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Developing Scalable Java Microservices for Healthcare Applications

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Abstract

Elderly people with infectious infections are challenging to treat; as they often present to consultations with severe, advanced symptoms, they are frequently sent to emergency care. The hypothesis was that a patient's health might be considerably enhanced and the strain on emergency health system services could be lessened by delaying an infectious illness diagnosis by a few days. Chatbots that can monitor a patient's status, deliver targeted information, promote drug adherence, and more might be especially helpful for patients with comorbidities or chronic illnesses. Chatbots need an appropriate underlying software architecture in order to carry out these tasks. A better data analytics approach promotes process efficiency in addition to offering helpful insights in IoT data. It is difficult to create a solid IoT-based safe analytical model for a number of reasons, including data from many sources, growing data volumes, and monolithic service design methodologies. In order to facilitate predictive analytics for individualised fitness data in an Internet of Things setting, this study suggested an intelligent blockchain-enabled microservice. The system's architecture supports microservice-based analytical features to provide dependable and safe Internet of Things services. A key strategy for creating scalable and maintained cloud-native apps is microservices architecture. Microservices, in contrast to conventional monolithic designs, break down applications into discrete, independently deployable services that interact via well-defined APIs. By improving modularity, this architectural change makes it possible to increase scalability, robustness, and flexibility. Because healthcare data is sensitive, it needs extra security against the possibility of illegal access. Data privacy is a crucial issue. In addition to presenting patient empowerment, this research emphasises the significance of data empowerment in the healthcare industry. Several facets of the traditional architecture and Service-Oriented Architecture against microservices architecture are examined in order to address the deployment of an appropriate and effective architecture for a remote healthcare monitoring system. A case study is provided on the RO-Smart Ageing programming system, which is used to enhance the management of health data.

Keywords: - IoT, Microservices Architecture, Health Data Management, Well-Defined APIs, Sensitive Nature, Emergency Health System Services, Blockchain-Enabled Microservice, Infectious Diseases, Data Privacy.

I. Introduction

The Internet of Things (IoT) is a new sector with cutting-edge tools and technology, such as methods for processing and analysing information to increase productivity and efficiency in the IoT environment. IoT [1] supports intelligent IoT applications by combining sensors and actuators with technology for communications and information in a digital environment where data is gathered, processed, and evaluated. Healthcare, business, infrastructure management, energy management, safety and security, and other areas all heavily rely on data analytics. However, the IoT analytics community is facing new hurdles as a result of its widespread use [1, 2]. Among these are the challenges of processing IoT data that is streamed from various devices, managing different data formats, and annotating sensor observations in real-time to understand their context and meaning. In particular, using and processing this data in conjunction with maintenance-related services rather than relying solely on unreliable method. In IoT applications, these problems negatively affect scalability, efficiency, and reusability. Such models are necessary to get beyond the aforementioned problems and extract useful information from information from the Internet of Things. Distributed ledger technology, the foundation of the blockchain, was developed to store irreversible financial data. By allowing parties to sign the transaction, a blockchain secures the record of every transaction [2]. A block that has been digitally encrypted and signed as a time stamp is part of the blockchain. Finally, cutting-edge cryptographic techniques are used to secure and defend the chain [2, 3]. The six levels of a distributed ledger database—network, data, smart contract consensus, application, and service—make up a blockchain. Data collection, authorisation, and control are usually carried out at the data layer and network layer. The consensus mechanism and smart contract layer are considered to include the incentive structure, consensus protocol, and smart contract functionality. Additionally, the blockchain consensus system uses a significant number of resources and processing power, which lowers throughput and latency [3, 4].

The service or service layer, which is visible to the application layer, controls the back-end operations of the blockchain network. The application layer manages the communication between the front end and back end. Over the last several years, a number of novel blockchain technologies have been put into use, such as smart contracts, consensus algorithms, permissions and privacy mechanisms, and [3, 4]. There are both private and public blockchains on the blockchain. In a private blockchain, the network is controlled and governed by the people who have registered. In a similar vein, whereas anybody may participate in the decentralised consensus and block creation processes in a permissionless blockchain, only registered participants in a permissioned blockchain can engage in the block creation mechanism. The permissioned blockchain is thus thought to be more scalable, transparent, and adaptable.

A software design methodology known as microservices architecture divides an application into many loosely linked, independently deployable services. Often called a "microservice," each service carries out a particular business activity and interacts with other services over lightweight protocols, usually message queues or HTTP/REST. Microservices design divides systems into smaller, modular components that may be independently built, tested, deployed, and scaled, in contrast to conventional monolithic architectures where all capabilities are tightly integrated into a single unit [5, 6]. Every microservice functions independently and is in charge of a certain area of the business domain. Teams may create, implement, and grow services thanks to this independence without affecting the program as a whole. A decentralised approach to data management results from the microservices design, where each service oversees its own database or data storage.

In contrast, monolithic designs often use a single, shared database. Lightweight protocols are used by microservices to communicate with one another. RESTful APIs may facilitate synchronous communication, whereas messaging platforms like RabbitMQ or Kafka can facilitate asynchronous communication. Through Continuous Integration/Continuous Deployment (CI/CD) pipelines and Automated Deployment, Microservices architecture facilitates quick development and deployment cycles. Building, testing, and deploying individual services is greatly aided by automation, which promotes quicker release cycles and better software. Failures may be graciously handled by microservices [6]. The system as a whole does not go down if one service fails since other services keep working. Circuit breakers and retries are two common patterns used to accomplish this resilience. Because each microservice is autonomous, distinct services may be created using the programming languages and tools that best meet their unique needs [6, 7]. Polyglot programming is the term for this adaptability. The design and management of software programs has changed significantly with the transition from monolithic to microservices architecture. Building a whole program as a single, cohesive codebase is known as a monolithic architecture, and it has been the conventional method for decades [6, 7].

These days, chatbots are quite popular in eHealth settings. A chatbot is a computer software that converses with the end user automatically using a variety of communication channels (such as mobile applications, messaging platforms, etc.). [8]. Chatbots have been gaining traction in the eHealth space over the last five years, thanks to the expansion of artificial intelligence and the widespread use of messaging platforms in society. Research indicates that support chatbots for breast cancer patients have had favourable outcomes, with an overall satisfaction rate of 93.95%. As virtual assistants, chatbots may support their users in a variety of ways, for as by collecting personal information, reminding users to take their medications, or checking for symptoms. Furthermore, doctors concur that chatbots can assist with the majority of automated, basic activities in healthcare settings [8, 9]. The algorithms that underpin them, their data sharing capabilities, their scalability, and the feeling of security and privacy they may in still and convey to their users, however, restrict their utility. Providing care for people with chronic illnesses or comorbidities is one of the eHealth scenarios that is expanding quickly and is predicted to do so much more so in the years to come.

An approach that is patient-centric and based on cooperation, empathy, and communication between patients and professionals is supported by the use of technological advances in healthcare. eHealth offers wearables or smartphones, omnipresent services, cloud-based adaptive resources, and mobility via portable devices [9, 10]. Clinical decision support systems (CDSS), telemedicine, health information management, electronic records, computerised order entry, e-prescribing, virtual healthcare teams, triage, [10], and medical mobility services (mHealth) are all included in eHealth research. Big data, artificial intelligence and machine learning, cloud-based solutions, mobile devices, and the internet of things (IoT) are examples of modern IT that supports eHealth.

However, since they involve increased responsibilities, technological installations may sometimes cause conflict between practitioners and nurses [11]. Furthermore, eHealth decision support tools do not release physicians from responsibility. Data-based systems also have to deal with the problem of limited and low-quality data for model training [11,12], which may sometimes become pricey because of processes that are ignored. Deployment is slowed by a new eHealth system's lengthy learning curve; modifications may also be seen as a danger to current working circumstances.

Anticipating an infectious illness diagnosis by a few days is thought to enhance a patient's quality of life, relieve the strain on the health system's resources, and lead to a "better perception" among family members [12, 13]. For national health systems, cost-effectiveness is a key motivator for enhancing citizen medical services. Vital sign alterations are indicative of the progression of an infectious process. The likelihood of contracting an infectious illness might be estimated using these statistics.

For predictive modelling, machine learning (ML) approaches may be used. They help identify patterns and predict how a disease will develop, which enhances management and treatment procedures. Machine learning is a branch of computer science that draws inspiration from artificial intelligence [14]. It yields positive outcomes in medicine and eHealth.

In order to provide nursing home medical personnel effective tools to forecast the onset of infectious illnesses, this study proposes the use of mobile communication, cloud services, and machine learning methods [15]. Because of its unique features, the methodology used in our research sets it apart from previous ideas. The patients were older individuals residing in nursing homes rather than receiving treatment in regular health centres.

A customised biosensor system was created for the project; microservices served as the foundation for the communications infrastructure for data collection, storage, and analysis; machine learning algorithms were incorporated into the microservices for prediction purposes; and three specific infectious diseases were taken into consideration: acute respiratory, urinary tract, and skin and soft tissue infections.

The implementation of a healthcare remote monitoring system using microservices for healthcare data management is presented in this work [16, 17]. to provide the reader a wide understanding of the delicate nature of medical information pertaining to patients' physical or emotional well-being. This information must be shielded from unwanted access. One of the biggest issues in the health sector is data privacy [18]. When combined with patient empowerment via digital technologies, data empowerment gives patients the ability to produce and manage their own data and serves as a catalyst for bettering access to healthcare.

1.1 Healthcare Data Empowerment

1.1.1 Healthcare Data and its Sensitive

Nature Healthcare data, or information about patients' health and well-being, is continually monitored and gathered by healthcare systems [19]. A vast quantity of healthcare data has resulted from the collection of such data via the use of health information technology. Healthcare data provides details about patients' ailments, treatment plans, and other information pertaining to people's physical or mental health. According to the General Data Protection Regulation (GDPR), "data concerning health" is considered personal data, also known as "sensitive data," and needs extra protection because processing it or allowing it to be disclosed without authorisation could seriously jeopardise a person's fundamental rights and freedoms [19, 20]. Thus, special attention is needed to address cybersecurity issues as well as privacy and ethical issues.

1.1.2 Approved Users of Medical Information

The main consumers of patient health information include:

- A patient who gives their primary care physician access to their past and present medical records;

- A primary care or consulting physician who evaluates a patient's medical information to determine the patient's needs and problems and creates a suitable treatment plan; suggests diagnostic tests [20,21], orders treatments, etc., and evaluates the results and the patient's progress; records the patient's medical requirements and keeps a continuous log of services rendered to guarantee continuity of care; works with other doctors to provide appropriate treatment;
- A clinical laboratory that records the findings of medical investigations so that it may be supplied upon request, prepares and analyses patient samples, and communicates the results to the patient's primary care physician [18];
- A nearby hospital that treats patients under the supervision of their primary care physician and keeps track of all services (diagnostic tests, therapy) rendered so that it may be used to explain the patient's development [18, 19].

1.1.3 Privacy and Security Requirements for Healthcare

Data security in healthcare relates specifically to the measures taken to safeguard the availability, confidentiality, and integrity of health information as well as to assist medical professionals in giving accurate information. It also directly refers to protection against unauthorised access. The security was first implemented for paper health records, but as electronic health records developed, [20] it became necessary to have regulations tailored to electronic health data.

The methods used to store data so that only authorised individuals may access it are connected to data security. Safeguarding the personal information of patients is known as health data protection. This is accomplished via a mix of regulations, rules, and recommendations pertaining to the security of health data as well as the storage and accessibility of health information [20, 21]. The patient's right to choose how his personal information is shared is known as health data privacy. Privacy depends on how information flows, who is engaged, how information is accessed, and why it is accessed [21, 22].

II. Emerging Empowerment Of Healthcare Data

One of the main concerns of the populace nowadays is access to healthcare. This reality is making it necessary for healthcare organisations to come up with innovative approaches to interact with patients to develop sustainable value and adapt to the expectations of the community [11, 12]. The patient must be empowered by electronic means and actively participate in managing his or her health state, and the providers must promptly and effectively address the patient's requirements. The practice of giving individuals the authority to manage and promote their own private information for their personal and society's benefit is known as data empowerment.

Table 1 Distinctions between healthcare data security and privacy. [22, 23]

Security	Privacy
Is the availability, confidentiality, and integrity of health information.	Is defined as the appropriate, self-determined use of a patient's medical records.
The medical organisation must use a variety of strategies, including firewalls and encryption, to avoid the compromising of health data due to network or technological weaknesses.	Without the patient's prior permission, the medical organisation is not allowed to sell their medical records.
is focused on maintaining confidentiality or safeguarding a medical organisation.	Is focused on safeguarding patient rights and information.
Security enables the ability to have faith that rulings are enforced.	The capacity to control what personal data may be accessed and where it is sent is known as privacy.

Table 2 GDPR and HIPAA-recommended security and privacy standards. [22]

Requirement	Description
Patients' understanding	Patients are fully entitled to know how any healthcare stakeholder uses and stores their private and sensitive health information.
Patients' control	Patients are able to control who has access to their medical records.
Confidentiality	People without authorisation should not be able to access health information.
Data integrity	It is strictly forbidden to alter, modify, or manipulate the original health information.
Consent exception	According to this, patient data may only be accessed without the patient's permission under dire circumstances.
Non-repudiation	The medical professional should deny that they have done anything with the patient's private information. Evidence should be used to back up such actions in order to prevent disagreement or suspicion.

People may benefit from data empowerment in three key ways:

1. **Ability to access data –** Must prioritise the level of relevance depending on people's demands in order to get relevant government data.; [22, 23]
2. **Capacity to produce and use relevant data –** Participation of individuals in the use of data and, in some situations, even in its initial gathering;
3. **Power to control personal data –** Recognising and deciding how to use their data and the advantages it offers.

Healthcare delivery and access have been redesigned as a consequence of patient empowerment via digital technologies. The main factors influencing this change in dynamics are:

III. Microservices

3.1 Monolithic and SOA vs Microservices

Developing an application using a monolithic architecture means combining all of the parts into a single, logical executable unit. It is the conventional method of creating software applications, where a special technology is used and the whole program is the main emphasis. Monolithic architecture's benefits include:

- The application's initial development and error tracing are quick and simple; [23],
- Every capability is controlled in one location;
- A small number of transformations can be done in the same context, therefore it is cost-efficient;
- Since just one code base is used, no new programming knowledge is required by the present development team; [24]
- Component communication is straightforward and much simpler to manage;
- It is suitable for small teams with few cross-cutting issues and is quite simple to implement.

3.2 Reasons for Using Microservices

Due to its many appealing features, microservices have become popular and can now be used on a big scale. The ones that are most representative are:

- **Agility and speed of deployment:** Various teams may concurrently create and link various service stages, resulting in a quicker time to market;
- **Flexibility:** It is possible to employ many technologies and programming languages simultaneously; [21, 22].
- **Scalability:** A service may be updated, used for a different purpose, or applied in a different setting;
- **Decentralized data management:** It makes it possible to choose the best kind of database and loosely connect services, which improves work speed and business performance; [22]

- **Fault isolation and detection:** A service failure may be identified more quickly. Without impacting the remainder of the application, the service may be terminated or replaced with another one;
- **Autonomous, cross-functional teams:** Specific business capabilities related to the individual services may be independently developed and reused by small teams with a variety of skill sets; [22, 23]
- **Increased quality of data:** It is simpler to better control the data and its flow since each service may have its own database and data management is decentralised.

3.3 Data Management Considerations in the Context of Microservices

Since each service is directly in charge of its own database, it must be strictly controlled, both in terms of security and privacy. Through a query utilising its API, other services may access this data. As additional services are introduced to the application, communication gets more complicated, making it difficult to aggregate data from several databases linked to different services using an API Gateway architecture [25]. Given that a service is loosely connected, independently developed, and reusable, any permitted modifications to the data schema may have an impact on the deployment and scalability of other services that utilise or depend on that particular database [24].

IV. Managing Healthcare Data with Microservices within Remote Healthcare Monitoring Systems

4.1 Remote Healthcare Monitoring Systems (RHMS)

Due to the restricted ability of health services to offer adequate healthcare, the increasing number of elderly patients, patients with mobility impairments, and patients with chronic illnesses worldwide presents a serious problem [25]. The need for strict medical control is further increased by chronic illnesses. In addition to improving health-related quality of life, proactive self-management and early detection of changes in one's health state may lower hospitalisation and treatment expenses.

The basic elements of RHMS are:

- **Data acquisition system:** Consists of a variety of wearable, tiny, non-invasive sensors for gathering environmental or crucial medical data. Wireless technology powers these sensors [23, 24]. Smartphones and other mobile devices with built-in sensors may also be;
- **Data processing system:** Focusses on processing data that has been sent or received.;
- **End-terminal at the hospital:** The doctor's computer, database, or smartphone;
- **The communication network:** connects the data processing and collection systems and sends data and alerts to a healthcare professional who is linked to the RHMS. The healthcare professional determines what has to be done. medication administration, safety precautions, and hospitalisation [23, 24].

4.2 Better Data Management for Healthcare: RO Smart Ageing System Case Study

4.2.1 Bringing the microservices power for healthcare data management

4.2 Improved Healthcare Data Management: A Case Study of the RO Smart Ageing System.

RO-Smart Ageing,

"Elderly health evaluation and non-invasive monitoring in a smart setting (RO Smart Ageing)".

a study that is now in its third stage, which involves the design of the overall architecture. The creation of a RHMS with an elderly-centered approach that can provide tailored assistance for healthcare services in a personalised smart environment is one of the project's primary goals [20, 21].

The foundation of RO Smart Ageing is healthcare data. The RO-Smart Ageing system is intended to provide a dependable substitute for managing the whole flow of medical data produced in a non-clinical setting [22, 23]. The RO-Smart Ageing architecture is organised in accordance with the unique features of healthcare data, which are complex, diverse, (un)structured, and often produced in large quantities from several sources in multiple places.

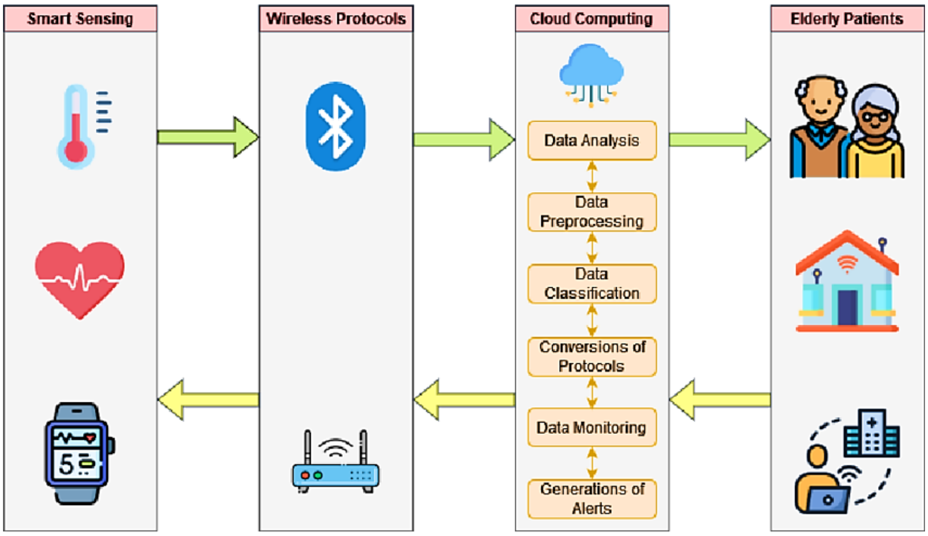

Fig. 1. Dataflow schematic for RO-Smart Ageing Healthcare [23–24].

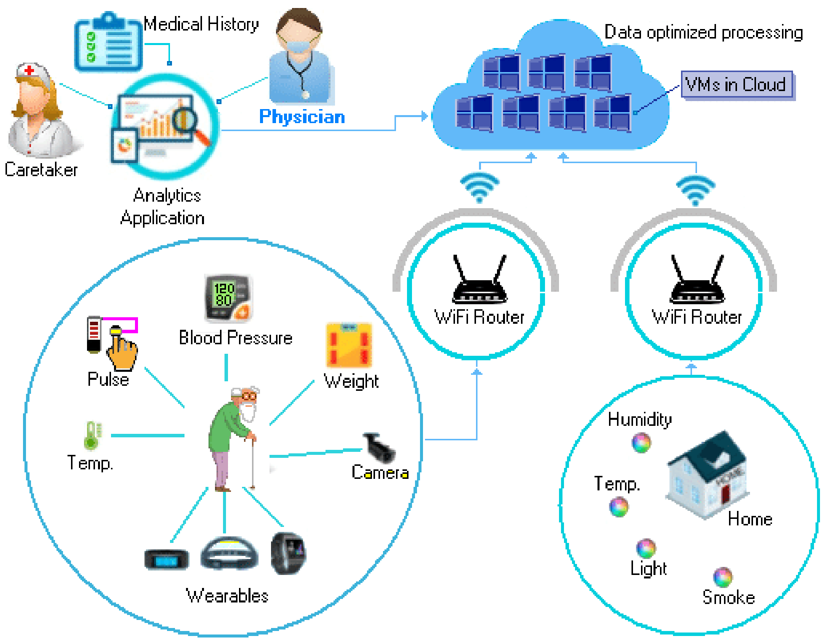

Fig. 2 The basic architecture of RO-Smart Ageing. [25]

4.3 RO-Smart Ageing general architecture

Microservices and the n-layered IoT architecture are used in the RO-Smart Ageing system design (Figure 2) to take advantage of both architectural types:

- **Perception Layer:** In order to achieve the finest environmental and health parameters, the raw data is collected from a variety of IoT devices, smart wearables, and other gadgets that are structured in a customised manner depending on the current requirements and wants of a certain older person [24–25].
- **Communication Layer:** In order to achieve the finest environmental and health parameters, the raw data is collected from a variety of IoT devices, smart wearables, and other gadgets that are structured in a customised manner depending on the current requirements and wants of a certain older person [24–25].
- **Edge / Fog Layer:** For quick administration, many microservices related to the data sources (devices) are gathered here. Every service has distinct capabilities, including local storage, processing, verifying, and parsing. If an anomalous value of a parameter is found, a time-sensitive decision-support function is offered as a consequence of the first local analytics and risk assessment.

- **Cloud Layer:** Databases that support Create, Read, Update, and Delete (CRUD) operations retain the data produced by the earlier levels after it has been thoroughly examined and processed [26, 27]. In applications with a clear goal, such as "Diagnostic Support Services" or "Patient Health Management," data may also be filtered to only deliver the most relevant information required. Periodically, in a controlled manner, the Cloud Layer is accessed in order to quickly use the resources.
- **Visualization & Action Layer:** Individualised access to the apps created under RO-Smart Ageing is granted to the end beneficiaries, beginning with the elderly.

V. Discussion

Microservices enhance the RO-Smart Ageing system's present and future development in terms of scalability, flexibility, and reliability (since they can be applied to various healthcare domains) or fault tolerance (because the system can continue to function even if one of its services fails) [23]. Given the need of trigger warnings and ongoing monitoring of the elderly, these are critical features of a RHMS. Furthermore, the system may be adjusted to accommodate both the changing nature of age-related illnesses and the unique health circumstances of an elderly individual [24, 25].

The primary functions of the Edge/Fog layer include scheduling, storing, and managing the data obtained from wearables, the Internet of Things, and devices; this eliminates an extra computational load on the Cloud Layer [28]. Since RO-Smart Ageing features pertaining to in-depth analytics need extensive processing and storage power, the Cloud Layer is thought to be the most effective location for them [30]. Additionally, this amount of data storage offers constant data agility and accessibility [29, 30].

VI. Conclusion

In addition to analysing the prediction of infectious illnesses based on the vital signs gathered during the pilot study, this research suggests an eHealth monitoring system that is affordable, accessible, adaptable, and pleasant for residents in nursing homes. Its economical application makes it possible to reach underserved communities and people who are more difficult to approach.

The system is simple to use, and nurses need not require IT expertise, as this article has shown. Furthermore, the procedure improves connections with carers and is particularly resident-friendly.

The microservice-based design is scalable and reasonably priced. When the system reaches saturation, the stress tests show it. The microservices' ability to provide the best possible service has been verified. The mobile application is an open standard that requires little modification to deploy on any Android smartphone.

The development and deployment of contemporary apps has been completely transformed by microservices architecture. Organisations may increase scalability, flexibility, and resilience by decomposing large, monolithic systems into smaller, independently deployable services. The fundamental ideas of microservices, such as data management, inter-service communication, and service deconstruction, have been discussed throughout this investigation. Important architectural patterns that are necessary for creating reliable microservices systems have also been covered, including API Gateway, Circuit Breaker, and Service Discovery. A thorough analysis of scalability—one of the main advantages of microservices—was conducted, emphasising strategies like load balancing, elasticity, and horizontal scaling.

In a global ageing culture, patient and healthcare data empowerment has becoming more noticeable. A microservices-based architecture may enable the quick extension, maintainability, and flexibility of personalised RHMS, which are a dependable option for better medical services. In order to demonstrate the advantages of microservices for a RHMS that must be scalable, have a high degree of personalised complexity, and be adaptable in order to handle the constantly changing devices and technology, this article presented the RO Smart Ageing system's underdevelopment. Additionally, attention will be given to the microservices-based architecture's potential for customisation for various forms of monitoring, such as the one required in the context of the COVID-19 pandemic.

VII. References

[1] Fourati, M. H., Marzouk, S., & Jmaiel, M. (2022). Epma: Elastic platform for microservices-based applications: Towards optimal resource elasticity. Journal of Grid Computing, 20(1), 6.

[2] Fritzsch, J., Bogner, J., Wagner, S., & Zimmermann, A. (2019, September). Microservices migration in industry: intentions, strategies, and challenges. In 2019 IEEE International Conference on Software Maintenance and Evolution (ICSME) (pp. 481-490). IEEE. Gannon,

[3] D., Barga, R., & Sundaresan, N. (2017). Cloud-native applications. IEEE Cloud Computing, 4(5), 16-21.

[4] Koschel, A., Hausotter, A., Lange, M., & Gottwald, S. (2020). Keep it in Sync! Consistency Approaches for Microservices-An Insurance Case Study. In SERVICE COMPUTATION 2020, The Twelfth International Conference on Advanced Service Computing (pp. 7-14). IARIA.

[5] Kratzke, N., & Siegfried, R. (2021). Towards cloud-native simulations–lessons learned from the front-line of cloud computing. The Journal of Défense Modelling and Simulation, 18(1), 39- 58.

[6] Laszewski, T., Arora, K., Farr, E., & Zonooz, P. (2018). Cloud Native Architectures: Design highavailability and cost-effective applications for the cloud. Packt Publishing Ltd.

[7] Mahajan, A., Gupta, M. K., & Sundar, S. (2018). Cloud-Native Applications in Java: Build microservice-based cloud-native applications that dynamically scale. Packt Publishing Ltd.

[8] Márquez, G., Villegas, M. M., & Astudillo, H. (2018, September). A pattern language for scalable microservices-based systems. In Proceedings of the 12th European Conference on Software Architecture: Companion Proceedings (pp. 1-7).

[9] Pandiya, D. K. (2021). Scalability patterns for microservices architecture. Educational Administration: Theory and Practice, 27(3), 1178-1183.

[10] Ong, M.; Romano, P.; Edgington, S.; Aronow, H.; Auerbach, A.; Black, J.; Marco, T.; Escarce, J.; Evangelista, L.; Hanna, B.; et al. Effectiveness of Remote Patient Monitoring After Discharge of Hospitalized Patients with Failure. JAMA Intern. Med. 2016, 176, 310–318.

[11] Chatwin, M.; Hawkins, G.; Panicchia, L.; Woods, A.; Hanak, A.; Lucas, R.; Baker, E.; Ramhamdany, E.; Mann, B.; Riley, J.; et al. Randomised crossover trial of telemonitoring in chronic respiratory patients (TeleCRAFT trial). Thorax 2016, 71, 305–311.

[12] Cornacchia, M.; Ozcan, K.; Zheng, Y.; Velipasalar, S. A Survey on Activity Detection and Classification Using Wearable Sensors. IEEE Sens. J. 2016, 17, 386–403.

[13] Esch, J.; Rashidi, P. A Survey on Ambient Intelligence in Healthcare. Proc. IEEE 2013, 101, 2467–2469.

[14] Uddin, M.Z.; Khaksar, W.; Torresen, J. Ambient Sensors for Elderly Care and Independent Living: A Survey. Sensors 2018,

[15] Shakshuki, E.; Reid, M. Multi-Agent System Applications in Healthcare: Current Technology and Future Roadmap. Procedia Comput. Sci. 2015, 52, 252–261.

[16] Russo, G., Moretta Tartaglione, A. & Cavacece, Y. (2019). Empowering Patients to Co-Create a Sustainable Healthcare Value, Sustainability, 11(5), p.1315.

[17] Saransig, A. & Tapia, F. (2019). Performance Analysis of Monolithic and Micro Service Architectures – Containers Technology. In:

[18] Mejia J., Muñoz M., Rocha Á., Peña A. & Pérez-Cisneros M. (eds.), Trends and Applications in Software Engineering (CIMPS 2018), 270-279. Part of series: Advances in Intelligent Systems and Computing, vol 865, Springer, Cham.

[19] Synergus, R W. E. (2019). The Empowered Patient – Revamping healthcare through digital solutions.

[20] Triantafyllidis, A. K., Koutkias, V., Chouvarda, I., Adami, I., Kouroubali, A. & Maglaveras, N. (2016). Framework of sensor-based monitoring for pervasive patient care, Healthcare Technology Letters, 3(3), 153-158.

[21] Walker, R.C., Tong, A., Howard, K. & Palmer, S. C. (2019). Patient expectations and experiences of remote monitoring for chronic diseases: Systematic review and thematic synthesis of qualitative studies, International Journal of Medical Informatics, 124, 78-85.

[22] Yuan, B. & Li, J. (2019). The Policy Effect of the General Data Protection Regulation (GDPR) on the Digital Public Health Sector in the European Union: An Empirical Investigation, International Journal of Environmental Research and Public Health, 16(6), p.1070.

[23] R.S. Wallace, The elements of AIML style, Alice AI Foundation, 2003 doi:10.1.1.693.3664.

[24] L. Catarinucci, D. de Donno, L. Mainetti, L. Palano, L. Patrono, M.L. Stefanizzi, L. Tarricone, An iot-aware architecture for smart healthcare systems, IEEE Internet Things J. 2 (6) (2015) 515–526.

[25] R. Hill, D. Shadija, M. Rezai, Enabling community health care with microservices, CoRR

[26] O. O'Brien, R.D. O'Reilly, Beats-per-minute (bpm): a microservice-based platform for the monitoring of health-related data via activity trackers. In: 2018 IEEE 20th International Conference on e-Health Networking, Applications and Services (Healthcom), 2018, pp. 1–7.

[27] M. Yan, P. Castro, P. Cheng, V. Ishakian, Building a Chatbot with Serverless Computing, Proceedings of the 1st International Workshop on Mashups of Things and APIs – MOTA '16, 2016, pp. 1–4.

[28] A.M. Rahman, A.A. Mamun, A. Islam, Programming challenges of chatbot: current and future prospective, 2017 IEEE Region 10 Humanitarian Technology Conference (R10-HTC), 2017, pp. 75–78.

[29] C. Huang, M. Yang, C. Huang, Y. Chen, M. Wu, K. Chen, A chatbot-supported smart wireless interactive healthcare system for weight control and health promotion, 2018 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM), 2018, pp. 1791–1795.

[30] N. Lasierra, A. Alesanco, S. Guillén, J. García, A three stage ontology-driven solution to provide personalized care to chronic patients at home, J. Biomed. Inform. 46 (3) (2013) 516–529.

[31] Bagam, N. (2021). Advanced Techniques in Predictive Analytics for Financial Services. Integrated Journal for Research in Arts and Humanities, 1(1), 117–126. https://doi.org/10.55544/ijrah.1.1.16

[32] Sai Krishna Shiramshetty, "Big Data Analytics in Civil Engineering : Use Cases and Techniques", International Journal of Scientific Research in Civil Engineering (IJSRCE), ISSN : 2456-6667, Volume 3, Issue 1, pp.39-46, January-February.2019

[33] URL : https://ijsrce.com/IJSRCE19318

[34] Sai Krishna Shiramshetty, " Data Integration Techniques for Cross-Platform Analytics, IInternational Journal of Scientific Research in Computer Science, Engineering and Information Technology(IJSRCSEIT), ISSN : 2456-3307, Volume 6, Issue 4, pp.593-599, July-August-2020. Available at doi : https://doi.org/10.32628/CSEIT2064139

[35] Shiramshetty, S. K. (2021). SQL BI Optimization Strategies in Finance and Banking. Integrated Journal for Research in Arts and Humanities, 1(1), 106–116. https://doi.org/10.55544/ijrah.1.1.15

[36] Sai Krishna Shiramshetty. (2022). Predictive Analytics Using SQL for Operations Management. Eduzone: International Peer Reviewed/Refereed Multidisciplinary Journal, 11(2), 433–448. Retrieved from https://eduzonejournal.com/index.php/eiprmj/article/view/693

[37] Sai Krishna Shiramshetty "Integrating SQL with Machine Learning for Predictive Insights" Iconic Research And Engineering Journals Volume 1 Issue 10 2018 Page 287-292

[38] 57. https://ijope.com/index.php/home/article/view/166

[39] Harish Goud Kola. (2022). Best Practices for Data Transformation in Healthcare ETL. Edu Journal of International Affairs and Research, ISSN: 2583-9993, 1(1), 57–73. Retrieved from https://edupublications.com/index.php/ejiar/article/view/106

[40] Kola, H. G. (2018). Data warehousing solutions for scalable ETL pipelines. International Journal of Scientific Research in Science, Engineering and Technology, 4(8), 762. https://doi.org/10.1.1.123.4567

[41] Harish Goud Kola, " Building Robust ETL Systems for Data Analytics in Telecom , IInternational Journal of Scientific Research in Computer Science, Engineering and Information Technology(IJSRCSEIT), ISSN : 2456-3307, Volume 5, Issue 3, pp.694-700, May-June-2019. Available at doi : https://doi.org/10.32628/CSEIT1952292

[42] Kola, H. G. (2022). Data security in ETL processes for financial applications. International Journal of Enhanced Research in Science, Technology & Engineering, 11(9), 55. https://ijsrcseit.com/CSEIT1952292.

[43] Santhosh Bussa, "Advancements in Automated ETL Testing for Financial Applications", IJRAR - International Journal of Research and Analytical Reviews (IJRAR), E-ISSN 2348-1269, P- ISSN 2349-5138, Volume.7, Issue 4, Page No pp.426-443, November 2020, Available at : http://www.ijrar.org/IJRAR2AA1744.pdf

[44] Bussa, S. (2021). Challenges and solutions in optimizing data pipelines. International Journal for Innovative Engineering and Management Research, 10(12), 325–341. https://sjmars.com/index.php/sjmars/article/view/116

[45] Bussa, S. (2022). Machine Learning in Predictive Quality Assurance. Stallion Journal for Multidisciplinary Associated Research Studies, 1(6), 54–66. https://doi.org/10.55544/sjmars.1.6.8

[46] Bussa, S. (2019). AI-driven test automation frameworks. International Journal for Innovative Engineering and Management Research, 8(10), 68–87. Retrieved from https://www.ijiemr.org/public/uploads/paper/427801732865437.pdf

[47] Annam, S. N. (2020). Innovation in IT project management for banking systems. International Journal of Enhanced Research in Science, Technology & Engineering, 9(10), 19. https://www.erpublications.com/uploaded_files/download/sri-nikhil-annam_gBNPz.pdf

[48] Annam, S. N. (2018). Emerging trends in IT management for large corporations. International Journal of Scientific Research in Science, Engineering and Technology, 4(8), 770. https://ijsrset.com/paper/12213.pdf

[49] Sri Nikhil Annam, " IT Leadership Strategies for High-Performance Teams, IInternational Journal of Scientific Research in Computer Science, Engineering and Information Technology(IJSRCSEIT), ISSN : 2456-3307, Volume 7, Issue 1, pp.302-317, January-February-2021. Available at doi : https://doi.org/10.32628/CSEIT228127

[50] Annam, S. N. (2022). Optimizing IT Infrastructure for Business Continuity. Stallion Journal for Multidisciplinary Associated Research Studies, 1(5), 31–42. https://doi.org/10.55544/sjmars.1.5.7

[51] Sri Nikhil Annam , " Managing IT Operations in a Remote Work Environment, IInternational Journal of Scientific Research in Computer Science, Engineering and Information Technology(IJSRCSEIT), ISSN : 2456-3307, Volume 8, Issue 5, pp.353-368, September-October-2022. https://ijsrcseit.com/paper/CSEIT23902179.pdf

[52] Harish Goud Kola. (2022). Best Practices for Data Transformation in Healthcare ETL. Edu Journal of International Affairs and Research, ISSN: 2583-9993, 1(1), 57–73. Retrieved from https://edupublications.com/index.php/ejiar/article/view/106

[53] Kola, H. G. (2018). Data warehousing solutions for scalable ETL pipelines. International Journal of Scientific Research in Science, Engineering and Technology, 4(8), 762. https://doi.org/10.1.1.123.4567

[54] Harish Goud Kola, " Building Robust ETL Systems for Data Analytics in Telecom , IInternational Journal of Scientific Research in Computer Science, Engineering and Information Technology(IJSRCSEIT), ISSN : 2456-3307, Volume 5, Issue 3, pp.694-700, May-June-2019. Available at doi : https://doi.org/10.32628/CSEIT1952292

[55] Kola, H. G. (2022). Data security in ETL processes for financial applications. International Journal of Enhanced Research in Science, Technology & Engineering, 11(9), 55. https://ijsrcseit.com/CSEIT1952292.