11th International Conference on Electrical, Electronics and Computer Engineering (IcETRAN), Nis, 3-6 June 2024

Realization of Software System for Synchronization of Mandatory Vaccination in the Republic of Serbia

Aleksandar Veljanovski
Faculty of Electronic Engineering
University of Nis
Aleksandra Medvedeva 14, 18000 Nis, Serbia
aleksandar.veljanovski@elfak.ni.ac.rs
& ORCID 0009-0004-5840-0928

Aleksandar Milenković
Faculty of Electronic Engineering
University of Nis
Aleksandra Medvedeva 14, 18000 Nis, Serbia
aleksandar.milenkovic@elfak.ni.ac.rs
& ORCID 0000-0003-1796-7536

Marija Veljanovski
Faculty of Electronic Engineering
University of Nis
Aleksandra Medvedeva 14, 18000 Nis, Serbia
marija.veljanovski@elfak.ni.ac.rs
&ORCID 0009-0007-3091-0207

Dragan Janković
Faculty of Electronic Engineering
University of Nis
Aleksandra Medvedeva 14, 18000 Nis, Serbia
dragan.jankovic@elfak.ni.ac.rs &
ORCID 0000-0003-1198-0174

Petar Rajković
Faculty of Electronic Engineering
University of Nis
Aleksandra Medvedeva 14, 18000 Nis, Serbia
petar.rajkovic@elfak.ni.ac.rs &ORCID
0000-0003-4998-2036

***Abstract*—The vaccination that covers a significant percentage of the population has helped eliminate some severe diseases infamous for the extremely high spread rate and death toll. On the other hand, vaccination, as a process, is performed to make previously common diseases rare. Monitoring the vaccination process is necessary to track and ensure the progress of a protection rate among the general population is protected. This paper presents the realization of a software system for the synchronization of vaccination data gathered in the local medical information systems (MIS) with the central state data repository system of Serbia. Data synchronization can be performed in synchronized or unsynchronized mode. The described functionality is implemented as part of MIS MEDIS-NET, actively tested, and used in the live environment.**

Keywords— vaccination, synchronization, MIS, EHR, MEDIS.NET, IZJZS, BATUT

I. INTRODUCTION

Vaccination is considered one of the most cost-effective public health interventions. If a high percentage of the population is vaccinated against infectious diseases, it is more likely that disease outbreaks won't happen. This is often called 'community immunity' or 'herd immunity'. However, even if the vaccine does not protect 100% against some diseases, it protects against severe illness and, in some cases, death. Also, the vaccinated population prevents diseases from spreading across the population, which minimizes the chances for vulnerable people to contract a disease. People with weak immune systems, cancer patients, young children, older adults, and people who cannot be vaccinated for medical reasons are all at risk when diseases start spreading through the population. These people can be helped by vaccinating the rest of the population. Widespread vaccination is responsible for eliminating smallpox and polio from Europe and making previously common diseases become rare [1].

As a result of a variety of causes, regular vaccination has been on the decline in recent years, which leaves room for outbreaks of epidemics of forgotten diseases. For example, the whooping cough epidemic in Belgrade began in 2024 [2]. Urgent vaccination is necessary to provide 'herd immunity'. However, to take concrete further steps, it is necessary to have accurate data on the vaccinated population. Therefore, the first step is to make vaccination statistics available in one place. To improve the percentage of the vaccinated population Institute of Public Health of Serbia – "Dr Milan Jovanovic Batut", the original name "Institut za javno zdravlje Srbije", (IZJZS) [3] implemented a complete information system that enables integration with local MIS. In the scope of this paper, only the part regarding the vaccination data is explained. IZJZS exposes the service for CRUD operations of vaccination data and catalogues of possible values that should be used. Once the IZJZS has accurate data, it can plan the next steps. Based on this data it can be concluded:

1. The vaccination percentage is satisfied, and 'herd immunity' is provided.

2. The vaccination percentage is not satisfied yet; a possible epidemic/pandemic is at the doorstep of the outbreak.

The MIS MEDIS.NET [4-7] is developed and constantly improved at the Faculty of Electronic Engineering in Nis in the Laboratory for Medical Informatics and represents one of the licensed MIS for use in primary healthcare by the Ministry of Health of the Republic of Serbia. MIS was not obligated to support the collection of vaccinated data. Nevertheless, MEDIS.NET supported collecting vaccination data for mandatory vaccination according to the prescribed mandatory vaccination calendar of the Republic of Serbia (Table. 1). This vaccination calendar is rigorous, and IZJZS provides it. Although collecting vaccination data was enabled, not all primary healthcare institutions used this functionality. The existing functionality did not fully support the required functionality of the IZJZS. Most of the data is supported but certain specificities are missing or were not mandatory in the previous use. At the end of each year, IZJZS publishes a new vaccination calendar for the following year. In most cases, calendars are the same. Possible changes include new vaccines based on World Health Organization [8] recommendations and vaccine availability in the Republic of Serbia. With publishing a new vaccination calendar, is published for which patients are valid, for example, born after the 1st of January 2024. This makes tracking mandatory vaccines challenging.

This work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia [grant number 451-03-65/2024-03/200102].

TABLE I. MANDATORY IMMUNIZATION

Calendar of Mandatory Immunization in the Republic of Serbia	
Age	***Type of vaccine***
At birth	BCG HB + HBIG
2nd month	HB (2nd dosage)
3rd month	DTP (1st dosage) OPV (1st dosage) Hib (1st dosage)
after 3.5 months	DTP (2nd dosage) OPV (2nd dosage) Hib (2nd dosage)
5th month	DTP (3rd dosage) OPV (3rd dosage) Hib (3rd dosage) HB (3rd dosage)
2nd year (12 to 15 months)	MMR
2nd year (2 months after MMR)	DTP (1st revaccination) OPV (1st revaccination)
7th year (before elementary school)	DTP (2nd revaccination) OPV (2nd revaccination) MMR (revaccination)
12th year (6th grade elementary school)	HB (vaccination for those who didn't receive vaccination in 0,1, 6 months)
14th year (8th grade elementary school)	dT (3rd revaccination) OPV (3rd revaccination)

This paper presents the realization of gathering vaccination data in MIS MEDIS.NET and synchronization with IZJZS.

II. COLLABORATION OF MIS AND IZJZS

Physicians, in general, can prescribe a vaccination by using MIS. Patients can accept vaccination or reject it. As shown in Table 1, mandatory vaccination is for the minors. In the case of a minor, the patient's parents can accept or reject vaccination or some of the vaccines. In the case of acceptance, the most common case is that the patient goes to the vaccination room. The vaccination staff performs vaccination and fills in all the necessary data. All collected data is sent to the IZJZS (Fig. 1). If it is necessary, sent data can be revoked (deleted from IZJZS) or altered (updated at IZJZS). In this way, IZJZS can have live data regarding vaccination.

Based on the current situation, it is possible to predict the status of the vaccinated population. One of the possible steps is to generate promotional content (ads) that supports the importance of vaccination and promote vaccination in schools and public events. Prepare medicines supplies in case of an infection outbreak and prepare emergency medical personnel for potential epidemic / pandemic crises. World Health Organization (WHO) proposing the following steps to increase the percentage of vaccination coverage [9]:

- Invest in the management of national vaccination programs
- Invest in advanced immunization information systems able to track each person's immunization status
- Invest in strategies to immunize under-vaccinated and unvaccinated persons
- Invest in modernizing vaccine supply chains.

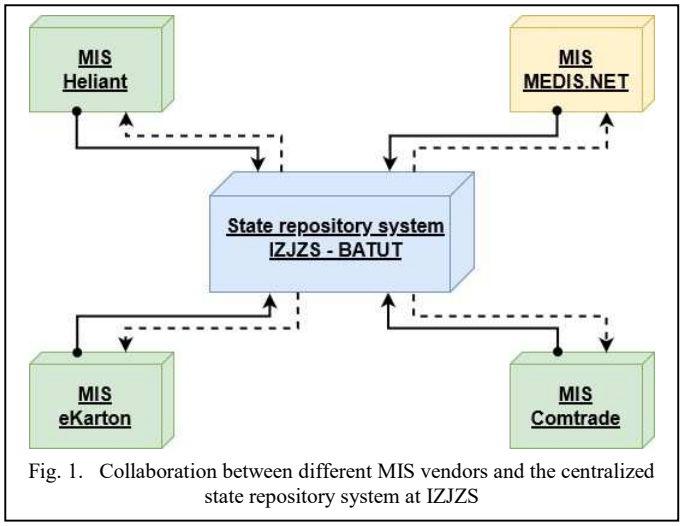

Fig. 1. Collaboration between different MIS vendors and the centralized state repository system at IZJZS

III. IMPLEMENTATION OF VACCINATION AND SYNCHRONIZATION DATA IN MIS MEDIS.NET

Patient tracking in MIS MEDIS.NET tries to reflect the exact patient's moves within the medical institution. The patient starts the flow in MIS once it is registered and added to the waiting room of the desired physician by the medical nurse. The waiting room is represented as a list of patients to be examined. The physician takes the next patient from the list by FIFO order and opens his electronic health record (EHR). In an emergency, the

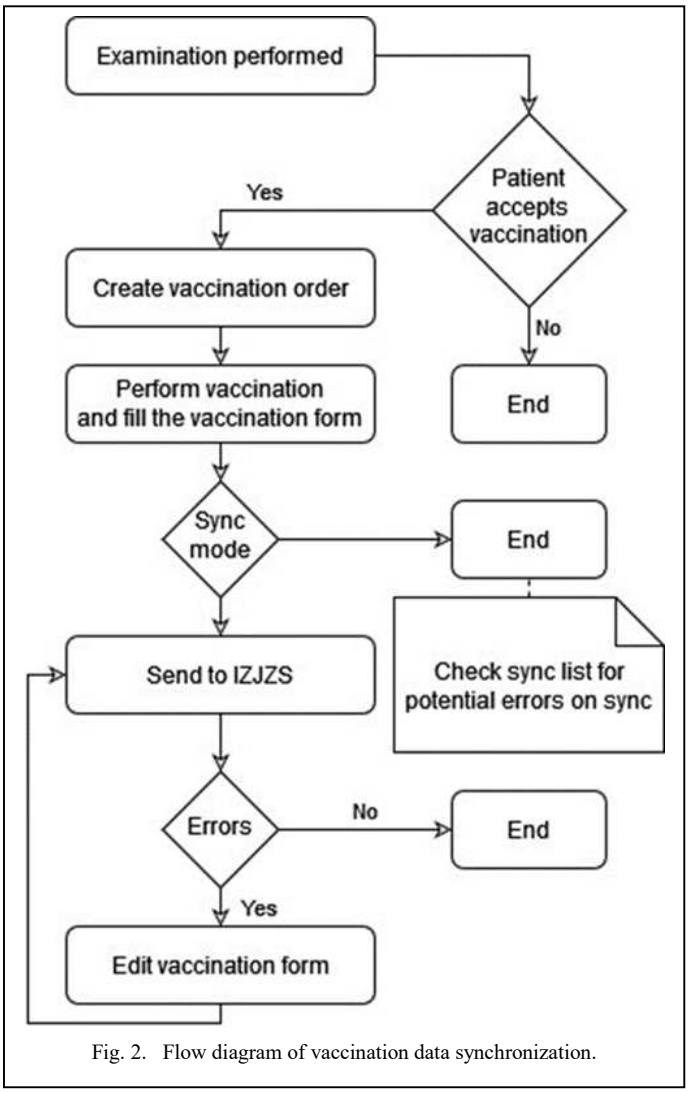

Fig. 2. Flow diagram of vaccination data synchronization.

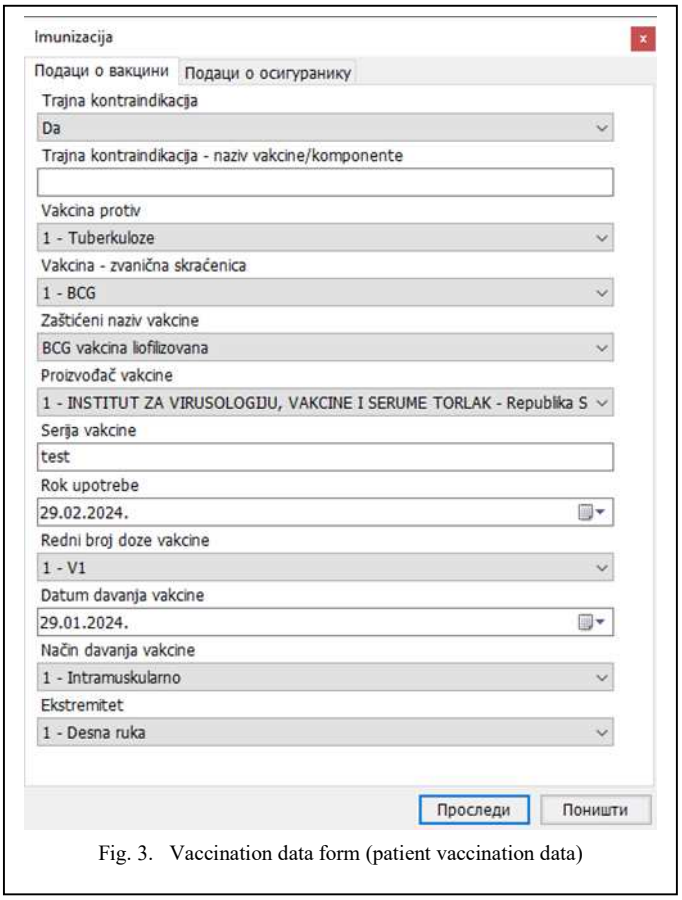

Fig. 3. Vaccination data form (patient vaccination data)

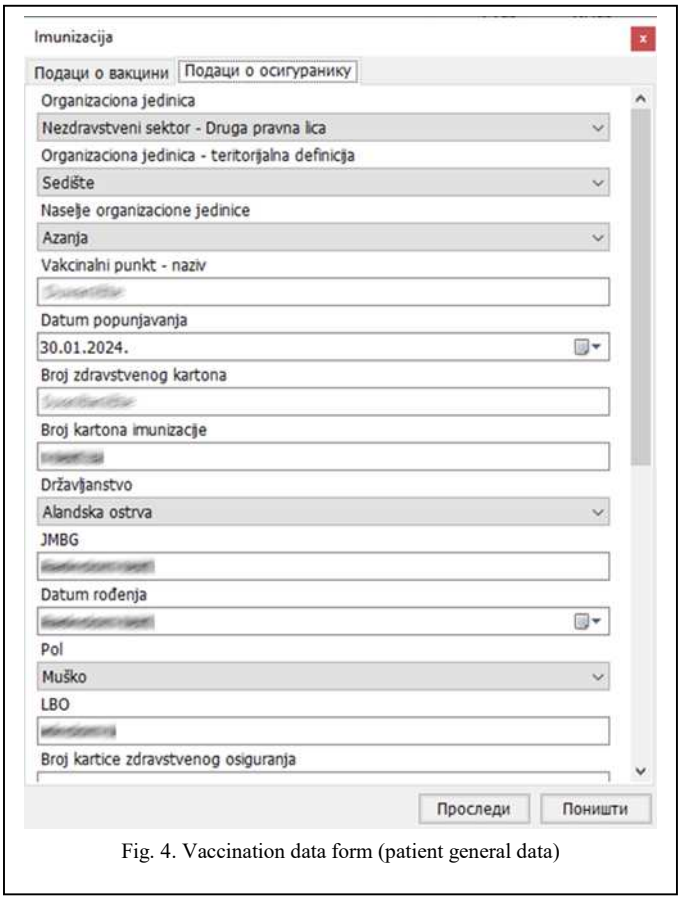

Fig. 4. Vaccination data form (patient general data)

physician does not have to follow the FIFO order of patients. The physician can choose required actions from the EHR, such as regular examinations, systematic examinations, clinical trials, vaccination prescriptions, etc. To prescribe vaccination, the physician must examine the patient. Vaccination may be postponed or not applicable depending on the patient's health status. Only healthy patients can receive vaccination. It is not suggested that vaccinations be mixed with other medicaments. In some extreme cases, this is allowed but finally, the physician must approve it. Once the physician determines that vaccination can be processed, the patient has the final word by accepting or declining vaccination (Fig. 2). In case of acceptance, the physician creates a vaccination order for the required vaccine.

To receive the vaccination, the patient goes to the vaccination room. With an active vaccination order, vaccination staff performs vaccination and inquiries necessary data to MIS. Fig. 3 shows the official name of the vaccine (e.g. BSG, HB, DTP, DTaP, Hib), against which illness, vaccine medication name, vaccine manufacturer, serial number, expiration date, number of dosages, method of vaccine administration, and extremity. In case that contraindication exists, this needs to be filed, too. In most cases, this is added later when and if it happens.

Other than vaccination data, patient data must be inquired. Some of the required patient data are displayed in Fig. 4, like the organization unit in the facility, territory definition, location, query date, nationality, social ID, health ID, sex, name, surname, etc. Most of this data already exists in the MIS. However, necessary data are not gathered in the MIS or cannot be inquired from other systems that are synchronized with MIS. Also, the existing functionality in MEDIS.NET did not use the same catalogues of values that IZJZS gives. This requires that some existing data needs to be reentered by medical staff.

Once the necessary data is collected, it can be sent to IZJZS. In the case of synchronized mode, data are sent right away, and in the case of errors, vaccination staff has the opportunity to fix the data right away and try again. If it is set to asynchrony mode, data will be sent later. In this case, the vaccination staff must periodically check the daily synchronization list. If there are objects in the list with a synchronization error, those objects need

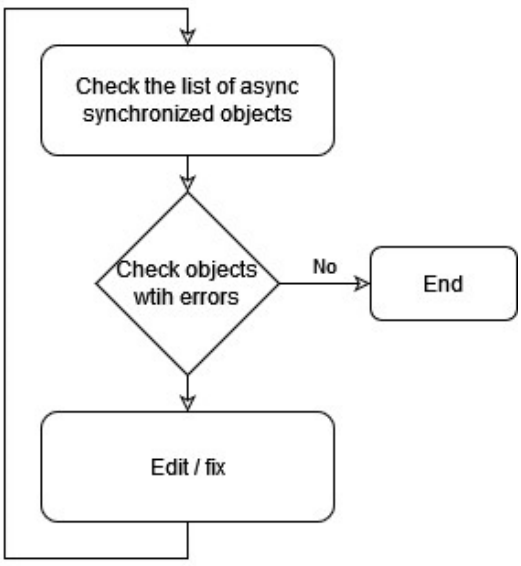

Fig. 5. Flow diagram of synchronization checklist

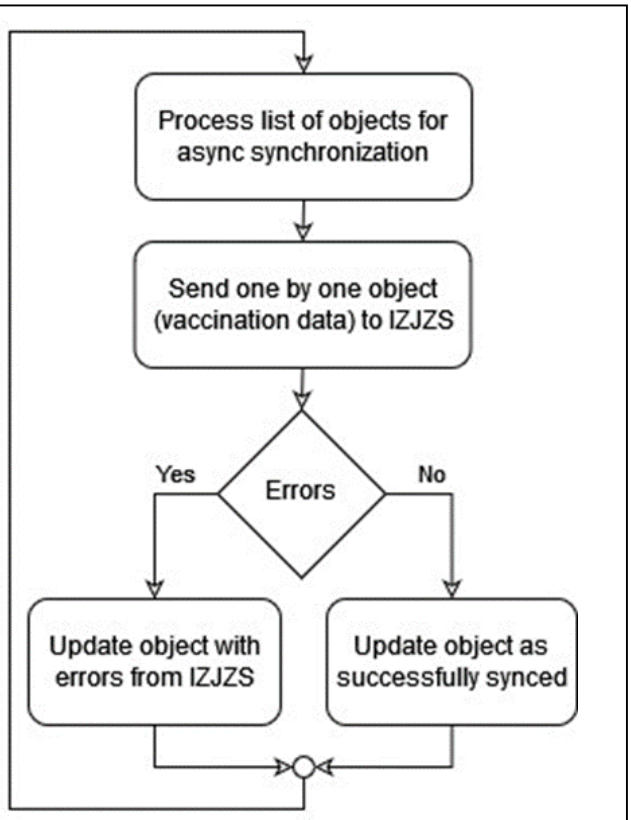

Fig. 6. Flow diagram of synchronization module

to be attended to by medical personnel and retried again (Fig. 5). Errors can be divided into two groups: connection errors and data errors. In case of connection errors, all that is needed is for data to be resent. Medical personnel must fix and resend the data in case of data errors. The described process needs to be repeated while synchronization errors exist.

An additional service is provided for asynchrony mode to synchronize unsynchronized data (Fig. 6). The service periodically checks for data with sync status *MarkForSending*. The period for checking is configurable and by default is set to 30 seconds. In each iteration, only the batch of oldest data tries to be synchronized. The maximum amount of data per iteration is configurable and by default is set to 20. Each data set is sent to IZJZS, the response is stored in the database, and the synchronization object is set to proper sync status. Before data is sent to IZJZS, the sync status is set to *Sending*. This prevents sending the same data more than once. If the timeout period expires on sending, the sync status is set to *ErrorSending*. Also, if the error is from the group of connection error the same status is set. If the response does not contain errors the sync status is set to *Sent*. If there are errors in the response, the sync status is set to *SentWithErrors*.

When checking the synchronization list, the statuses of interest are *ErrorSending* and *SentWithErrors*. An error message should be read, and data should be corrected before marking data with sync status *MarkForSending*. Expected errors for sync status *ErrorSending*:

- The physician is not allowed to send data. This requires setting up privileges for the physician in IZJZS.

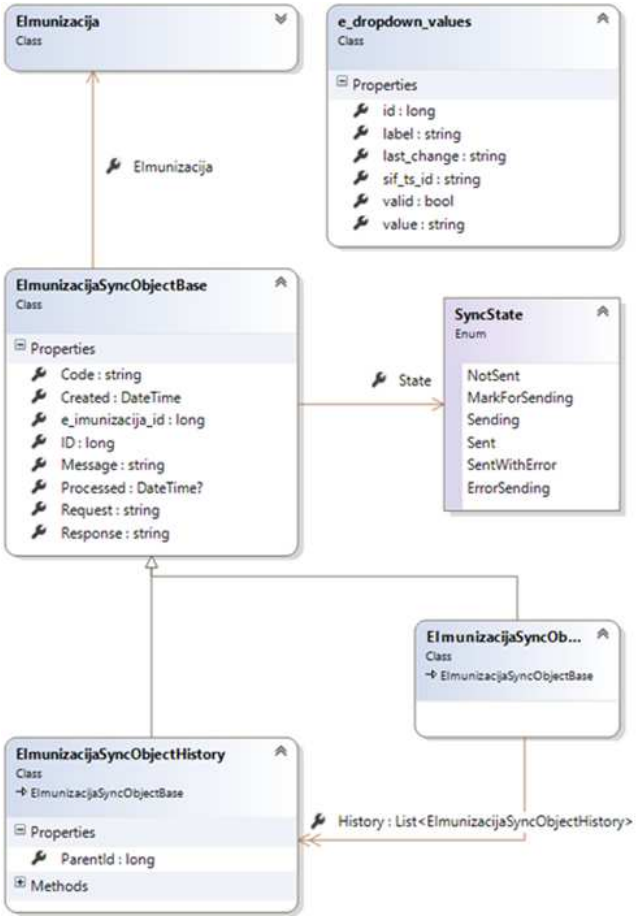

Fig. 7. Class diagram of vaccination synchronization entities between MIS MEDIS.NET and IZJZS

- The endpoint does not listen (It is expected if the IZJZS service is down). In this case, all currently syncing data should get the same error and wait for the IZJZS system to get back on.
- Timeout expired. This means the response did not arrive in the expected time. No additional action is needed. Data should just be marked for sending.

Data with the sync status *SentWithErrors* have a detailed error message attached. It can have one or multiple errors. All provided errors must be fixed before changing the sync status to *MarkForSending*.

The IZJZS system exposes Web REST API to synchronize data with MIS. Each MIS manufacturer receives a unique token and credentials to connect to the system. Only registered facilities with corresponding MIS can access via the given token. Physicians who are users of corresponding MIS need to have appropriate privileges set for IZJZS so the vaccination data can be synchronized. Data is carried as JSON object under TLS 1.2. The authorization process uses JSON Web Token (JWT) which is defined under internet standard RFC 7519 [10]. MEDIS.NET is implemented in MS .NET C#. In MEDIS.NET, vaccination data are stored as an object of class *EImunizacija*. During synchronization, MEDIS.NET converts this data into JSON objects. Each object of *EImunizacija* has the unique object of *EImunizacijaSyncObject* (Fig. 7). It stores the last valid data for synchronization like *SyncStatus*, *Created* (timestamp when was

initially created), *Processed* (timestamp when was data sent), *Request* (vaccination JSON object data), *Response* (JSON object response data), and *Message*. Properties *SyncStatus* and *Message* are set based on the value in the *Response* property. The message represents user-readable values of the synchronization errors. Also, *EImunizacijaSyncObject* contains a list of objects *EImunizacijaSyncObjectHistory*.

Every change in *EImunizacija* or *EImunizacijaSyncObject*, triggers a new object *EImunizacijaSyncObjectHistory* which represents the replica of *EImunizacijaSyncObject*. By using the list of *EImunizacijaSyncObjectHistory* it is possible to show the history of changes for each vaccination data, whether they were made by the user or done by the system during the synchronization process.

Catalogues of possible values provided by IZJZS are stored under *e_dropdown_values*. Properties of interest are:

- *sif_ts_id* – represents catalogues code. Based on this code only values are paired with the proper properties of vaccination data.
- *label* – represents text that is displayed to the user.
- *value* – actual value that is sent as vaccination data for the chosen label.
- *valid* – indicator if the value is still in use.

These catalogues are downloaded from IZJZS once a week, as they are not expected to be frequently changed.

IV. Discussion

Gathering vaccination data in one place is a great idea, and it has to be done. Vaccination is crucial for modern society. Therefore, monitoring the vaccination process is vital during this integration. By monitoring vaccination data, irregular and potential vaccinations can be detected. Following the given calendar of vaccinations and vaccination rules, it can be detected when the next vaccine should be received. MIS MEDIS.NET's vaccination calendar is organized in one row per vaccination (Fig. 8). Each row contains a cell per vaccination dosage. If a vaccine is given to a patient, the cell is colored green, and the vaccination date and age are shown. Currently, local MIS MEDIS.NET contains reports that based on the entered data predict patients that should receive vaccination in the next month. Based on this report, local primary healthcare institutions can contact those patients or their parents for vaccination reminders [11]. Although this exists and works locally, integrating this at the republic level could be part of eGovernment's digitalization process [12]. According to the Republic of Serbia law, regular vaccination is required for

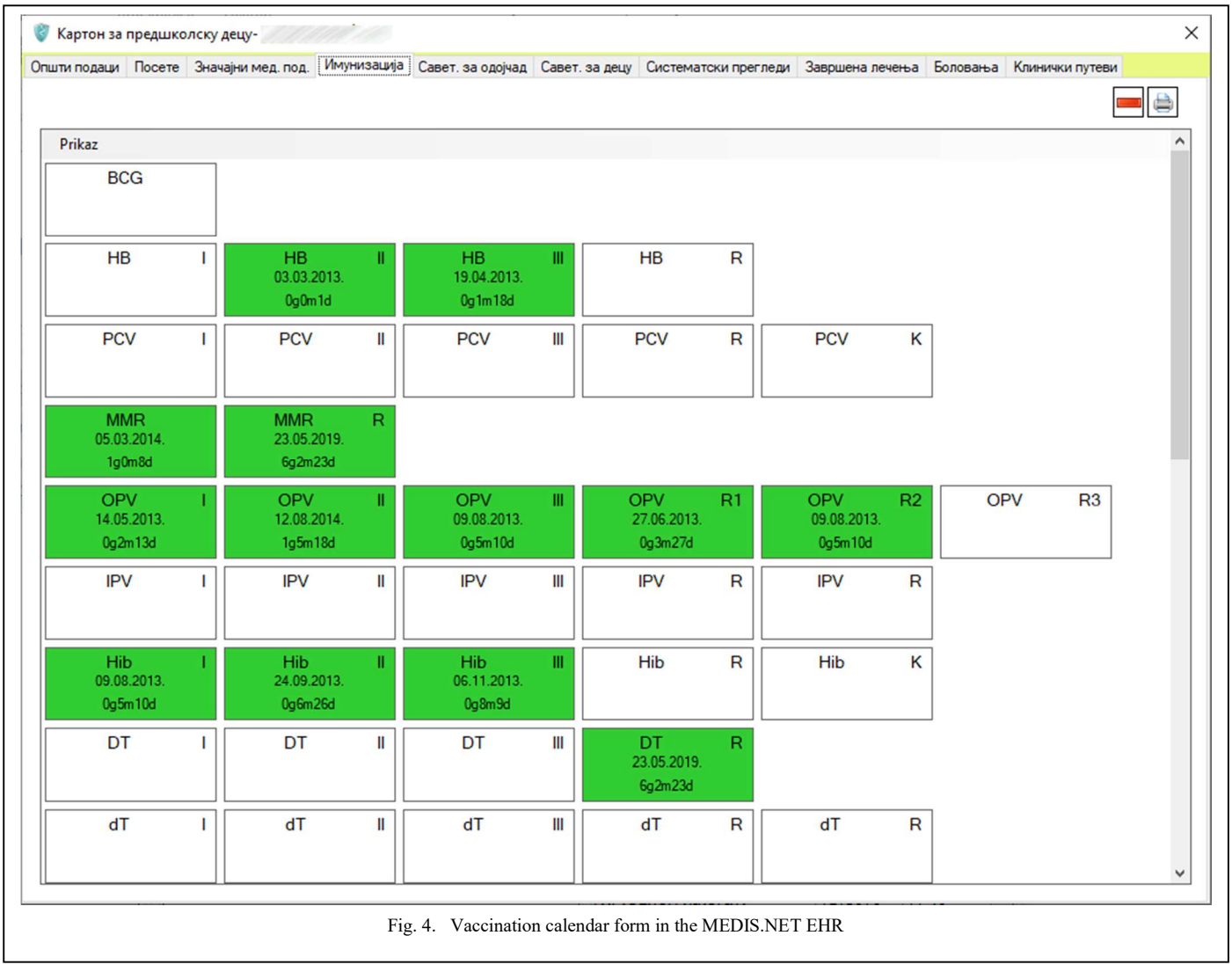

Fig. 4. Vaccination calendar form in the MEDIS.NET EHR

children to enroll in kindergarten and elementary school and receive child support. Currently, the parent has to get a vaccination certificate from the chosen physician in local primary healthcare institutions for each enrollment including eGovernment certificate that could be a click away.

Although the system was initially designed to track mandatory vaccinations, there is potential for tracking seasonal vaccines. By tracking season vaccines, we could see the influence on the number of ill people. It would be interesting to see the percentage of seasonal vaccinated patients per age or geographical region with the number of infected in those categories.

Most of the integration process went smoothly. However, there is an issue with data conversion. Patient general data is not used in the identical catalogues that are required for sending vaccination data. One of the reasons is the diversity of sources for patient data. For example, most of the patient data comes from the Republic Fund of Health Insurance (RFHI) web service. Service provides the latest data regarding patient health insurance like end date of health insurance, health ID, patient address, employing company, etc. This service is provided by the Republic Fund of Health Insurance (*Republički fond za zdravstvenu zaštitu* – RFZO) [13]. This patient data is used in integration with other systems such as mojDoktor [14, 15], eDoktor [15, 16, 17]. Hopefully, this catalogue will be unified soon. Most of the values are similar between different source catalogues. Whenever there is a match, MIS automatically selects the best matching value. However, the user's responsibility is to verify and correct the value if needed. Some of the values were not catalogized in MIS or were not identified as required patient data. For example, the previously mentioned nationality was not required for patient data. Also, for example, a generic name for a vaccine used is DTaP and IPV are two separate generic names. They are now joined as DTaP-IPV if given with Tetraxim vaccine or Pentaxim for DTaP-IPV-Hib. Previously supported vaccination functionality in the MEDIS.NET is not fully compatible with the required vaccination data. The biggest challenge is creating an automatic data converter to escape user interaction.

V. Conclusion

The described integration is one more step to the WHO's suggestion: "Invest in advanced immunization information systems able to track each person's immunization status". Currently, MIS MEDIS.NET enables vaccination data collection and sending it to the centralized system IZJZS. The challenges in developing data converters are left to be overcome. This should make the job easier for medical personnel and enable them to spend less time filling out the paper form. Potential for including vaccination certificates in eGovernment exits and should be expected to be included. Besides vaccination certificates, vaccination reminders can be sent through eGovernment like it is done for property taxes. The system for gathering vaccination data is there and in use. It remains crucial to raise awareness in society about the necessity of mandatory vaccination or vaccination at one's request if it is a question of vaccines for seasonal diseases such as the flu. Realized integration is one of the essential parts of MIS to improve the public health service in the Republic of Serbia.

Acknowledgment

This work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia [grant number 451-03-65/2024-03/200102].

References

[1] European Vaccination Information Portal - An initiative of the EU, https://vaccination-info.europa.eu/en/about-vaccines/benefits-vaccination/, last access date: 12.03.2024.

[2] WHO and UNICEF press release, https://www.unicef.org/serbia/en/press-releases/who-and-unicef-say-urgent-vaccination-is-necessary-to-protect-lives-of-children, last access date: 12.02.2024.

[3] Institute of Public Health of Serbia – "Dr Milan Jovanovic Batut", https://www.batut.org.rs/index.php?lang=2/, last access date: 12.03.2024.

[4] Stein, T. (ed.), "The electronic physician: Guidelines for implementing a paperless practice", Allscripts Healthcare Solutions, USA, 2005.

[5] J. Rodrigues, S. S. Compte, I. Díez, "e-Health Systems - Theory and Technical Applications", eBook ISBN: 9780081012055

[6] M. Alsadi, A. Saleh, "Electronic health records implementation readiness: an integrative review", Open Journal of Nursing (2019), 9(2), 152-162.

[7] H. Atasoy, B. N. Greenwood, J. S. McCullough, "The digitization of patient care: a review of the effects of electronic health records on health care quality and utilization", Annual review of public health (2019), *40*, 487-500.

[8] World Health Organization, https://www.who.int/health-topics/vaccines-and-immunization, last access date: 15.03.2024.

[9] Plans-Rubió P. Strategies to Increase the Percentages of Vaccination Coverage. Vaccines (Basel). 2022 Dec 8;10(12):2103. doi: 10.3390/vaccines10122103.

[10] RFC 7519: JSON Web Token: https://oauth.net/2/jwt/, last access date: 20.05.2024.

[11] M. Stojkovic, A. Veljanovski, A. Milenkovic and D. Jankovic, "Automatic notification system and its application in medical information systems", 2012 20th Telecommunications Forum (TELFOR), Belgrade, Serbia, 2012, pp. 1657-1660, doi: 10.1109/TELFOR.2012.6419543.

[12] FORBES – "National Digital Transformation: A Conversation With Serbia's Prime Minister Ana Brnabic", https://www.forbes.com/sites/robertwolcott/2021/06/15/national-digital-transformation-a-conversation-with-serbias-prime-minister-ana-brnabic/?sh=7f64f9c23889, last access date: 15.03.2024

[13] RFHI – Republic Fund of Health Insurance, http://www.eng.rfzo.rs/, last access date: 13.03.2024.

[14] MojDoktor – Integrated Health Information System of the Republic of Serbi, " Integrisani zdravstveni informacioni sistem Republike Srbije", https://www.mojdoktor.gov.rs/about, last access date: 13.03.2024.

[15] A. Veljanovski, A. Milenković, M. Veljanovski, P. Rajković, D. Janković, "Realization of Software System for Synchronization of Prescribed Therapy with the Software System of Pharmacies", YUINFO 2023, 12-15 March 2023, pp. 32-36, ISBN 978-86-85525-29-2.

[16] National Medical Platform for Prevention and Diagnostics, https://edoktor.e-zdravlje.gov.rs/, last access date: 13.03.2024.

[17] Veljanovski, A. Milenković, M. Veljanovski, P. Rajković and D. Janković, "Realization of Software System for Collaboration of Specialist Proposed Therapy and Physician Accepted Therapy," 2023 10th International Conference on Electrical, Electronic and Computing Engineering (IcETRAN), East Sarajevo, Bosnia and Herzegovina, 2023, pp. 1-5, doi: 10.1109/IcETRAN59631.2023.10192181