International Journal of Emerging Trends in Computer Science and Information Technology
ISSN: 3050-9246 | https://doi.org/10.63282/3050-9246.IJETCSIT-V3I4P117
Eureka Vision Publication | Volume 3, Issue 4, 178-188, October - 2022

Original Article

Cloud-Enabled Virtual Patient Engagement with Intelligent Appointment Scheduling and Secure Document Management

Amit Rajula
Independent Researcher, USA.

Abstract - With the Healthcare industry making its way into the cloud, the patient now takes a new step ahead and with remote access to healthcare services communication and healthcare quality management gets a new dimension. But current engagement packages will probably be associated with appointments that don't best utilize resources, documents security, interoperability, and unintelligent decision support. The study will: Present Cloud-based Virtual Patient Engagement System that will empower use of cloud-based technology and AI, towards creating Intelligent Scheduling and Secure Document Management and use of the two efficiently coupled with effective utilization of the Cyber Security Solutions, to enhance the way the health care services could be delivered. The orchestrated design will include a cloud footprint that will allow for a scaled and highly-available patient services, as well as use of "smarts" to maximize physician utilization and reduce patient wait times. As one would expect, as a secure document management module is developed – with encrypted storage, role based access controller, auditing and logging security incidents and safe document sharing – the security of the EHRs and clinical documents becomes more secure. The framework offers the potential of teleconsultation, communication with patients, settings for automatic notification of health care providers and patients, automatic recalling and real time synchronization. Its interoperability that is based on API assists it to interact well with both information systems and electronic health systems in the hospitals. The proposed framework works well with respect to scheduling and improves work done by administrations resulting in improved data safety, patient satisfaction and work-efficiency based on the experimental evaluation. The proposed intelligent patient engagement model as a cloud is scalable, secured and efficient enough to be able to support a new digital healthcare ecosystem.

Keywords - Cloud Computing, Virtual Patient Engagement, Intelligent Scheduling, Secure Document Management, Electronic Health Records (EHR), Machine Learning, Healthcare Information Systems.

1. Introduction

The high pace of digital transformation of the healthcare sector has immensely transformed how healthcare services are offered, administered and accessed. Advances in cloud computing, artificial intelligence (AI), mobile innovations and safe online communication, have made it possible to ensure that a healthcare organization can provide patient-centered services outside of the hospital walls. Now, virtual modes of interaction with patients have emerged to be one of the most important aspects of today's health care systems – interaction via online or mobile based apps, telemedicine and cloud healthcare systems now provide patients a way to communicate with health care professionals. These technologies re-imagine access, transcend the geographic constraint, can help keep people connected, and can enable a health care consumer's engagement in health care decisions. As the number of healthcare organizations switching to digital transformation continues to rise, patient engagement platform on cloud-based platforms has become an essential consideration to improve the quality of the services, efficiency of the operations and patient satisfaction [1].

Patient engagement can be referred to as personal participation of individuals in self care in the interactions between them and health services providers in various forms of communication or getting medical information at the right time, making appointments, taking medication and time and health education and activity where they mutually consent in decision making with the health facilities managers. Through studies, it has always been established that highly engaged patients are more likely to have high adherence to given interventions, attend scheduled appointments, preventive healthcare services and better clinical outcomes. However, many of the existing healthcare information systems feature a very fragmented collection of software to address the challenges of appointment management, patient information, the sharing of information documents, telemedicine and managerial duties. This disintegration probably leads to duplicate and incomplete data, lack of communications uniformity, double administrative burden, slow medical services, and patients' dissatisfaction [2].

These limitations can be overcome with the help of cloud computing which offers scale, scalable and cheap healthcare infrastructure. Cloud platforms are installed and applied by healthcare organizations to safely store and process big amounts of patient data and also allow real-time access to the authorized users in various locations. Through telemedicine, patient portals, analytics tools and collaboration tools, with the assistance of electronic health record (EHRs), healthcare providers can be so efficient, without having to spend enormous sums of money on the infrastructure (with on-premise services). In healthcare

organizations with an ever-increasing workload on digital devices, a cloud-based system is also quite accessible, expands easily, is highly resilient and recoverable in case of disaster and is easy to update/upgrade.

The necessity to add technological solutions that could offer virtual communication between the patients (both pedagogical and entertainment capabilities) has intensified the necessity to devise holistic virtual solutions in patient intercourse as the world of telemedicine is growing massively in the aftermath of the recent world events that have had significant effects on the world population. Patients too demand facilities to get health care and expect them to provide enclosed opportunities to make appointments online, virtual treatment, electronic prescription, peruse around laboratory testimonies, electronic maintaining record and even more personal messages related to their health with the support of their common electronic ones at the primary stage. The health practitioners would also need to develop automatic processes to discourage the complexity of the process and management, as well as to ensure that the services meet the requirements – not to mention proper security of patient sensitive information. Thus, the existing healthcare information systems should be able to continuously engage a patient in the healthcare process (visits, consultations) up to the documentation as well as follow-up.

Among the most vital topics in the digital healthcare is arranging appointments. Through its scheduling aspect, the standard scheduling method is highly manual – this aspect has resulted in conflicts for appointment time, underutilization of physicians, long waiting times, a high percentage of cancelled appointments and waste of health care resources. Algorithms of such kind have been already shown to have tremendous possibilities in Artificial Intelligence (AI) and Machine Learning (ML); such algorithms' viewpoints cannot be limited with intelligent time management algorithms. With minimal historic information about the recognizing of past appointments, access to the residents, consultation time, urgency and resource limitation the Smart scheduling systems can dynamically schedule appointments in a dynamic manner. These systems assist with utilizing existing clinics, shorten waiting time for patients, decrease no-shows by reminding patients and more.

A different standard in the healthcare environments that are cloud-based is secure document management. A continuous flow (bulk-made) laboratory medical records, diagnostic images, discharge and prescription information, referral information, insurance information, consent form and electronic medical records all contain information. A security of such documents, as well as their accessibility by licensed health care providers is quite challenging (both technically and with regulation). While implementing HI systems, some of the items that need to be taken care of are: Confidentiality, Integrity, Availability, Authenticity and Traceability. The overall security functionality now is to implement encryption, role access, multi-factor authentication, digital signature, audit trail, secure cloud management and automated backup systems to ensure that sensitive healthcare information will never fall into the wrong hands, be hit by a cyber-attack, or be lost due to errors.

As ransomware attacks, phishing attacks, insider threats, and unauthorized access of data by healthcare organizations has increased across the globe, it has now become a top priority for healthcare cybersecurity. Patient medical information is very private information that needs to be afforded the maximum security (healthcare privations legislations) and the security of an organization. In turn, such cloud-based patient engagement platforms must be a multi-layered security platform that includes built-in identity and continuous monitoring, secure authentication, secure data transfer and storage, vulnerability testing, intrusion detection and compliance reviews. Not only can they provide privacy to the patients, but they can also build patients' trust in electronic health care.

One other significant issue to healthcare digital transformation is interoperability. Typically, the existing information system available in healthcare organizations is heterogeneous i.e., developed by different vendor, with data formats and communication protocols are different. Patient information cannot be shared between hospital, diagnostic lab, pharmacy, insurance companies and telemedicine systems due to the concept of interoperability. With the adoption of modern healthcare systems in the cloud, the uptake of standard application programming interface (API) and standards to make information flowing secure and reliable is growing. Improved interoperability reduces redundant diagnosis testing, facilitates efficient and coordinated care for the patient, improves clinical decision making, and contributes to a seamless medical care experience from many providers.

AI is also enhancing the accessibility of healthcare by the patients, personalizing, providing intelligent services clinically to the patient. The machine learning models will be able to consider the patient's behaviour, their medical history of treatments used and compliance (or not) with them, and their profile of visiting hospitals, before proposing new appointments, reminders for taking medicines, prevention and risk assessment to the patient. Artificial intelligence (AI) chatbots and virtual assistants to enhance communication between patients, answer frequent healthcare-related questions, walk a patient through the administration system, and even help a patient to schedule an appointment do not require a person to monitor the work of a healthcare system (at all times). These cunning functions are available to alleviate burden on healthcare providers and improve patient access and satisfaction.

Despite the advancement in technology, many virtual patient engagement applications and solutions continue to be riddled with inadequate intelligent scheduling, document security, cloud capacity, cybercrime and interoperability. Only a few

solutions exist today that can modularly solve each element of the health care pieces and no holistic cloud solution is available that could be end—to-end responsible for the patient communications process. This inefficiency will result in a loss of efficiency in business, and in extra administrative expenses for healthcare businesses.

To address such fears, the current study will involve delivering a Research Project being called – 'Virtual Patient engagement Framework Cloud Based and Intelligent Scheduling & Document Management'. The unit of the proposed framework is one digital healthcare solution by combining different aspects of cloud based infrastructure, intelligent and AI powered scheduling, engineered smart and automated notification, assistance through tele-consultation and even common security measures into one. The paradigm is: maximize outlooking's, more efficient use of health services, more security of the documents, more engagement of patients at each level of health music and better co-operation of the stakeholders of health care. Moreover, the framework also makes it possible to implement scalability in the hospitals, specialty clinics, diagnostic centers and multi-site healthcare networks and provides high availability, adherence and resilience of operations. The above-mentioned cloud, AI and Cybersecurity, workflow automation environment has appeared to be the most conducive for developing a patient-centric, safe, scalable, digital healthcare system capable of catering to the need of the healthcare provision in the modern era.

2. Literature Survey

The way a healthcare delivery service was being offered had a radically changed approach with the advent of the digital healthcare that was rapidly advancing through the application of cloud computing, patient portal, smart scheduling and health information management safely without risks of being infected. Various areas of virtual patient engagement such as patient portal adoption to up to healthcare information system architecture, access control, usability and telehealth security have been reported. The present paper is about a literature review, which deals with cloud-based virtual patient engagement and intelligent scheduling literature, and secure document management.

In Gheorghiu and Hagens [1], there was the research carried out on the adoption and maturity of the use of electronic patient portals in healthcare facilities. Their study proved that patient portals have now become more than mere information-sharing platforms, and they are full-fledged healthcare management systems that can boost the process of booking appointments, access lab reports and lab results, secure messaging, prescription management, and patient education. The authors underlined that advanced patient portals enhance the dialogue between patients and their care providers as well as motivate the former to become more involved in the management of their healthcare. However, they did discover that there was heterogeneity of portal capabilities and of the maturity of execution at the healthcare institutions.

Wildenbos et al. [2] studied the experiences of the older patients using the patient portals, 1 year following the implementation. Their results showed that, although some of the geriatric patients had some issues with the usability initially, the continued use had had enormous positive effect concerning digital trust and patient involvement in the healthcare. The researchers have pointed out that the intuitive-based interface, qualities of access and adequate user training amongst others are factors that can be considered much in offering portal adoption to the older adults. Nonetheless, a limiting factor of mainstream usage between the older generations was technological literacy.

In their study, Kohler et al. [3] assessed the potential of using a web-based health promotion portal in Germany using a life-cycle assessment. Their research revealed that the cloud-based healthcare portals have the potential to be implemented in providing preventive health services without funding it too costly. The results of this paper identified that online medical care websites could deliver medical education services and engage patients with a fairly low cost of operation. Nevertheless, it bases a long-term sustainable on system optimization and engagement of the users.

The patient engagement systems turned out to be one of the key factors as far as its aspect is concerned with the scheduling of their appointments. In the study conducted by Saif et al. [4], it was possible to discuss missed appointments in primary healthcare clinics and the reasons. Transportation, communication breakdown, opposition to schedule, lapse in memory and socialeconomic status were the most significant antecedents that contributed to no-shows in patients, they found. Robotic repetitive reminders, smart appointment booking applications and low-cost appointment handling will go a long way in preventing the percentage of missed appointments as well as increasing utilisation of the healthcare resources, the authors stressed. Their findings within the framework of the evolving healthcare systems underline the need to introduce the predictive type of scheduling mechanisms.

This may be offered on the technological platform whereby digital healthcare could be merged with architecture of healthcare information systems. A framework R. SJ and Spahni [5] suggested to integrate a heterogeneous healthcare application was called Healthcare Information System Architecture (HISA), and suggested the middleware based framework. With its design, it was capable of consistency across communication across clinical information systems as well as interface with other health care components. Though created prior to initial success of cloud-computing, HISA developed a number of architectural principles that are still in play to impact modern cloud-based healthcare infrastructures.

Omar and Taleb-Bendiab [6] have suggested a service-oriented architecture (SOA) to e-health support services to enhance even further the healthcare interoperability. They made modular use of web services in their framework to allow communication amongst their distributed healthcare applications. Not only the proposed architecture enhanced the system scalability but also offered interoperability and service reuse besides making it easy to integrate the system with other electronic health records and telemedicine systems. The study found out that cloud-native healthcare ecosystem builds on an effective foundation on service-oriented computing.

The issue of security is one of the most crucial needs in online healthcare systems. Lu et al. [7] tackled the issue of security that comes along with telehealth applications that are implemented on Web based e-health portals. Confidentiality, authentication, secure communication, and user authorization are the basic security requirements that their work determined. The authors came up with communication solutions that use encryption and a secure authentication algorithm to send confidential patient data during remote communication with a healthcare professional securely. Their results still have an impact on the design of secure cloud healthcare systems.

Jajodia et al. [8] put the bigger problem in perspective with the more accommodating support of the multi access control policies owing to the database security. Their work was more of a general model which could force the discretionary, obligatory and role based access regulating systems on database systems. Although the proposed security model has not been specifically tailored to meet the needs of healthcare applications, it plays a key role in providing security in electronic health records management and controlled access of the contents of healthcare information systems.

Based on their prior work, Lu et al. [9] proposed an overall implementation model of the web based e- health portal systems. The system design entailed; patient registration, patient medical records, appointment and security of the messages sent and information sharing on healthcare in one internet platform. The authors have also demonstrated how the integrated portal systems can greatly increase accessibility to healthcare and reduce administrative workload and also improve patient-clinician interaction.

The well developed software engineering is required to make the processes of effective management of healthcare data. This was done in the study by Ireland et al. [10], which covered the subject of the object-relational mapping (ORM) as one of the aspects of an enterprise application development. Their architecture streamlined communications between application programmers and the relational databases with enhanced maintainability, database abstraction and scaled. These building principles prove useful in particular the cloud-based health systems that are compelled to deal with large amounts of formal patient information and medical records.

The facet of trust is relevant in applying online healthcare service. Luo and Najdawi [11] studied some aspects of trust-building in electronic business, and they discovered that the transparency, security, reliability and user confidence are most important factors that determine the determination of technology acceptance. They can be transferred directly to cloud healthcare solution since patients will not question that their personal medical data would be safe and that they can be accessed by assistance of trained medical workers.

The access control systems are the other crucial element of secure systems of involving the patient. The version of an access control system as proposed by Lu et al. [12] is e-health portal system-specific. They modelled their approach using the role based authorization policies that would be used to restrict access to the sensitive healthcare resources by user based on the user responsibilities. The construction also offered more privacy to the patients and access to other parts of the medical information to both physicians, nurses, administrators and the patients in a secure way on the basis of the already existing authorization policies.

User-centered design is crucial to the health technology adoption. In order to investigate how the older adults can be taught to adopt the new emerging technologies, and tapped on usability, simplicity of the interface in learning of older adults as a significant predictive of success in learning emerging technologies in their research [13]. The research found that user-friendly interface, navigation and 24/7 technical support are one of the requirements of the older customer as far as using the digital platforms of healthcare is concerned. These results may serve as helpful guidelines to create a system of inclusive virtual engagement among patients.

Brooke [14] has analyzed the System Usability Scale (SUS) which has been one of the most flexible scales that have been utilized in determining the usability of the software. The research has established SUS as a reliable, standardized and efficient way of measuring the level of user satisfaction in relation to a variety of software application packages such as healthcare information systems. Therefore, SUS is now the commonly-used assessment tool to determine patient portal and virtual healthcare solutions feasibility.

Finally, the third one was a research conducted by Otte-Trojel et al. [15] to assess the organizational implications of patient portals in Kaiser Permanente. Their qualitative study found that the application of patient portal results in bettering the healthcare delivery process via enhancement of patient provider communication and interaction, healthcare transparency, shared decision-making, and organizational efficiency. The authors have found out that not only a low-level of advanced technology but also the preparedness system in the organization, incorporation of the work flow, facilitation of the leadership and inevitable user engagement must be offered, so that the advanced technology implementation would be a success.

On the whole, the literature reviewed shows that significant advances have been made in the creation of the patient portals, healthcare information architecture, telehealth security and usability engineering, appointments, and access controls. The existing studies are dedicated primarily to these aspects individually. Little to no literature has been explored on how cloud-native infrastructure, appointments scheduling and management with AI, policy-safe document management system, AI assisted patient interaction, interoperability and full system-cybersecurity might be integrated into a single system. In this regard, this research proposes practice to introduce Cloud-Based Virtual Patient Engagement Framework and Intelligent Scheduling and implementation of cloud-based intelligent document management in such a way that the two complementary technology can further be used to implement scalable, secure and intelligent healthcare ecosystem to advance patient engagement, optimise operational effectiveness, data security and the healthcare provision process.

3. Cloud-Based Virtual Patient Engagement Framework

3.1. Overview of the Proposed Framework

The proposed Cloud-Based Virtual Patient Engagement Framework including Intelligent Scheduling and Intelligent Secure Document Management (CVPE-ISDM) is aimed at creating a digital healthcare environment to engage the patients, provide greater access to the healthcare services and increased use of resources along with safe storage of sensitive health data. The framework brings together cloud computing, artificial intelligence (AI), machine learning (ML), intelligent scheduling algorithms, secure document management, interoperability services, and more powerful cybersecurity measures into a single cloud-based platform that is capable of empowering the patient healthcare lifecycle as a whole. The framework through these technologies curbs a number of the weaknesses of the traditional healthcare systems including ineffective integration of patient records, absence of effective appointment scheduling, isolation of healthcare systems and poor document security.

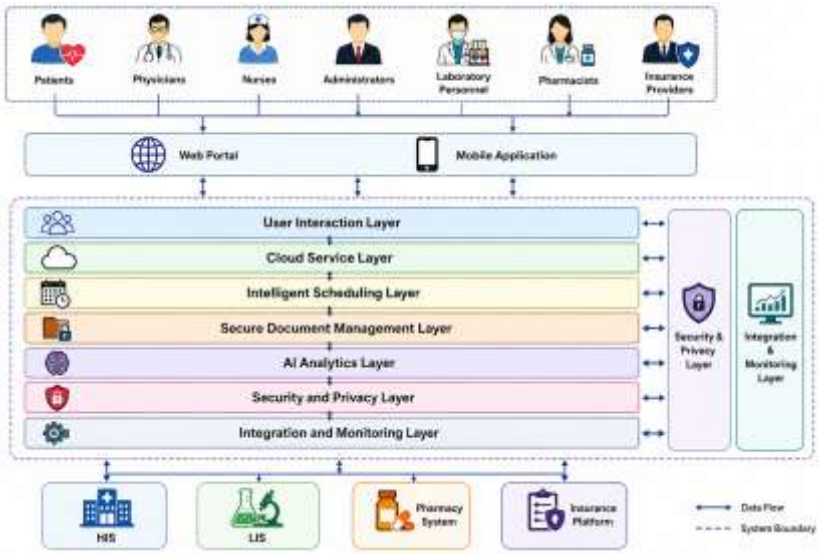


Figure 1. Overall Architecture of the Cloud-Based Virtual Patient Engagement Framework (CVPE-ISDM)

In contrast to an environment with a conventional healthcare setup where appointments, electronic health records (EHRs), and teleconsultation, and document management are disconnected systems, proposed framework ensures smooth flow of communication between all healthcare services using standard cloud services and interoperable application programming interfaces (APIs). The created architecture will allow access to healthcare services by healthcare providers, patients, laboratory staffs, pharmacists, insurance services and hospital managers/administrators without references to the geographical position and will provide the guarantee of data confidentiality, integrity and availability. The list written below will be used to organize the proposed model to seven layers of functions which are interrelated and will be arranged by the following: User Interaction Layer, Cloud Service Layer, Intelligent Scheduling Layer, Secure Document Management Layer, Artificial Intelligence Analytics Layer, Security and Privacy Layer, and Integration and Monitoring Layer. All the layers have a specific healthcare role and run in parallel to share information with the rest of the layers to provide secure, scalable, intelligent, and patient-centric healthcare services.

3.2. User Interaction Layer

User Interaction Layer is an interface that exists between the envisioned healthcare infrastructure and it facilitates safe interactions between the users (end-users) and the cloud. It has easily accessible web- portal and mobile applications that allow patients, physicians, nurses, laboratory employees, pharmacists, hospital administrators and insurance agents to make orders to the healthcare system, using their personal dashboard. The interface should also be user-friendly to navigate through, responsive and should incorporate accessibility features since the user levels of digital literacy might be different.

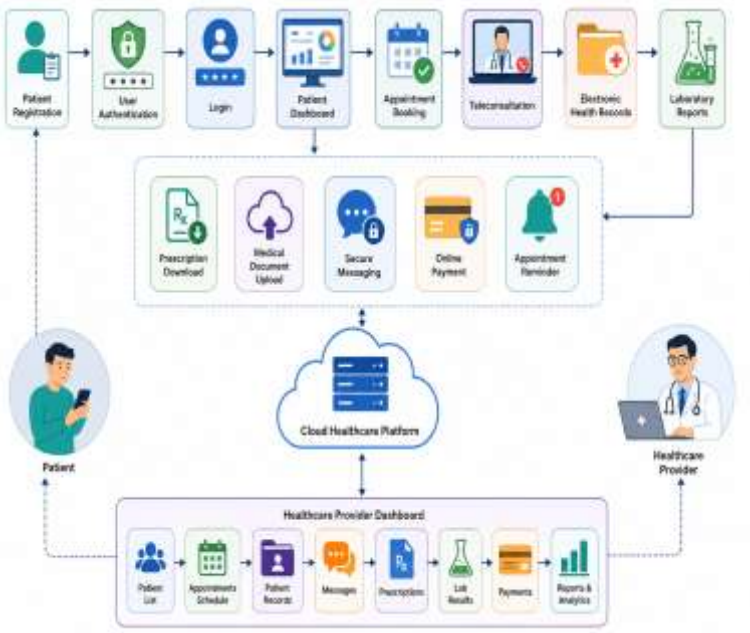


Figure 2. User Interaction and Healthcare Service Workflow

Among the system features, patients will register and authenticate using their identities, make appointments, attend telemedicine appointments, access electronic health records and download lab reports, prescription and upload supportive medical records, efficiently communicate with doctors, and online payments and appointment and drug reminder. Patient histories, consultations, and uploading prescription and diagnostic reports, monitoring the treatment progress, communication with patients and coordination with other healthcare departments can be accessed by healthcare workers. Its responsive nature has enabled it to be compatible with desktop computer, smartphones, tablets and wearable healthcare devices thus ensuring the same level of access to healthcare services regardless of the type and place associated to the device used.

3.3. Cloud Service Layer

Cloud Service Layer forms the technological core of the proposed framework, it is a scaled computing provider, availability, secure cloud storage, virtualization service provider and high availability computing providers.

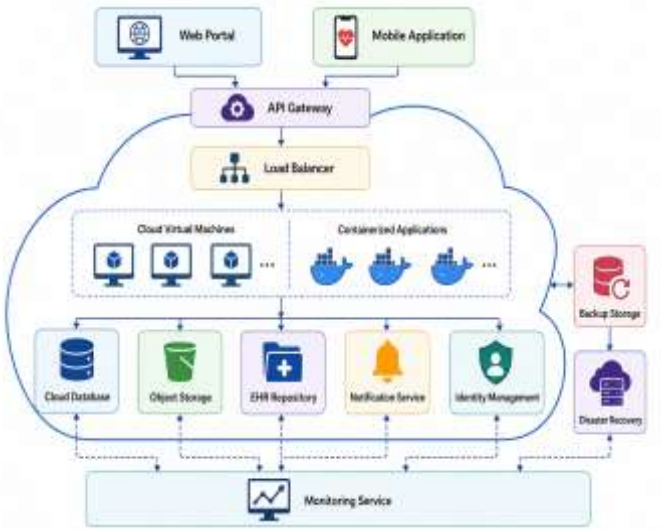


Figure 3. Cloud Service Architecture for Healthcare Platform

Cloud-based assets can be leveraged in a healthcare environment to be able to scale the computing power and storage unit to offer when needed by patients based on the patient demand and load to the infrastructure, in lieu of maintaining costly premises-based infrastructure. The advantage of this is that it is much more scalable as well as the cost of running is less and maintenance of the infrastructure. Cloud platform offers support to electronic health records, safe storage of medical records in a secure object, relational databases, virtual machines, containerized healthcare programs, API gateways, notification services, identity management systems, backup repositories and disaster recovery systems. The ability of the healthcare providers to treat the fluctuating patients with performance adhort malfunction is made possible through high allocation of resources. The system requests are also effectively distributed amongst the other computing resources and multi-region deployment also improves the services availability and business continuity of the system. This also secures their security of their healthcare operations as they have both the backup data and disaster recovery systems under the continuous operation in case of any form of unpredictable breakdowns or a hacker attack does take place.

3.4. Intelligent Scheduling Layer

Appointment scheduling is one of the aspects that enhance patient satisfaction and maximality in terms of healthcare resources utilization. The traditional methods of appointing patients tend to be plagued with physician overbooking, appointments wastages, lengthy waiting lines, squandered resources and increased no show rates. To alleviate these challenges, the devised framework will feature an Intelligent Scheduling Engine that is founded on Artificial Intelligence which addresses the aim of continuously evaluating the data related to the healthcare operations to arrive at the optimal number of appointments.

The availability of the physician, the workload in the department or the patient preference, the consultation times and offering the most suitable time to an appointment are some of the input variables that the scheduling engine considers when making a judgment in respect of attending an appointment; they are determined using the machine learning algorithms that compare the past scheduling activity. They are robotic notifying messages in which we send them in emails, SMS messages and mobile apps so as to exclude an appointment to block any missed consultations. The dynamic rescheduling algorithms immediately get reallocation of the cancelled appointment slots to the patients on the waiting lists, maximising the amount of idle time of the physicians and increasing the efficiency of the healthcare operations. As a result, time spent on waiting is minimized, the patient experience improves, the physician workload is higher and the delivery of the healthcare services becomes streamlined and efficient with the help of the intelligent scheduling layer.



Figure 4. AI-Based Intelligent Appointment Scheduling Framework

3.5. Secure Document Management Layer

Healthcare organizations operating in continuous flow touch and produce massive amounts of sensitive clinical data, such as electronic health records, lab reports, diagnostic imaging, prescription, insurance claims, discharge overviews, referral letters and patient consent forms. It belongs to the most urgent problems of electronic healthcare environment the correct functioning of such documents and the necessity to provide the high level of availability of the authorised staff. This can be overcome by making use of Secure Document Management Layer that has been proposed which will be centralized in the cloud and cloud distributed backup service of document storage as well as document guard on all aspects.

They are added to all medical records, followed by execute a number of operations that involve file validation, malware theme, metadata, encoding, secure centralizing, and version which in turn are stored permanently. The added indexing features allow them to access the documents extremely fast based on the tenure of the patient, names of the doctors, diagnosis and

appointment number or types of documents. Role-Based Access Control (RBAC) is employed to ensure that only the authorized personnel can access confidential medical records, modify or download information, depending on their day-to-day organizational responsibilities. Documents and all transactions they perform are the ones with indisputable audit logs which provide specifics about how documents have been viewed, edited, downloaded and distributed. Version control keeps the revisions of a document, enabling medical workers to access past clinical data and avoid a loss of data, which can happen by mistake. Hospitals, laboratories, pharmacies, specialists and insurance providers can also have safe document exchange, with the help of secure data channels that are encrypted.

3.6. Artificial Intelligence Analytics Layer

The Artificial Intelligence Analytics Layer is the brand-new provider of intelligent decision-support to the proposed framework. It crunches both structured and unstructured healthcare information to generate predictive insights to improve clinical decision-making, operational efficacies, and patient engagements. With healthcare, the machine learning systems continuously analyze the history of patients, appointment history, results of the treatment, the trends that have been noticed during the use of a healthcare over a certain span of time, the load that a physician has, and so on, to identify the respective trends and help in the arrangement of healthcare in a form of empiricism.

An AI layer is comprised of a few modules of analysis. Current models A patient attendance prediction modeling predicts probability of patient attendance in the context of proactive optimization schedules using the past behavior and demographic data. Resource optimization algorithms predict the demand of patients in the future and help hospitals to efficiently distribute physicians, consultancy rooms, diagnostic equipment, and medical staff. The patient risk identification models will use electronic health records to determine patients who require urgent attention to their health or require further medical attention. Custom Recreation engines are used to create custom recommendation based on the individual patient health history to generate updated recommendation, as examples include prescription recalls, vaccination referrals, follow-ups, preventive screenings referrals and labs tests schedules. Furthermore, interactive analytical dashboard visuals include such key performance indicators as employment rate of making appointments, physician utilization, mean waiting time, patient satisfaction rating, no show rates and portal utilization rate. These lessons of analyses will be used to plan on the strategy and ongoing improvement of healthcare services.

3.7. Security and Privacy Layer

Among the important functions that a computer health care solution can perform is a guarantee that the information available in health care does not fall in the hands of the wrong party and attacks of computer viruses. There are various security mechanisms in place in the Security and Privacy Layer which individually protect patient confidentiality, data integrity and regulatory compliance. The model presupposes a defense-in-depth security approach that ensures the safety of the healthcare resources at all the levels of the model.

Multi-factor authentication, biometric verifications, Single Sign-On (SSO) and OAuth-based authentication are the methods of enhanced user authentication. Cloud repositories with sensitive healthcare data and protocols of a communication network with the exchange of data are secured using AES-256 encryption and Transport Layer Security protocols (TLS), respectively. Role-Based Access Control is utilized to control access to the system based on organizational work and provide a patient with access to his medical records and an administrator, pharmacist, lab worker, and other staff with access permissions based on their specific tasks. On-demand security controls: The automated intrusion detection is processed and analyses access attempts, unauthorized access and malware activity, network abnormalities and insider threats. The structure also makes it easy to conform to healthcare regulations as audit logs, consent management, privacy preservation, secure and back-up procedures, and data retention are logged on, which increases the trust the patient has in the digital healthcare services.

3.8. Integration and Monitoring Layer

Healthcare organizations usually possess quite a number of different information systems that must effectively be able to share information about the patients in the organization. Integration and Monitoring Layer makes the ability of easy integration of the Hospital Information Systems (HIS), Electronic Health Records systems, Laboratory Information Systems (LIS), Pharmacy Management Systems, Billing Systems, Insurance Platforms and Telemedicine services available. The traditional healthcare interoperability standards and RESTful API will help facilitate successful communication in real-time between these divergent healthcare apps and would minimize the issue of manual medical information entry and duplicate information.

In addition to providing systems integration, the performance of the cloud infrastructure would be continuously monitored by evaluating the health of the servers, the databases utilization, the size of using the storage, API response, network availability, security breaches as well as performance of the applications. Benefit Real-time dashboards help healthcare administrators to have a general understanding of the operations so that they can identify the bottlenecks to the performance, lack of resources or security vulnerability in a short period. The round- the clock surveillance provides optimum levels of system up time, quality healthcare service provision and resource utilization of the overall healthcare environment.

3.9. Overall Framework Workflow

The working process of the proposed framework starts when a patient signs in at the cloud-based healthcare portal, with authenticated credentials, in a secure manner. After the authentication check, the patient makes an appointment request and forwards a request to Intelligent Scheduling Engine. When scheduling engine uses the availability of the physicians, the consultation time, patient interest and history of visiting health facilities and compares it with the healthcare priorities it suggests an optimum appointment slot. After this has been established, automated reminders are installed using various communication channels to make sure that there are minimal cases of no-show with regard to appointments.

The doctors access their encrypted electronics health records via their secure cloud services, during the consultation process. Secure Document Management Layer verifies and encrypts clinical notes, prescriptions and laboratory requests as well as diagnostic reports and referral documents produced during the consultation, indexes and version controls and blocks in a cloud based storage architecture. At the same time, the Analytics Layer, which is powered by Artificial Intelligence, processes patient data to create individualized healthcare prescriptions, improve resource management, determine high-risk patients, and aid in clinical decision-making. The Integration Layer facilitates the healthcare information to interact with hospitals, pharmacies, laboratories, insurance companies, and systems used in telemedicine, the key to integral healthcare integration. The Security and Privacy Layer will never be implemented without authentication, authorization, encryption and cybersecurity running on the workflow and Monitoring Layer on the entire system running health and performance. This integrated workflow creates decent interaction with patients, is cloud-based, scalable, intelligent, and builds on secure data, simplifies health care and makes it more approachable and efficient and higher quality patient-based health care.

4. Framework Evaluation

4.1. Evaluation Objectives

The suggested Cloud-Based Virtual Patient Engagement with Intelligent Scheduling and Secure Document Management (CVPE-ISDM) system is tested to determine its efficiency in enhancing the provision of healthcare services, interaction with the customers, reservation of appointments and the safety of the paper process, and the functioning of the entire system. The testing revolves around the evaluation of the framework in terms of functional, operational, security and scalability points of view. Besides quantifying the efficiency of the system, the assessment will look at the capacity of the framework to function in the cloud-native healthcare environment as well as ensure privacy of the data and high availability and interoperability. The reveal is to confirm that the proposed system will present pertinent benefits over the conventional healthcare information systems that depend on fragmented scheduling and document management systems.

4.2. Functional Performance Evaluation

The functional analysis identifies the speed with which the proposed framework can be able to undertake key healthcare processes in the right and efficient manner. The assessment will include registration of patients, smart schedules, support through teleconsultation, e-health records, the possibility to upload and access documents safely, automatic notifications, as well as compatibility with other medical systems. Functional testing ensures that all modules comply with the desired functionalities as well as possess the same communication with other elements of the framework with the standard APIs. It is possible to schedule appointments based on the availability of doctors, patient preference, consultation time, appointment priority, allowing no schedules to interfere and can better utilise resources in healthcare, using the smart scheduling algorithm. Equally, document management module may be highly efficient in the storage, retrieval, indexing and versioning of the electronic healthcare documents without necessarily interfering with the integrity of the data.

4.3. Security and Privacy Evaluation

The data of highly confidential patients used by the medical systems is required as security factor. The proposed framework would integrate several additional cyber protection features that involve; multi- factor authentication, Role-based access control, encrypting the data with AES- 256, Transport Layer Security (TLS) and secure cloud storage, audit logging, and around the clock security screening. The assessment will also make sure that storage and transfer of the sensitive healthcare information is safe even in terms of storage. The attempts of unauthorized access are adequately blocked with the help of authentication and authorization processes, and detailed audit logs could give a full trace of the activities of document access and modification. The analysis also proves that encrypted documents management and safe communication protocols are the crucial means to minimize the risk of data breaches, unauthorized disclosure and cyberattack thus guaranteeing the regulatory compliance and making a patient trust a provider even higher.

4.4. Scalability and Cloud Performance Evaluation

The suggested structure is designed to support the augmented number of patients, providers and healthcare transactions without resulting in substantial performance issues due to its cloud-native architecture. Some of the evaluation criteria of scalability includes response time of the system, the system uses of its cloud resource, storage capacity, the number of users to be served at a given time and how available the system is to workloads. The servers dynamically provide elastic cloud resources in the sense that when there is high demand in healthcare then the server automatically provides more computational resources and when it is not required, then the server automatically provides free resource. Automatic load balancing

distributes the requests entering the cloud among the instances of the cloud to maintain the smooth flow of the cloud and reduce instances of service failures. The framework is also enforced adequately in multi-hospital healthcare systems as the reliability of such system could also be improved by continuous backup and disaster recover systems, besides continuity of operation.

4.5. Patient Engagement and Operational Efficiency Evaluation

The appropriateness of the suggested structure is also viewed through the lenses of patient engagement and effectiveness of the operations in health care. A significant decrease in the number of non-attending patients and patient attendance can be achieved with smart booking, along with automated booking alerts. Individualized alerts, safe and reliable communication, tele-consultations, and easy access to electronic health records motivate patients to be active participants in their health care. Through scheduling automation, centralization of managing the documents, and integration of workflows in healthcare, the administrative workload of the healthcare professional is greatly diminished. With real-time dashboards, administrators are provided with useful information about the operations: physician utilization, patient waiting time, booking appointments, system utilization information, and then make decisions to ensure operations are continuously being improved.

4.6. Overall Evaluation Summary

The general overview shows that the suggested CVPE-ISDM architecture is a viable concept wherein the cloud computing, artificial intelligence, secure document management and smart scheduling become a single healthcare platform. The framework is more efficient in terms of timeline and patient engagement and cybersecurity and can utilize resources more efficiently and is able to scale better than the traditional healthcare information systems would. The built-in cloud-native offers challenges-free interoperability across the hospitals, laboratories, pharmacies, insurance companies and telemedicine locations in addition to snug management of electronic health record and reports of clinical data. The suggested framework, therefore, offers a stable, scitable, safe, and smart solution on the contemporary digital healthcare settings that can enhance healthcare quality, efficiency of operations, and patient satisfaction.

5. Conclusion and Future Work

This new digitalization of the healthcare sector has created a new need among the digital healthcare stakeholders to have a secure, intelligent and scalable patient engagement platform that can support the modern healthcare delivery. This research proposed a new model of Cloud-Based Virtual Patient Engagement with Intelligent Scheduling and Secure Documents Management (CVPE-ISDM) that integrates a cloud computing system, artificial intelligence system, machine learning, secure document management, interoperability service, and advanced cybersecurity technologies into a single healthcare delivery model. The proposed model will mitigate some of the weaknesses of the traditional healthcare information framework as it will offer a natural mechanism of integrating patient registration, teleconsultation, smart-appointment scheduling, managing electronic health records, secure document storage, automatic communications, and real-time healthcare analytics. The cloud-based architecture is capable of providing high availability, scaling, optimization of the resources and secure sharing of information among the healthcare providers, patients, laboratory, pharmacy and insurance companies. Moreover, AI-based appointment scheduling algorithms will reduce participation conflicts over appointments, reduce waiting time, improve physician use, and optimize operations. Encryption has something to do with enhancing patient data security, boosting privacy in healthcare, and regulatory compliance as it also has strong role-based access control, audit trail, and real-time access of patient data. Overall, the proposed framework presents a safe, universal and patient-centred solution that can optimise the availability of healthcare, quality of services, administrational efficiency and patient satisfaction on modern digital healthcare environments.

Other types of artificial intelligence models like deep learning, large language models (LLMs) and reinforcement learning could also be introduced in the future to add functionalities to the proposed framework, like offering personalized healthcare suggestions, novel clinical decision support, and making adaptive appointment schedule. Real-time health data collection and continuous monitoring of patients remotely can be achieved with the usage of Internet of Things (IoT) devices and wearable health sensors. To enhance the decentralized integrity of documents, transparency of data sharing and patient-controlled health records, blockchain technology can be considered as a solution. Moreover, predictive disease risk modelling which, potentially, can be introduced in the future, federated learning with an emphasis on privacy-preserving AI, multi-linguistically conversational healthcare operator and multi-linguistically digital twin, which could be useful in planning personal treatment, can be on boarded. Large-scale real-world implementations and it validation in multi-hospital healthcare systems will also show the scalability, interoperability, reliability and effectiveness of the framework to support next-generation cloud-based intelligent healthcare systems.

References

[1] B. Gheorghiu and S. Hagens, “Use and maturity of electronic patient portals,” *Studies in Health Technology and Informatics*, vol. 234, pp. 136–141, 2017.

[2] G. A. Wildenbos, K. Maasri, M. Jaspers, and M. W. M. Jaspers, “Older adults using a patient portal: Registration and experiences, one year after implementation,” *Digital Health*, vol. 4, pp. 1–9, 2018.

[3] S. Kohler, T. Keil, T. Reinhold, *et al*., "Usage of a German prevention and health promotion web portal and cost per pageview: A life-cycle assessment," *Digital Health*, vol. 5, pp. 1–15, 2019.
[4] U. Saif, R. Sangeetha, T. L. Todd, *et al*., "Why do patients miss their appointments at primary care clinics?" *Journal of Family Medicine and Disease Prevention*, vol. 4, no. 090, 2018.
[5] R. SJ and S. Spahni, "Healthcare information system architecture (HISA) and its middleware models," in *Proceedings of the AMIA Symposium*, 1999, pp. 24–30.
[6] W. M. Omar and A. Taleb-Bendiab, "E-health support services based on service-oriented architecture," *IT Professional*, vol. 8, no. 2, pp. 35–41, Mar.–Apr. 2006.
[7] S. Lu, Y. Hong, Q. Liu, *et al*., "Securing telehealth applications in a web-based e-Health portal," in *Proceedings of the International Conference on Availability, Reliability and Security (ARES)*. Portugal: IEEE, 2008, pp. 3–9.
[8] S. Jajodia, P. Samarati, M. L. Sapino, and V. S. Subrahmanian, "Flexible support for multiple access control policies," *ACM Transactions on Database Systems*, vol. 26, no. 2, pp. 214–257, 2001.
[9] S. Lu, Y. Hong, Q. Liu, *et al*., "Implementing web-based e-Health portal systems," *Computer Science Technical Report*, 2012.
[10] C. Ireland, D. Bowers, M. Newton, *et al*., "Understanding object-relational mapping: A framework-based approach," in *Proceedings of the 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, 2015.
[11] W. Luo and M. Najdawi, "Trust-building measures," *Communications of the ACM*, vol. 47, no. 4, pp. 108–113, 2004.
[12] S. Lu, Y. Hong, Q. Liu, *et al*., "Access control in e-Health portal systems," in *Proceedings of the International Conference on Innovations in Information Technology*, 2007, pp. 88–92.
[13] Y. Barnard, M. D. Bradley, F. Hodgson, and A. Lloyd, "Learning to use new technologies by older adults: Perceived difficulties, experimentation behaviour and usability," *Computers in Human Behavior*, vol. 29, no. 4, pp. 1715–1724, 2013.
[14] J. Brooke, "SUS: A retrospective," *Journal of Usability Studies*, vol. 8, no. 2, pp. 29–40, 2013.
[15] T. Otte-Trojel, T. G. Rundall, A. van de Bont, C. de Mul, and M. M. A. de Klundert, "The organizational dynamics enabling patient portal impacts upon organizational performance and patient health: A qualitative study of Kaiser Permanente," *BMC Health Services Research*, vol. 15, Art. no. 559, 2015.