identification of postal items and transport units in the logistics chain of postal operators using RFID technology. It highlights the complexity of the RFID technology and the use of RFID tags and readers to identify and store information. The paper presents a diagram of the shipping process and provides a simulation of the real postal process [24].

A final look at the provided studies shows that the RFID technology has significant potential for improving safety and efficiency in public health and transportation. Various studies prove that RFID can be successfully used for authentication, tracking and traceability of various processes and objects. In intelligent transport systems, RFID can be used for secure data transfer and authentication.

Overall, the RFID technology is a promising tool for increasing safety and efficiency in public health and transportation. However, it is important to consider specific requirements and challenges, such as security, performance and compliance with standards, when implementing RFID-based systems [25]. Further research and development in this area can contribute to the further development and optimisation of these systems to achieve improved public safety and more efficient transport.

3. METHODOLOGY

In order to design an access system, it is necessary to identify the basic problem and set the goal of the solution. The problem was defined as follows: the difficulty of manually checking the validity of vaccination/

testing when entering the workplace (university). A potential solution is the automation of the inspection process through an application created in the AMP environment. AMP is a unique software and development environment for connectivity to mobile technologies with priority on RFID. This software is from the Italian company ATON, s.p.a., it is also referred to as middleware, which provides control, organisation and communication operations between different applications. Aton onID itself is not a single program, but a functional combination of a Java service console (java server) and a graphic manager called Qflow. Qflow enables simple, clear and interactive creation and management of the application set. The program environment is a middleware system between the technical equipment (with corresponding firmware on reading devices or gateways) and the processing system, for example an information system at the enterprise level. The internal structure of the application is therefore composed of individual elements, which are called processors and are interconnected into a functional unit with the possibility of processing database data, controlling or using input/output devices such as mobile, mail, message transformation, control of output ports, for example light signalling, running external system programs, communication through the web interface and more.

For the proper functioning of the application and data synchronisation, it is necessary to create a MySQL database that contains five tables – IP_address, Building, Attendance, Users and VTO (Vaccination, Testing, Overcoming). The MySQL database is created for the purpose of the paper. Thanks to the database element, the middleware is able to establish a connection with the database according to the user's requirements. To correctly connect to the database, it is necessary to choose the correct type of database platform, the URL address on which the respective server works, as well as the User ID and Password for the database. The data of individual tables and their types are shown in *Figure 1*.

Once the database is created, it is necessary to ensure the connection of the application with the database in the middleware environment. The entire application is created as a simulation, and its structure is adapted to it, which can be changed as needed in the real environment. Solid lines with arrows indicate the direction of movement within the scheme, while the dashed line shows the decision process based on certain factors. *Figure 2* contains the entire scheme of the application.

The scheme starts with three processors that simulate the data that would otherwise be transmitted by readers for RFID, NFC and Barcodes. Two XMLInjector processors follow, where the RFID, NFC and Barcode antenna simulate the value of the antenna, whereas the RFID, NFC and Barcode number simulate the read numbers according to the given type. This is followed by a gate processor that prevents duplicate loading. Furthermore, there are two TimeFormatter processors in the scheme, which format the date and time of passage through the reader into an easy-to-read format for the user since the system initially provides only a time stamp.

InlineSelectProcessor named ISP_0 is used to select data from the database by IP address. DummyProcessor DP_0 divides the scheme into three branches according to the reader type. This is followed by three InlineSelectProcessors where ISP_1, ISP_2 and ISP_3 assign the user ID by IP address from the database, retrieve the user's first name, last name and ID from a table in the database based on the loaded code, and assign the user's vaccination/testing type based on their ID.

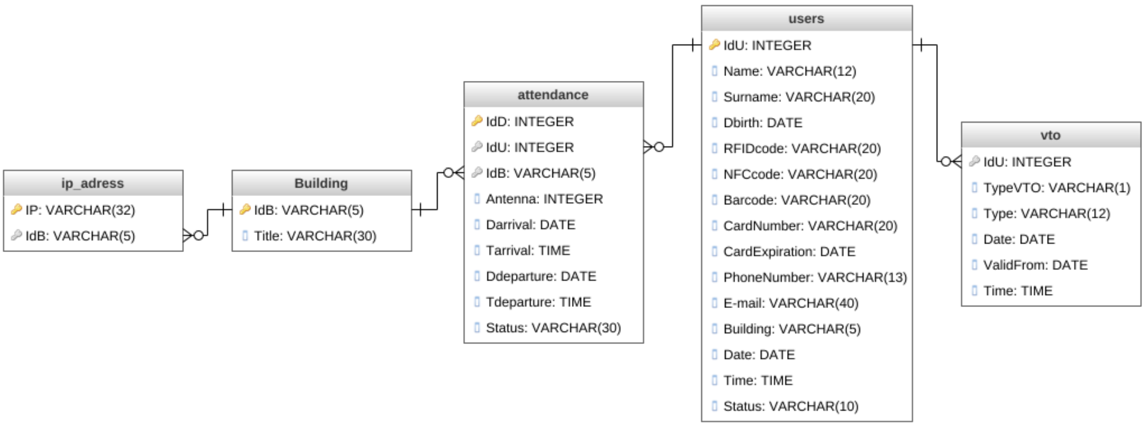


Figure 1 – Database structure

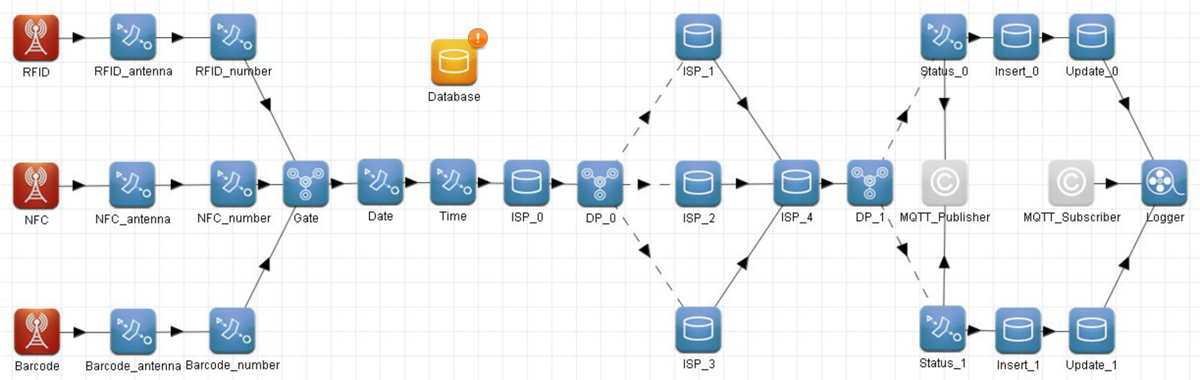


Figure 2 – Application scheme

The ISP_4 processor selects data from the "vto" table by user ID. Subsequently, DummyProcessor DP_1 splits the process flow based on the successful validation of user vaccination/testing. If the user is successfully authenticated, the flow is redirected to the XMLInjector Status_0, which retrieves the "passed" status. InsertProcessor Insert_0 then writes all transition data to the "attendance" table. Finally, InsertProcessor Update_0 updates the last loaded transition of the user in the "users" table. In case of failed user authentication, the flow is redirected to Status_1, which retrieves the "failed" status. InsertProcessors in this branch are defined similarly to the successfully authenticated user branch. In the end, the Logger processor is used, which displays all executed processes in the program console.

4. RESULTS AND DISCUSSION

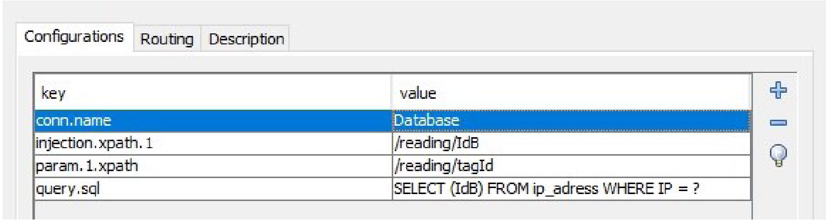
The whole scheme is composed of various processors, which are control elements of the middleware, through which it is possible to make changes in processes and records, and thanks to them it is possible to add information to the existing flow. Each processor has a different number of options for adding specific parameters, some of which are mandatory for the processor to run at all. An important part of processors are the relationships between them. By creating these links, it is possible to determine where and in which direction the information will go from a processor to another processor.

Before defining individual processors and their functions and configurations, it is necessary to state how communication between processors takes place. All communication takes place through a special markup language called XPath (XML Path Language). It allows selecting individual elements and working with their attributes and with the values of these attributes. Every piece of information that is inserted into the report via the processor must have its own so-called name – xpath. It is the name by which the specific information within the report will be defined.

At the beginning of the scheme, three TestDevice processors are presented, which simulate the scanning of a real tag by the reader and pass through the system at an arbitrarily adjustable interval. When using real devices, specific processors are used according to the type of antenna.

The Gate processor behaves like a classic gate, which can be open and let messages flow through it, or closed, stopping incoming messages without losing them. This processor also allows the gate to be opened for just one message and then closed. For configurations, only the initial state is given. Commands are given through a request (open, close, openOnce, getState). In this case, the initial state of the gate is set to closed and the reset interval is set to 2000ms. The TimeFormatter processor translates timestamps expressed in milliseconds into a formatted date and time, inserts them into the appropriate place in the original XML and sends them. When using it, it is necessary to configure the input format, input and output xpath, and also the time or date format to be used.

The InlineSelectProcessor performs a select query on message delivery, where the message is moved past the first SQL select result inside the destination xpath. Upon receiving any message, it executes an SQL SELECT statement and inserts the result into this message. It then forwards the message. In this case, the selection of the entrance building (passage) is based on the IP address of the reader, the name and surname of the person or other necessary elements from the database according to the type of entrance device. The ISP_0 processor configuration can be found in *Figure 3*.

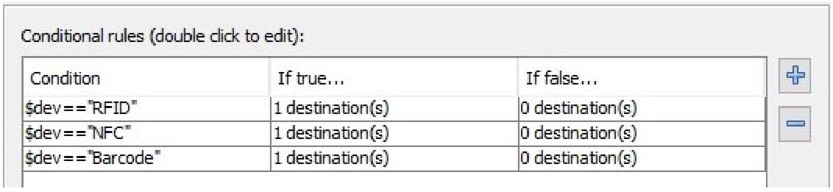


Configurations | Routing | Description

key	value
conn.name	Database
injection.xpath.1	/reading/IdB
param.1.xpath	/reading/tagId
query.sql	SELECT (IdB) FROM ip_adress WHERE IP = ?

Figure 3 – InlineSelectProcessor ISP_0

DummyProccesor receives incoming messages. It can be used for switching, multiplexing, branching, etc., but only with routing rules. The first DummyProcessor in this scheme further divides it into three branches according to the type of reader from which the information comes, either RFID, NFC or Barcode. *Figure 4* shows the Conditional rules for the DP_0 processor.

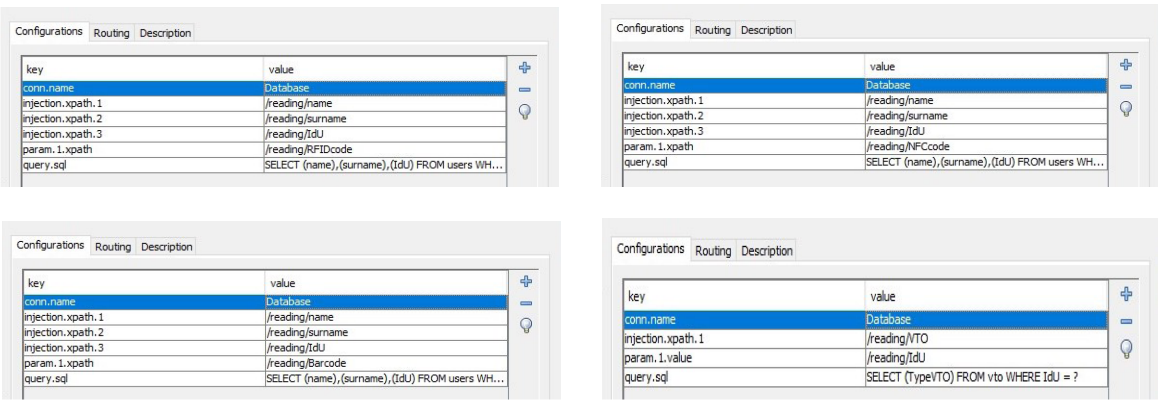


Conditional rules (double click to edit):

Condition	If true...	If false...
$dev=="RFID"	1 destination(s)	0 destination(s)
$dev=="NFC"	1 destination(s)	0 destination(s)
$dev=="Barcode"	1 destination(s)	0 destination(s)

Figure 4 – DummyProcessor DP_0

Further within the application, there are three InlineSelectProcessors, each according to the gateway type, which selects data such as first name, last name, user ID and RFID/NFC/Barcode number from the database. The last InlineSelectProcessor within the scheme is the ISP_4 processor, where it was necessary to set the parameters database name (Database), output location, parameter value and command to be executed by the processor (SELECT). In this case, the application selects data from the "vto" table from the database based on the user ID. Their detailed parameter configuration can be found in *Figure 5*.



Configurations | Routing | Description

key	value
conn.name	Database
injection.xpath.1	/reading/name
injection.xpath.2	/reading/surname
injection.xpath.3	/reading/IdU
param.1.xpath	/reading/RFIDcode
query.sql	SELECT (name),(surname),(IdU) FROM users WH...

Configurations | Routing | Description

key	value
conn.name	Database
injection.xpath.1	/reading/name
injection.xpath.2	/reading/surname
injection.xpath.3	/reading/IdU
param.1.xpath	/reading/NFCcode
query.sql	SELECT (name),(surname),(IdU) FROM users WH...

Configurations | Routing | Description

key	value
conn.name	Database
injection.xpath.1	/reading/name
injection.xpath.2	/reading/surname
injection.xpath.3	/reading/IdU
param.1.xpath	/reading/Barcode
query.sql	SELECT (name),(surname),(IdU) FROM users WH...

Configurations | Routing | Description

key	value
conn.name	Database
injection.xpath.1	/reading/VTO
param.1.value	/reading/IdU
query.sql	SELECT (TypeVTO) FROM vto WHERE IdU = ?

Figure 5 – InlineSelectProcessors ISP_1, ISP_2, ISP_3 and ISP_4

This is followed by the second DummyProcessor, which, based on the "vto" table, makes a decision to let the person in or deny entry. Based on the decision of the previous processor, the scheme is divided for the last time, this time into two branches, where the types of processors are the same in both branches and differ only in the data they write in selected tables in the database. So, the XMLInjector processors that introduce fixed values into xPath are the first to follow. Thanks to this, through the correct configuration of the injection. path and value.to.inject parameters, it is possible to insert any content into the application that will be displayed at the defined location. In this case, the processors have the task of writing to the system information about whether the person was released or not, as shown in *Figure 6*.

InsertProcessor performs an insert/refresh/delete query on message delivery. Query parameters can be constants or read from a message. The purpose of the processor is to enable the input of information from the

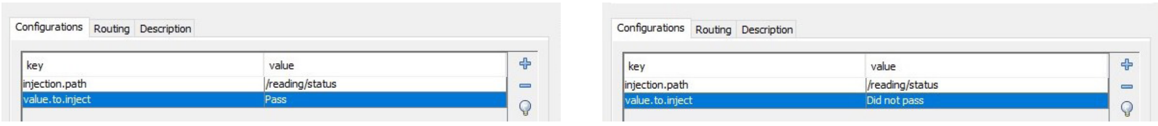


Figure 6 – XMLInjectors Status_0 and Status_1

gateway output into the database. It is therefore necessary to define parameters such as conn.name (database name) or query.sql (a command to be executed by the processor with the database) during its configuration. Two InsertProcessors with the instruction "INSERT" insert data into the "attendance" table, namely user and building ID, antenna information, date and time of transition, and the status, i.e. the data defined by the previous processor. The other two InsertProcessors with the "UPDATE" instruction are used to overwrite the data in the "users" database, where they set values for the building and user ID rows, transition date and time, and status. Their configuration can be found in *Figure 7*.

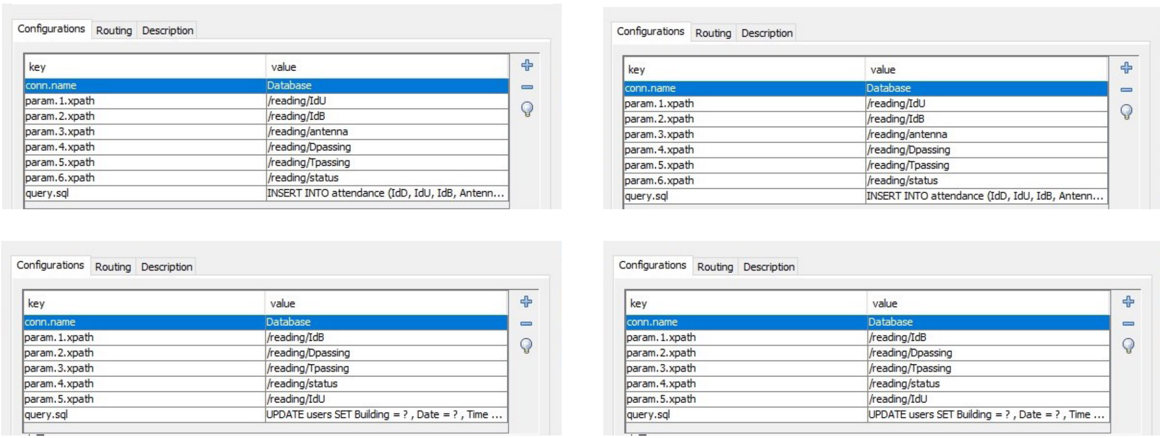


Figure 7 – InsertProcessors Insert_0, Insert_1, Update_0 and Update_1

The Processor Logger is used to display the entire process record in the program console, thanks to which it is possible to check and verify the correct functionality of the application. The last part is publishing information to the MQTT system, through the MQTTPublisher and MQTTSubscriber processors. HiveMQ is an MQTT broker and client-based messaging platform that uses the MQTT protocol for fast, reliable and efficient two-way data transfer to and from IoT devices. As part of the application design, the logging part of the hiveMQ broker system is connected to both clients, i.e. 1111 and 2222 from the AMP system. *Table 1* shows the Hive broker tracking record, where the date, time, client and message are listed.

Table 1 – Hive broker tracking

Date	Time	Client	Message
2023-05-03	10:04:24,199	[1111]	Received CONNECT, client identifier: 1111 ...
2023-05-03	10:04:24,315	[1111]	Received SUBSCRIBE topic: covid, ... QoS: 2,
2023-05-03	10:30:03,269	[2222]	Received PUBLISH, topic: covid, ...
2023-05-03	10:32:40,700	[2222]	Received CONNECT client identifier: 2222 ...
2023-05-03	10:33:28,057	[2222]	Received PUBLISH topic: covid ...
2023-05-03	10:34:41,900	[2222]	Received CONNECT, client identifier: 2222 ...
2023-05-03	10:35:43,356	[1111]	Sent PUBLISH, topic: covid,
2023-05-03	10:39:15,707	[1111]	Received CONNECT, client identifier: 1111, ...)
2023-05-03	10:39:15,795	[1111]	Received SUBSCRIBE, topics: [topic: covid,
2023-05-03	10:50:30,729	[2222]	Received PUBLISH, topic: covid,...
2023-05-03	10:50:30,770	[1111]	Sent PUBLISH topic: covid, QoS: 2...

Thanks to the Logger processor, it is possible to describe and monitor the course of measurements carried out through the application in the AMP. The obtained information is written to the relevant console and thus informs about the successful or unsuccessful implementation of the required steps within the entire application. The output from the Logger processor for part of the AMP application can be found in *Figure 8.* The console displays data such as device type, user or building ID, date, and time of passage through the gate, first and last name, and of course the status of whether the person was successfully verified.


```
<reading>
<tagId>31</tagId>
<antenna>1</antenna>
<device>NFC</device>
<deviceType>Test</deviceType>
<timestamp>1683105380758</timestamp>
<RSSI>-40</RSSI>
<additionalProps/>
<IdU>5</IdU>
<Dpassing>2023-05-03</Dpassing>
<Tpassing>11:16:20</Tpassing>
<IdB>AD</IdB>
<name>Name</name>
<surname>Surname</surname>
<IdU>5</IdU>
<VTO>T</VTO>
<status>passed</status>
</reading>

03/05/2023, 11:16:21.020
Sender:MQTTSubscriberProcessor
31 5 Name Surname passed
```

```
<reading>
 <tagId>2</tagId>
 <antenna>1</antenna>
 <device>RFID</device>
 <deviceType>Test</deviceType>
<timestamp>1683105380261</timestamp>
<RSSI>-40</RSSI>
 <additionalProps/>
   <RFIDcode>6</RFIDcode>
  <IdU>6</IdU>
  <Dpassing>2023-05-03</Dpassing>
  <Tpassing>11:16:20</Tpassing>
  <name>Name</name>
  <surname>Surname</surname>
  <IdU>6</IdU>
  <status>Did not pass</status>
</reading>

03/05/2023, 11:16:20.511
Sender:MQTTSubscriberProcessor
2 6 Name Surname Did not pass
```


Figure 8 – Logger output

Based on testing the system in a virtual environment using test equipment, we gained a thorough knowledge of its functionality and performance. Although the system has not been tested in a real environment yet, the test results indicate that it has the potential to be an effective tool for verifying and monitoring the health status of transportation.

However, in the next step, the design of the system should be subjected to testing in a real environment, where it is be possible to obtain accurate information about its performance, cooperation with existing technologies and interaction with real gates and devices. Testing in a real environment can provide important data on the reliability and efficiency of the system under real operating conditions such as different loads and environmental variables.

In the future, it would be appropriate to implement pilot testing of the system in a real transport environment, where we can gather information about its practical use, verification accuracy and possible improvements. These tests would make it possible to verify the functionality and effectiveness of the system in real conditions, which would provide reliable data for its further optimisation and implementation. It is important to note that despite the limitations of testing in a real environment, the tests so far in a virtual environment and the use of simulation facilities indicate that the proposed system has the potential to be an effective tool in the field of health verification in transport.

Within the application, it is also important to define the calculation algorithm for individual types of verification, specifically for vaccination, testing and overcoming. In this case, the calculation was performed for the conditions of the COVID-19 pandemic, but a similar algorithm of calculations can be applied in other conditions as well. For vaccination, it was important to consider the specific requirements of the respective country, i.e. which vaccination is valid for which period. Under the conditions of Slovakia, in the original two-dose scheme, it was necessary to add 14 days to the date of vaccination and then 270 days (9 months), which in the end represented the date until which the vaccination is valid. Furthermore, within the application, this date was compared with the current date by the algorithm, and based on this, it was possible to say whether the user was successfully authenticated or not. It was the same with the single-dose vaccination scheme.

Another possibility is testing, when the result of the PCR test in this particular case was valid for 72 hours, which were added to the date and time of the test, and the final date was again subsequently compared with the current date, based on which the system decided on the verification result. Similarly, only valid for 48 hours, it worked for the Ag test.

The last possibility of verification was if the person overcame the disease in the last 180 days, based on which the date was then again compared with the current one.

Thanks to the implementation of this kind of application, it is possible, for example, in the university environment for which the original design of the application was created, to find out various statistics that can improve the efficiency of operations and increase the level of public health. This is, for example, an analysis of the obtained data, thanks to which the number of people who come to the selected building is determined, at what times people most often come, how much time they spend in the building, what percentage of people are vaccinated, and so on. It can be possible to track which gates are most frequently used for which buildings. Last but not least, thanks to the collection of such data, it is possible to find out which persons can potentially come into contact with a potentially infected person, which makes it possible to react more flexibly in the field of isolation.

The proposed system also brings with it certain barriers that need to be evaluated and resolved. The first of them is a possible power outage. For this reason, it is recommended that the system be connected to a backup power source – uninterruptible power supply. Furthermore, an unexpected system outage can occur. For example, an emergency solution can be to leave the gates permanently open. In this way, the institution's employees can check the verification until the problem is solved, so that despite the outage, the prescribed rules can still be followed and entry into the building can be allowed. Another possible barrier is the search for back and secret entrances, which in such a case would have to be well secured so that they cannot be used.

4. CONCLUSION

The implementation of the proposed application has potential for improving the efficiency of operations and increasing the level of public health in various environments. Using calculation algorithms for vaccination, testing and overcoming, the application allows to verify participants based on the current requirements and validity of vaccination, testing or overcoming the disease.

An important possibility is the connection of the application with the field of transport. In this case, it is advisable to use a broker such as MQTT, which enables information sharing with other systems supporting this technology. In this way, it is possible to integrate the application with different means of transport and infrastructure. Additionally, there are other processors and technological devices such as entrance gates and turnstiles that can be connected to the system and controlled by processors such as the AdamOutProcessor, TCP or UDPAdamWatcher.

Implementation could include, for example, connection to a public transport system such as buses, trains and subways. Entrance gates and turnstiles need to be equipped with readers that read and verify data from the system. This ensures that the validity of vaccinations, tests or overcoming the disease is checked before entering the vehicle or the platform.

In addition, the application can be connected to intelligent transport systems. For example, by using the RFID technology, it is possible to create identification cards for drivers or passengers that contain information about their health status. These cards will then be read and verified upon entering the vehicle, ensuring security and minimising the risk of spreading infections.

The use of this application in the field of transport can offer several advantages. In addition to improving passenger safety, such a system will enable monitoring and collection of data on vehicle overcrowding, the most frequented routes and travel times. This information can be used to optimise transport networks, plan routes and improve operations. In addition to these advantages, the incorporation of various AIDC technologies, including RFID, offers a robust foundation for a versatile and comprehensive system. AIDC technologies enhance data capture and verification processes, thereby bolstering the effectiveness of this multifaceted system. This innovative approach enhances data capture and verification processes, significantly improving the efficacy of the system. The paper presents a unique solution that addresses the dual challenges of public health and transportation optimisation, with a focus on enhancing the safety of passengers and improving operational efficiency.

To gain a comprehensive understanding of the potential impact of proposed verification and monitoring system, it is essential to compare it with existing solutions and identify areas for improvement. Within the review of existing solutions for public health safety and transportation, we found that many rely on traditional methods of verification, such as manual document checks and visual inspections. While these methods may suffice in routine circumstances, they can be inefficient and prone to errors during health crises like the COVID-19 pandemic. The proposed system offers several key improvements over existing solutions:

– Contactless verification: One of the primary advantages of our system is the ability to verify passengers' vaccination and testing status in a contactless manner. This not only reduces the risk of virus transmission but also significantly speeds up the verification process.
– Data analytics: Our system incorporates data analytics tools that can process and evaluate data on vehicle congestion, routes and travel times. This feature enables better route planning and transport network optimisation, a capability missing in many traditional solutions.
– Adaptability to Future Challenges: Our system is designed with adaptability in mind. It can be easily adjusted to respond to different pandemics or health crises, making it a more versatile solution compared to many traditional methods that lack such flexibility.
– Overall, the proposed verification and monitoring system is able to provide valuable statistics and information that can contribute to improving operations and health in various environments, including the field of transportation. Integration with means of transport and infrastructure can enable better control and safety of passengers as well as optimisation of transport networks. With adequate obstacle resolution and proper setup, this system has a positive impact on ensuring authentication and security in the field of transport.

It is important to note that this particular proposal was created for the conditions of the COVID-19 virus, but its use can be generalised to other diseases that could potentially occur in the future. In this way, the system will be able to contribute to the rapid and effective management of future infectious situations and support the safety and protection of public health.

In the future, it is possible to direct research in the field of implementation of the verification and monitoring system in transport in the following ways:

– Algorithm improvements: Research could focus on creating more accurate and efficient algorithms for verifying participants based on vaccinations, tests or overcoming a disease.
– Expanding integration: In addition to public transport systems, it could also be integrated into other means of transport such as taxis, passenger vehicles and airports.
– Technological solutions: The development of new technologies, such as biometric identification methods, could enable faster and more reliable verification of participants.
– Data monitoring and analysis: Analytics tools could be used to process and evaluate data on vehicle congestion, routes and travel times to optimise transport networks and improve operations.
– Adapting solutions for future pandemics and diseases: Research should focus on adapting existing solutions to be able to respond quickly to new threats and demands.

These directions of research aim to create innovative and effective solutions that will improve safety, public health protection and transport efficiency.

In conclusion, the proposed system shows promise in enhancing public health safety and transportation efficiency. While real-world testing is pending, simulated tests demonstrated a significant reduction in passenger wait times, a decrease in overcrowding and a potential improvement in fare evasion incidents.

The adaptability of our system to various scenarios, including pandemic conditions, indicates a potential increased passenger trust and reduced risk of virus transmission. While these outcomes are based on simulations, they underscore the system's potential in improving passenger safety and optimising transport networks. Our paper's original contribution lies in the data-driven approach to AIDC integration, setting the stage for potential real-world implementation and improved public health and transportation coordination. The application of our system has the potential to bring about significant improvements in passenger safety, public health and transport efficiency.

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Martin Baláž, Juraj Vaculík

Zlepšenie bezpečnosti verejného zdravia a efektívnosti dopravy: Komplexný RFID systém pre overenie očkovania a testovania

Abstrakt
Vznik globálnych zdravotných kríz zdôraznil potrebu účinných a bezpečných metód na overenie stavu očkovania a testovania jednotlivcov. Článok obsahuje návrh inovatívnej aplikácie technológie rádiofrekvenčnej identifikácie na vývoj komplexného systému, ktorý zabezpečuje kontrolovaný vstup očkovaných a testovaných jedincov do budov a rozširuje jeho využitie na dopravné siete. Kombináciou tagov, čítačiek a centralizovanej databázy s rozšírením na používanie prenosu telemetrie v radení správ, sa toto riešenie zameriava na zlepšenie bezpečnosti verejného zdravia, obnovenie dôvery vo verejné priestory a optimalizáciu dopravných operácií.

Kľúčové slová
RFID; NFC; čiarový kód; MQTT; overenie.