Patient-Centered Smart Healthcare Information System

Kamen Spassov, Denisa Chekresi, Gerta Dervisi, Enduena Lleshanaku, and Maria Velichkova

Abstract

Healthcare is a complex system with many actors involved such as Patient, General Practitioner, Hospital, and Pharmacy. The focus is on the Patient, however, actors collaborate to deliver the best healthcare service to the patient. Each of the elements of the healthcare system is a separate complicated system. This paper proposed a patient-centric smart healthcare information system (PCSHIS) integrates and orchestrates Patient Records Repository, General Practitioner Information System, Pharmacy Information System, and Hospital Information System to optimize the expenses of health service delivery and to ensure the best possible healthcare. All systems are built and integrated into a prototype PCSHIS with a software platform for building applications dOS of dWare company.

Keywords

Patient-Centric smart healthcare information system • Patient records repository • General practitioner information system • Pharmacy information system • Hospital information system

1 Introduction

Health care is one of the most critical sections in the economy of a country. New technologies are now affecting every sector, including the health care sector.

As Eysenbach (2001) proposes:

> e-Health is an emerging field in the intersection of medical informatics, public health, and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology.

According to the World Health Organization (2018):

> E-Health (Electronic Health) is the Use of Information and Communication Technologies (ICT) for Health.

e-Health involves the integration of information involved in the delivery of health care by using information systems and technologies. These information systems involve Patients and their data, General practitioners (GP) and doctors in general, Hospitals, and Pharmacies with their medical, management, and administrative functions and data.

All people are patients or potential patients with their medical history represented by their medical data stored in medical records. Medical records could be on paper or electronic. In this paper, we will consider all patient medical records are in electronic form. Patient's medical records are supposed to be kept in Patient Records Repository (PRR).

In many countries, patients visit GPs firstly. GPs prescribe patients treatments and/or medicines or recommend patients to a specialized doctor or hospital. GPs record their findings and prescriptions in the medical records of the patients. GPs use GP Information Systems (GIS).

Hospitals provide medical treatment of patients forwarded to them by GPs or visited directly by patients. For medical treatment, doctors in hospitals use medicines sourced from hospital pharmacies. Hospitals use Hospital Information Systems (HIS). Doctors and nurses in the hospital record their findings, treatments, and prescriptions in the medical records of the patients.

Pharmacies (also hospital pharmacies) provide medicines according to prescriptions of doctors (GPs or from the hospital). Pharmacies use Pharmacy Information Systems (PIS). Pharmacists record medicines purchased by patients in the medical records of the patients.

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In some countries, GIS, HIS, and PIS are very well integrated. In other countries, they are partially integrated. In many countries, these systems are not integrated, or even some or all of them do not exist.

Access to and maintenance of the medical records of the patients is crucial to a successful patient-centric healthcare system.

The analysis started with a research on health care systems of Bulgaria and Albania—home countries of the authors. The transition from healthcare to e-Healthcare in other countries (Austria, Canada, Denmark, Estonia, Ireland, Netherlands, Norway, UK, and Scotland) was studied. The initial idea was to analyze successful implementations of e-Health systems in order to put together functional requirements for a patient-centric smart healthcare information system (PCSHIS) for Albania. During work, we decided to define and test PCSHIS in general.

2 Patient-Centric

> Patient-centered applications are defined as systems that enable a partnership among practitioners, patients, and their families (when appropriate) to ensure that procedures and decisions respect patients' needs and preferences. Developers should solicit patients' input regarding the education and support that patients require to make decisions and participate in their care (Demiris et al. 2008).

In an ideal world, Patients should be in the focus of all organizations, members of the healthcare industry. A patient-centric e-Health system empowers patients. Patients deserve more extensive involvement in making the decision, expressing an opinion about different health-related issues like problem-solving, information sharing, acceptance of health team instructions, etc. We assume that all involved parties use specialized information systems, e.g. GIS, HIS, and PIS.

3 The Goal

In our work, we defined the goal to create a prototype of an integrated Patient-Centered Smart Healthcare Information System (PCSHIS) that provides the functionality of GIS, HIS, and PIS at a common platform to avoid the challenges of integration of systems from different vendors based on different platforms.

The patient's medical records are the main integration element of GIS, HIS, and PIS.

4 PCSHIS Subsystems

PCSHIS is built around Patients' Records Repository and integrates GIS, HIS, and PIS.

4.1 Patients' Records Repository (PRR)

Once the only principle is a core around which patients' record repositories are built. In Norway, for example, they use "One citizen, one record" slogan (Accenture 2018).

Kjernejournal (Summary Care Record) is a collection of health records used when in need of urgent medical access. Kjernejournal was developed in strict compliance with statutory requirements for security and data privacy. Access to Kjernejournal is granted solely to patients and health care facilities authorized by the Norwegian Directorate of eHealth. Access is obtained in a secure health service network. Through Kjernejournal, the Directorate has enabled health care professionals in Norway to share information about patients across geographies and care levels. They have also given patients transparency about what health information about them is recorded and allowed them to update their information through a web portal, empowering patients to take an active role in their care.

The Austrian e-Health approach is also based on electronic health record—ELGA short (Bugnar 2010). In Canada, electronic health record (EHR) is also implemented (Canada Health Infoway 2018).

Patients' Records Repository (PRR) contains all data related to the patient's health; medical treatments; visits to doctors, hospitals, and pharmacies; results from laboratory analysis; prescribed and purchased medicines. Patients own their records and manage access to the data.

Medical records of each patient are unique. Each patient needs to have a unique electronic identifier (UEI). GPs register Patients at PRR with their UEIs. After the initial registration, patients can manage the access of health care providers to their medical records, but cannot delete records.

GPs, doctors, and nurses at hospitals and pharmacists can create and amend records relented to their findings, medical treatments, recommendations, prescriptions, medicines, provisioning, etc. They cannot delete medical records.

Patients receive notifications about any access to their medical records.

4.2 General Practitioner Information Systems GIS

Not all the countries have the same structure of primary health care system, but most of the health care takes place in primary care section, with a family doctor known as a General Practitioner (GP). Patients visit GPs firstly and later GPs recommend the patient to a specialized doctor or hospital. Very rarely do patients contact a specialized doctor without first going to the GP for a referral. In developed countries, GPs usually use computerized systems in their practices.

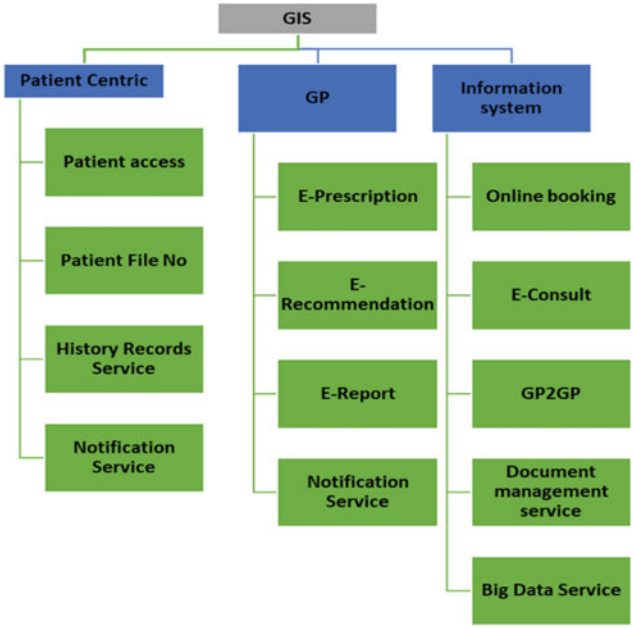


Fig. 1 General Practitioner Information System (GIS) structure and modules

Structure and the main modules of a GIS are presented in Fig. 1. GPs have access to the patient's records. They can send the patient to another doctor (s) or hospital, prescribe medicines and/or treatments, etc. GPs and patients can use the GIS to book a visit to the doctor. GPs can use GIS to as other doctors for consultation. GIS is a valuable tool to organize GP's documentation and to perform different types of analysis.

4.3 Hospital Information Systems (HIS)

Hospitals are very complicated systems. In Fig. 2 structure and modules of a Hospital Information System (HIS) is presented. In general, we can divide HIS into three central systems Patient Management System, Hospital Management System, and Hospital Support Management System.

Patient Management System relates to every piece of data regarding the patient's treatment in the hospital (medicines, procedures, clinical laboratory results, etc.).

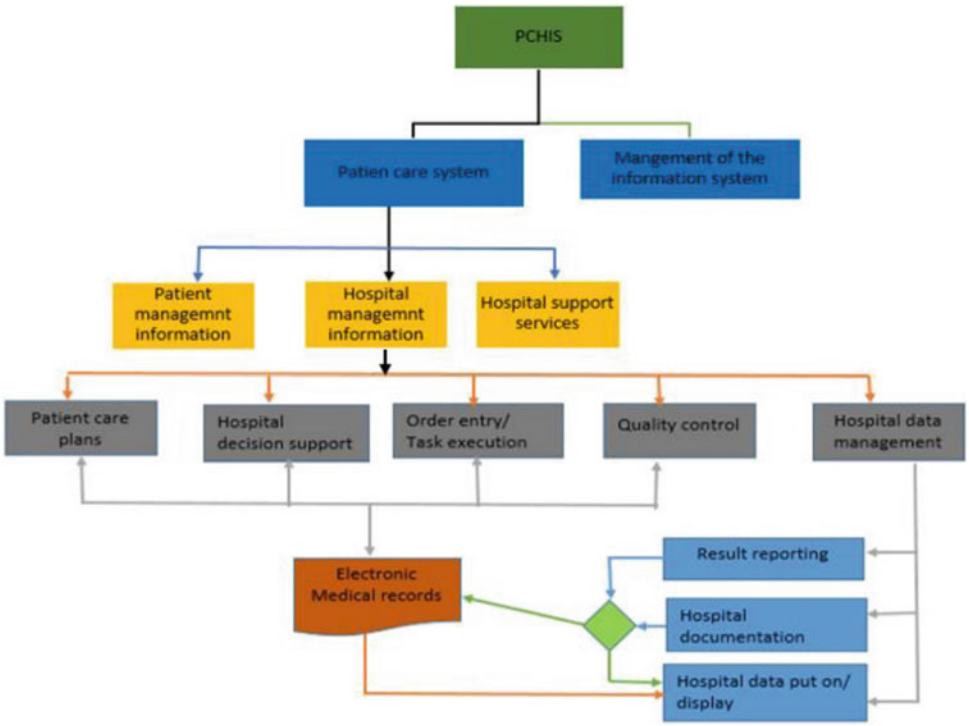
Hospital Management System relates to the overall management of the medical personnel and medical equipment employed for the medical treatment of patients.

Hospital Support Management System relates to the management of the hospital's facilities—similar to hotel management.

HIS was built following the standards established with the 5th edition of Joint Commission International Accreditation Standards for Hospitals (2014).

HIS needs to be divided into two main subsystems: one devoted to medical treatment of patients; and another Inpatient Admission and Catering Information System (similar to hotel management systems).

Fig. 2 Hospital Information System (HIS) structure and modules



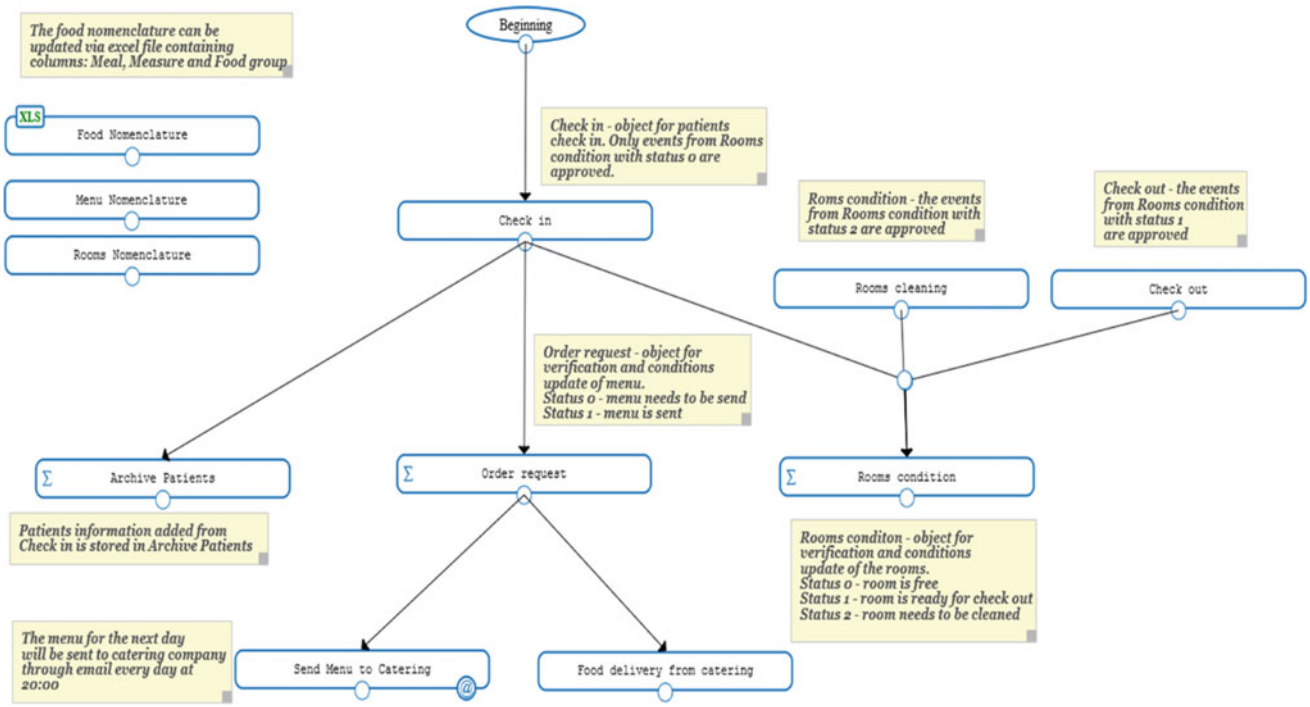


Fig. 3 Inpatient admission and catering subsystem

Objects of HIS were defined.

Inpatient admission and catering subsystem are shown in Fig. 3. This is an essential part of Hospital Support Management System. In essence, Inpatient admission and catering system is similar to a hotel with a restaurant management system. Specifics are related to the hospital clinics and their specific requirements to the beds and related equipment, capacities, etc. In a hospital, food requirements could be different for each of the patients and are dependent on doctor's recommendations.

4.4 Pharmacy Information Systems (PIS)

Pharmacies have been regulated heavily in the recent 100 years. In different countries, different regulations apply. For example:

The prices of branded prescription drugs have been regulated in the UK since 1957 under a voluntary agreement between the Association of the British Pharmaceutical Industry ("ABPI") and the UK Department of Health, which applies to all branded, licensed prescription drugs available on the National Health Service ("NHS") (2017). The arrangement is called the Pharmaceutical Price Regulation Scheme ("PPRS"). Other countries Germany, Netherlands, Canada, etc. have similarly their own regulations.

e-Prescription links patients, doctors, and pharmacists. Each e-Prescription is unique and contains the UEI of the patient. Each e-Prescription is part of the medical records of a patient.

Pharmacists register in the medical records of a patient all medicines distributed to the patient regardless they have prescription or not.

A pharmacy could be standalone, hospital pharmacy, or any other kind.

The inventory management system is part of PIS.

PIS needs to include reimbursement medication service.

Objects of PIS were defined.

Figure 4 represents a Pharmacy Information System structure and main objects.

5 Patient-Centric Smart Healthcare Business Processes

Business processes at GPs, hospitals, and pharmacies were analyzed and presented in general using BPMN.

Figure 5 depicts a clear picture of business processes in a patient-centric smart healthcare information system. It is supposed that GIS, HIS, and PIS are built on the same platform, and the integration is seamless.

Patients can access PCSHIS through their GP or going directly to a hospital. Eventually, they can purchase over the counter medicines going directly to a pharmacy without a prescription.

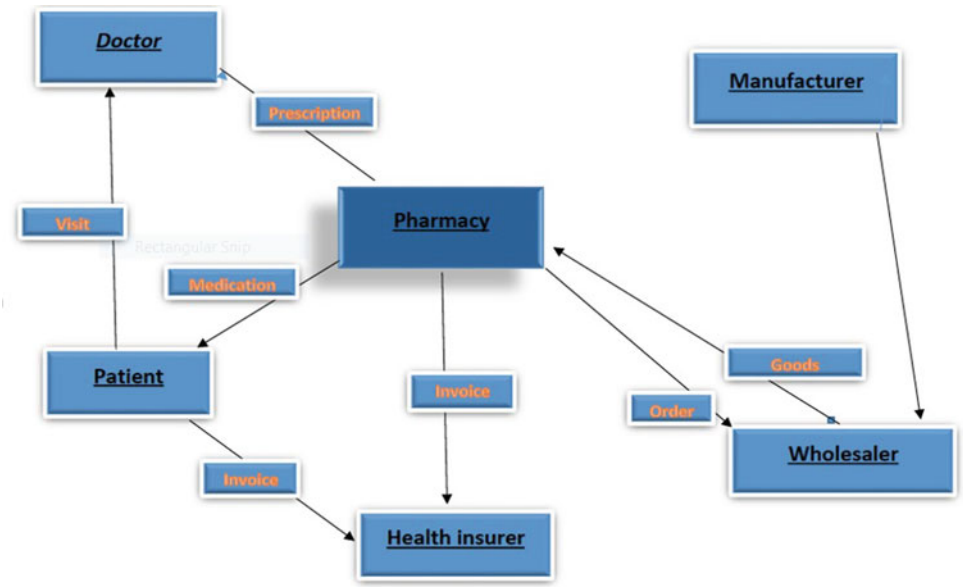


Fig. 4 Pharmacy Information System (PIS)

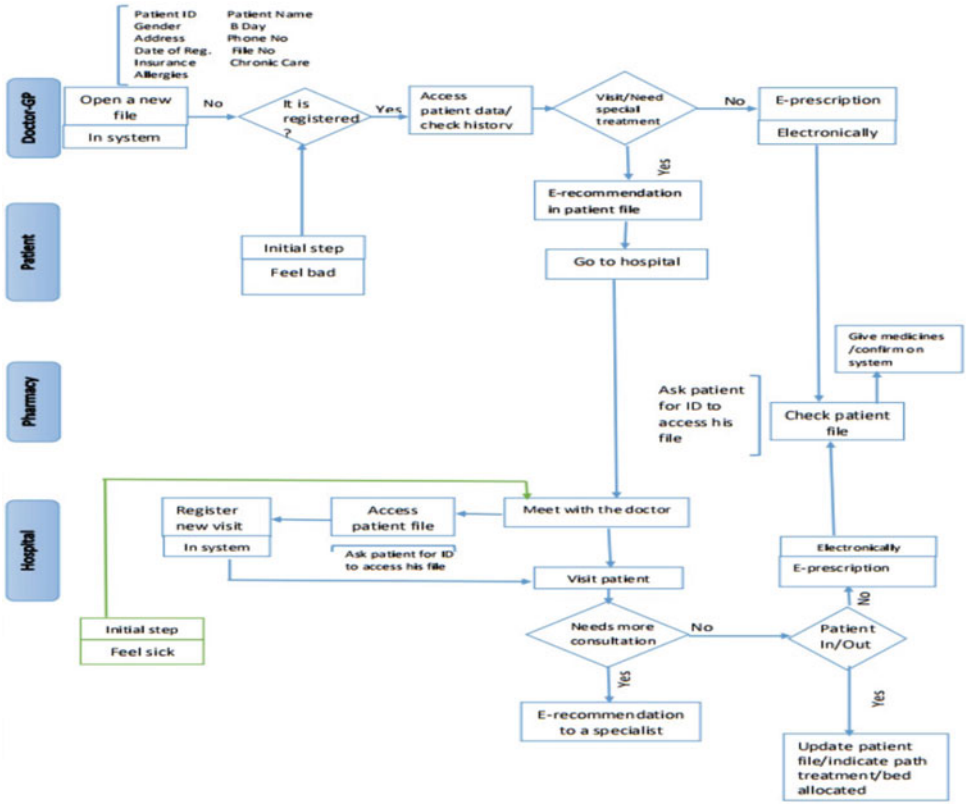


Fig. 5 A simplified business process in PCSHIS

GP checks the patient health status and either prepare e-Prescription or sends the patient to a hospital (independent doctors with their cabinets could be treated as hospitals).

At the hospital, the patient passes a healthcare check and eventually, a set of medical treatments (inpatient or outpatient). In most of cases, hospital doctors also prepare e-Prescription(s).

6 Functional Model

A simplified model of Patient-centric smart healthcare information system (PCSHIS) is presented in Fig. 6. Information systems of General practitioners, Hospital information systems and Pharmacist information systems are

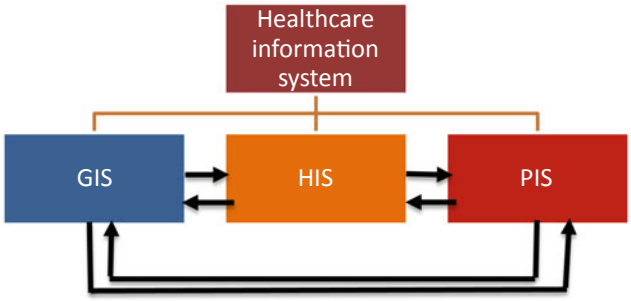


Fig. 6 A patient-centric smart healthcare information system integrates General practitioner information system, Hospital information system, and Pharmacist information system. All these systems are built around patients' medical records

connected and exchange data related to each of the patients. The common element of all these systems is the medical record of a patient. The essence of the Healthcare information system is the repository of patients' medical records. It is crucial that all other systems be able to read and write data to a patient's medical record following the will of the patient and the rules related to their roles as medical care providers.

As it was discussed earlier, in most of the cases GIS, HIS, and PIS are built by different vendors, using a variety of technologies, and in most of the cases, this requires significant effort and investment for integration. A special requirement to build this patient-centric health care pilot system was to develop GIS, HIS, PIS, and patients' medical records repository within the same platform with integration capabilities by design. In this case, semantic and technical interoperability of each of the systems to be agreed before the design of each of the respective information systems.

It is essential for all systems to protect personal data in compliance with the European General Data Protection Regulation (GDPR).

7 Technical Solution

dWare dOS platform was selected to develop the pilot PCSHIS. dWare company provided free documentation, training, and access to the platform. dWare Operating System is a business operating environment developed by dWare. dOS is the software implementation of an event model to reflect reality. Business processes can be presented in dOS as consequences of events. The system provides tools to define objects, attributes, spaces, and functions (2018). In dOS, the new application is generated in and admin site and then it is exported to user site. There is no need for software development.

Business processes in GPs, Hospitals, and Pharmacies were developed in details. For example, at Fig. 7, the business process of an existing patient visit is presented.

All business processes were created in dOS admin site.

Before that, objects derived from analysis and defined in functional requirements were created in dOS admin site. Each object consists of multiple layers that need to be configured a description, physical layer, logical layer, presentation layer, attributes, and functions. Figure 8 is shown an example of a configuration screen of Description of the object Patient data.

It Fig. 9, a screenshot of the configuration of the logical layer in dOS for the Patient data object is presented. At this stage object's attributes are generated.

After building the system in the admin site, it is exported and then imported to the user site. For example, in the user site, the Patient data object looks like it is presented in Fig. 10.

As it was mentioned above, dOS platform consists of admin and user sites. The new application, PCSHIS, in our case, was created on the admin site and then transferred to the user site. The configuration of admin and user sites is

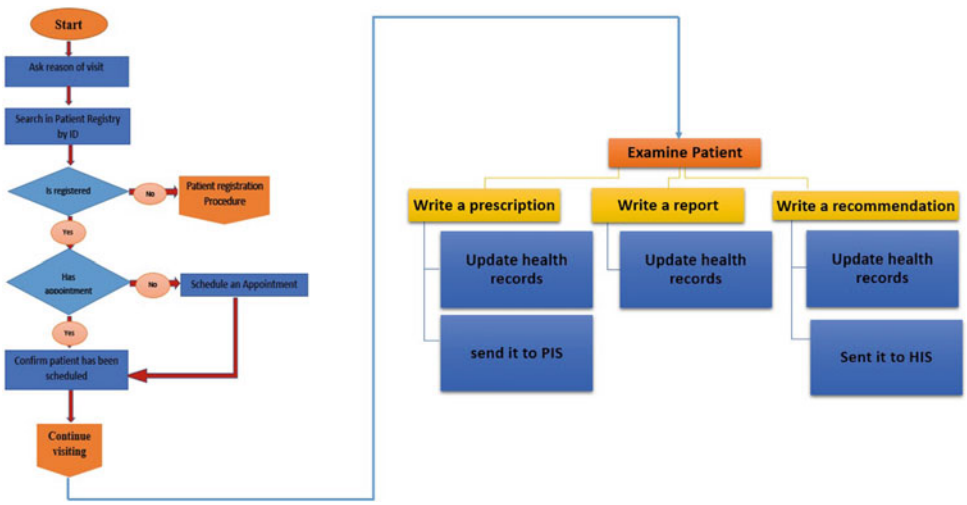


Fig. 7 The business process of an existing patient visit to General practitioner

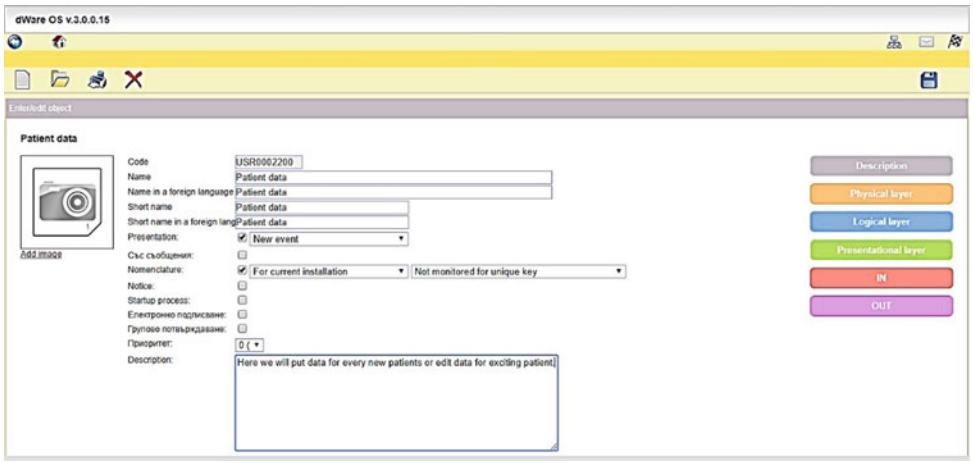


Fig. 8 A system view of Description in Patient Data object in dOS admin site

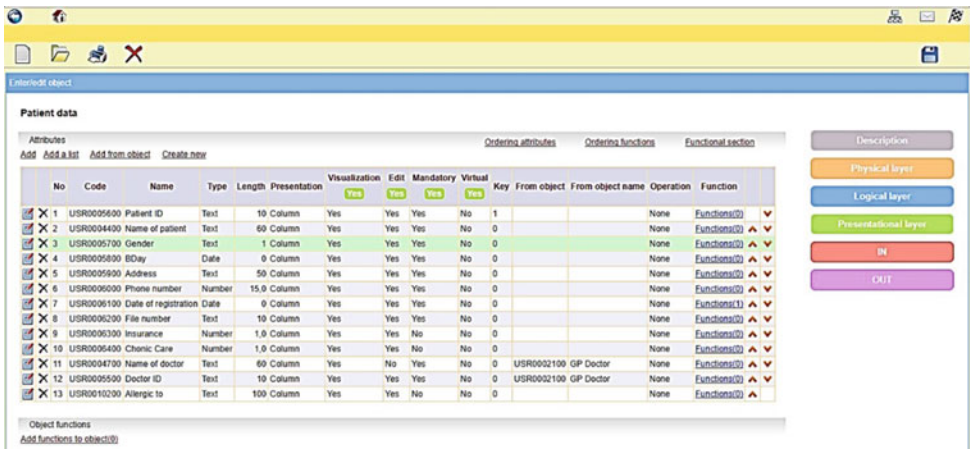


Fig. 9 A system view of Logical Layer at Patient Data object in dOS admin site

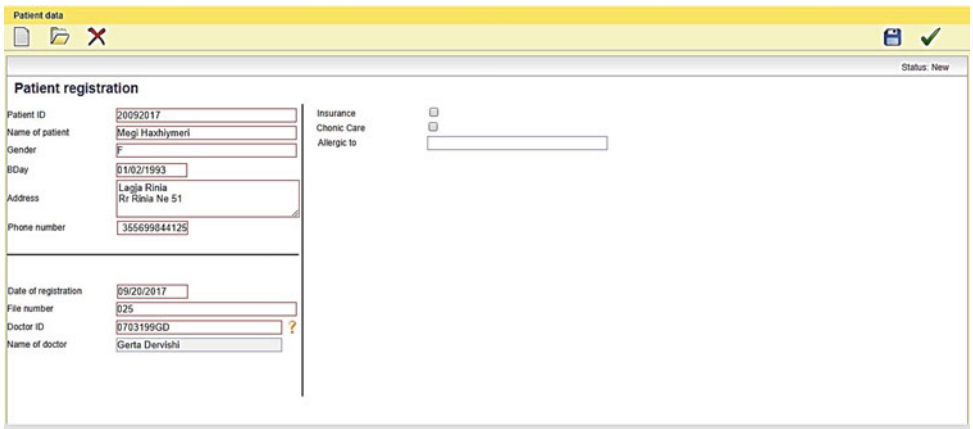


Fig. 10 A system view of Presentation of Patient Data object in dOS user site

presented in Fig. 11. Special measures are taken to ensure data security and system scalability. GIS, HIS, and PIS were created in dOS separately. After a successful testing GIS, HIS, and PIS were integrated into PCSHIS. Three complicated scenarios were created, covering real-life cases to test PCSHIS. All tests passed successfully and proved the viability of the pilot PCSHIS.

8 Conclusion

A prototype of Patient-Centric Smart Healthcare Information System (PCSHIS) was developed in the dOS software platform. The system integrates GIS, PIS, and HIS built around the patient medical records in Patients' Records

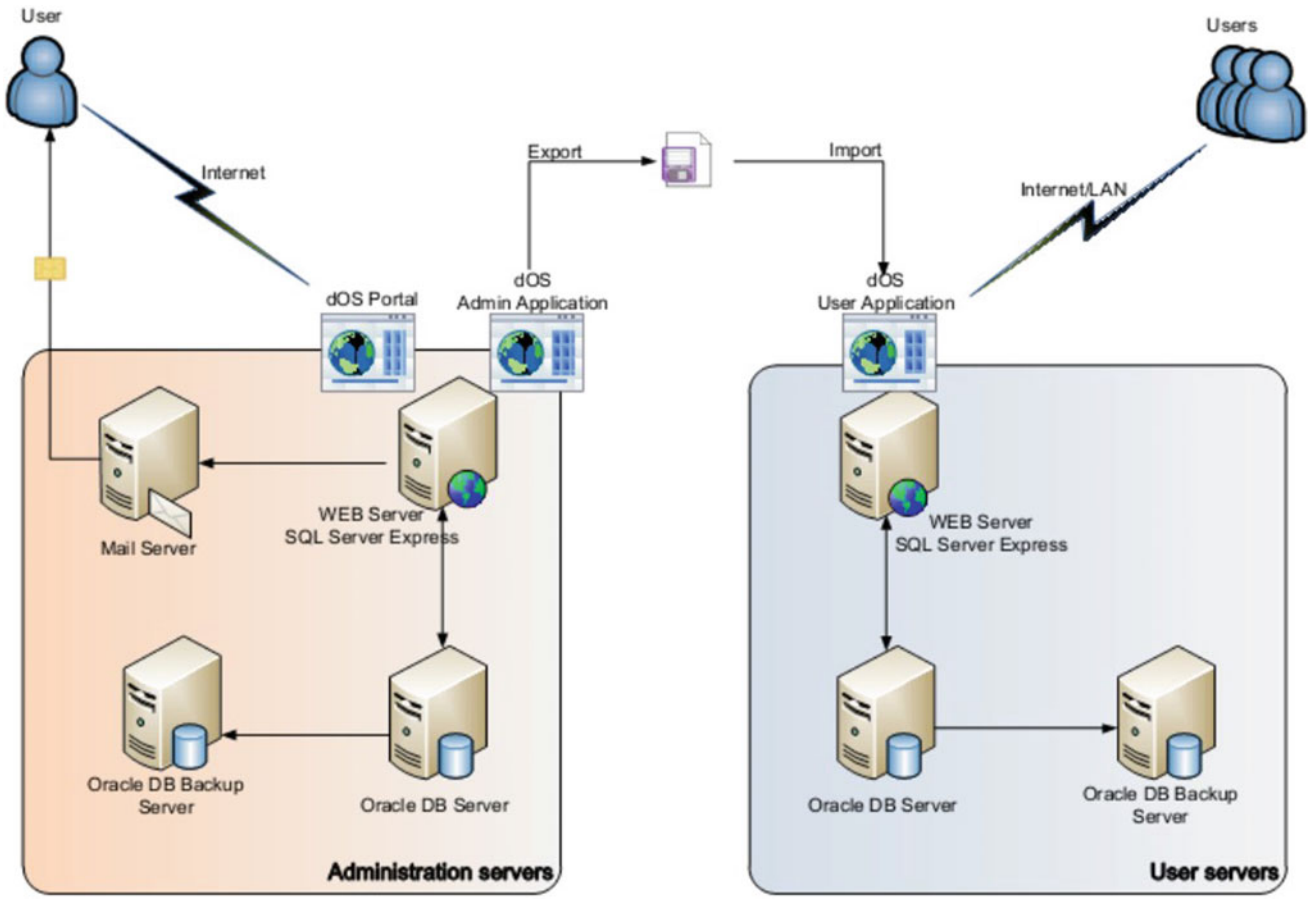


Fig. 11 Configuration of admin and user sites in dOS

Repository (PRR). General practitioners, hospital doctors, nurses, and pharmacists can access patient records and enter their observations, prescriptions, results from laboratory analysis procedures, etc.

Different scenarios of patient cases were tested successfully. It was proven that the pilot system meets the functional requirements. Tests were conducted with few patients, one GP one hospital and one pharmacy generated within the dOS platform. A real implementation will require the generation of multiple objects of General practitioners, hospitals, and pharmacies. In the core of such a system, thousands and millions of patients' records need to be supported.

Due to the centralized approach to building the patient-centered smart healthcare information system it is relatively easy to generate all kinds of reports and analysis to use them for policy making in general and decision-making at managerial level.

The use of dOS platform allowed Business Analysts to build the PCSHIS without any software development, just defining objects and business processes.

The development and testing of the pilot of the patient-centric smart healthcare system prove the viability of the described approach. To implement the PCSHIS in reality there is a need to build an ecosystem of patients, GPs, hospitals, and pharmacies at local, regional, or country-level who support e-Health. dOS platform was used to create software solutions at all levels and proved its scalability. It is not difficult to conclude that the development and implementation of a PCSHIS at local, regional, or country-level predominantly depends on the political will of the authorities.

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