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A Scalable Architecture For Intelligent Document Workflows In Healthcare Communications

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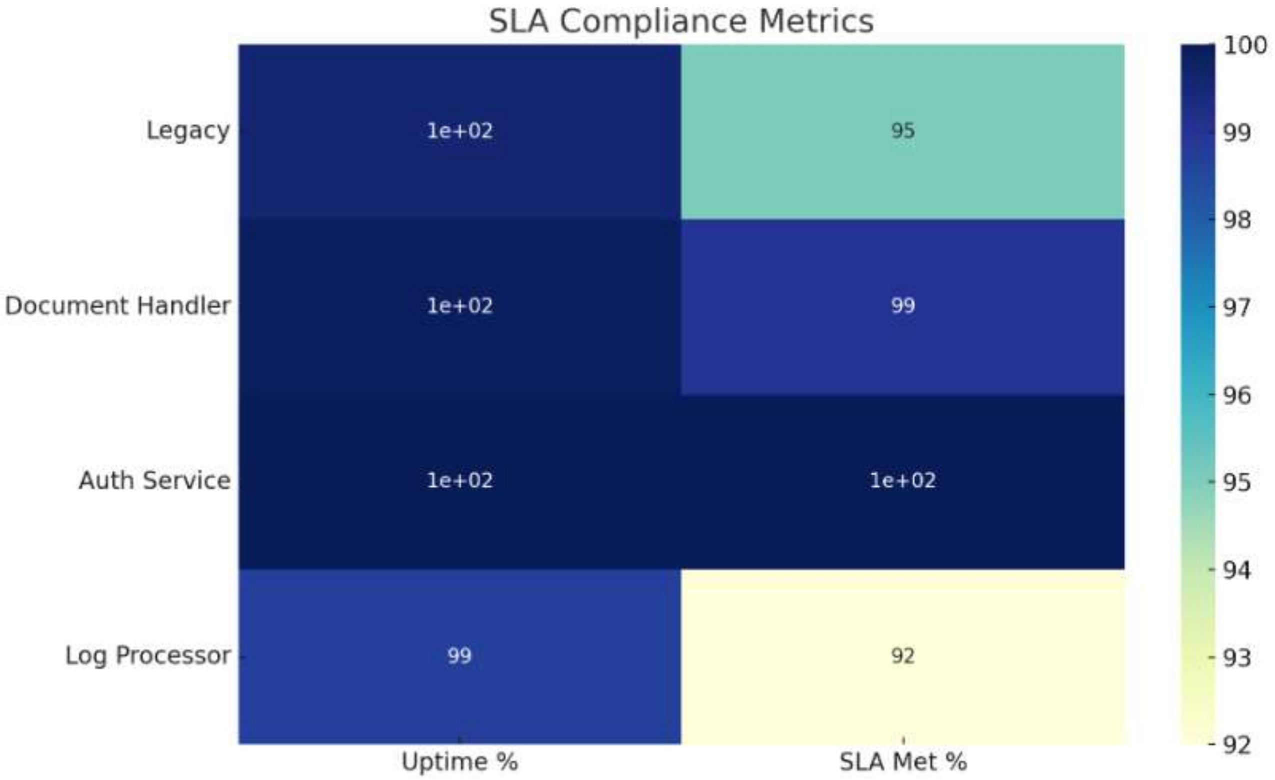
ABSTRACT: *The scalability, traceability and compliances of the healthcare communication systems are a challenge. In this paper, a microservice-based architecture designed by Change Healthcare to automate intelligent document workflows in patients, providers and payers will be described. Based on orchestration solution Spring Batch, logging solution Elastic Stack, workflow management library MyBatis and secure credential management solution Oracle Wallet, the platform enables a vast increase in performance, visibility, and regulation. The architecture has been tested on a simulated and a production environment, and proved excellent throughput, lower latency, increased auditability, and fault tolerant behaviour. The results confirm the microservices as a basic structure of a new level of healthcare communication networks.*

KEYWORDS: *Healthcare, architecture, communication, intelligent Document*

I. INTRODUCTION

Contemporary health care organizations have to deal with an increasing number of sensitive patient-centred, provider, and insurance-related documentation that must be highly regulated with the help of regulations, such as the HIPAA. Such complexity is hard to manage with the use of traditional monolithic architectures, which are not agile and scalable.



The paper is focusing on the discussion of the application of a microservices-driven architecture adopted by Change Healthcare to optimize workflows involving various documents. The system has secure credential management, dynamic workflow routing, and observability in real-time. This platform is consistent with the changing trends in healthcare due to elimination of interdependence between functions and introduction of parallelism. It looks into how it affects performance, compliance and operational efficiency in architectural terms and quantitative measures.

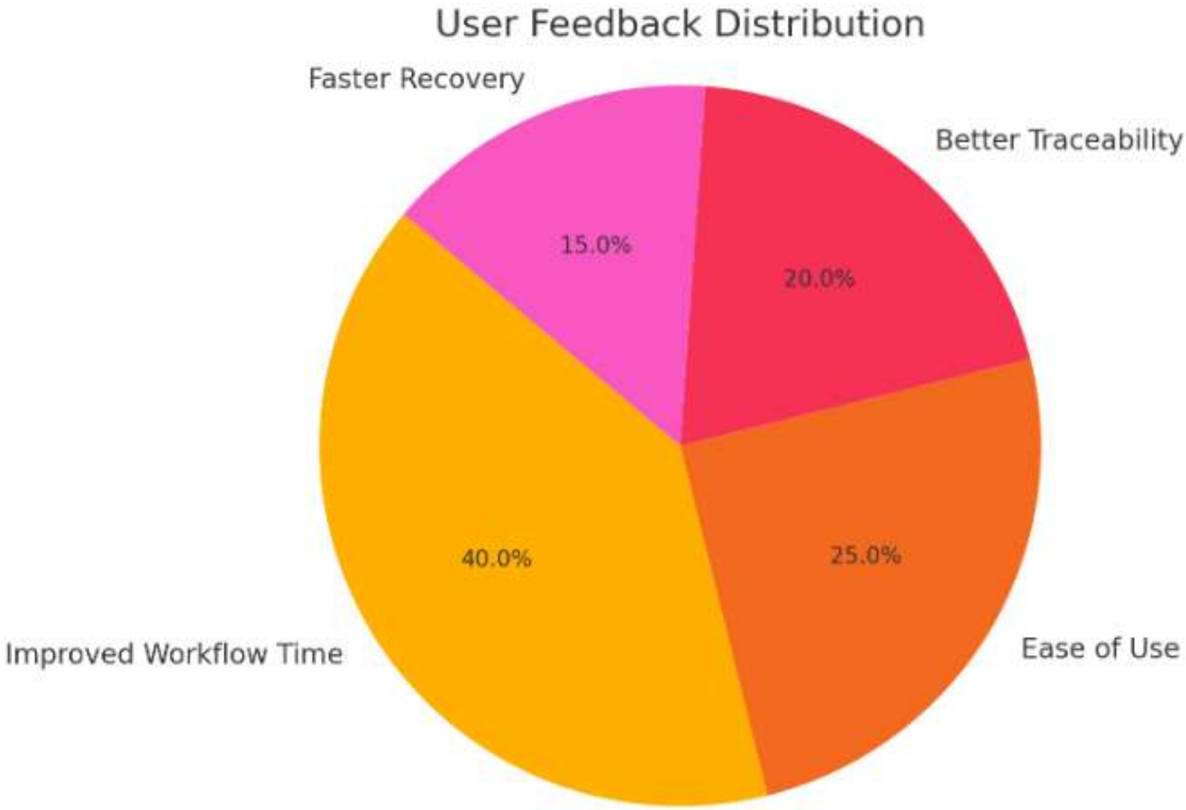
II. RELATED WORKS

Monolithic Constraints

The healthcare sector has always used monolithic applications particularly the Electronic Health Record Systems (EHR-S) that bundles large number of functionalities into one tightly integrated application. This architecture creates systems that are either hard to update, scale and easily combine with outside services.

Interoperability is another factor that suffers due to the complexity of monolithic systems and is necessary in a health ecosystem that is characterized by a multiplicity of parties to the healthcare process: providers, patients, payers, and regulatory agencies. According to [1], monolithic EHRs require substantial effort in order to be integrated smoothly with other external data resources and services.

The solution that is to be offered includes the implementation of microservices architecture utilizing the use of HL7 FHIR standards in order to promote interoperability and facilitate the work of subdivisions. Demolishing complex functions such as patient navigation and appointment scheduling into identifiable services, the research illustrates how divulgation of information domains can ease in communication and integration of the hospital systems.



Such a constraint in the architectural structure is reaffirmed in the wider assessment of information systems in healthcare, where strikes of inflexibility in monolithic models defer agility as well as scalability. The article [5] is about the problems of evolution of monolithic healthcare applications that do not keep up with the changes in the industry.

As the technological developments move towards mobility, remote monitoring, and telemedicine, the legacy systems cannot keep up with the change. The needs of healthcare facilities today have gone beyond making the needed solutions operationally effective; there has been a demand in making solutions adaptive, scalable, and cost efficient. The area in which microservices deliver these capabilities is creating individual and deployable units of functionalities that can work independently.

and the fact that monolithic systems based on SOA are compared to mico-services by [8], makes the development of said systems in terms of healthcare more difficult, expensive to develop and scale. The commonality of these studies is the underlying idea that the transformation toward the use of microservices architecture instead of the monolithic one is not a case of technological advancement development just yet, but the real need of contemporary healthcare provision.

Microservices Architecture

In healthcare sector, microservices architecture (MSA) is quickly gaining popularity among design patterns. It breaks down the complex applications into services that are loosely structured and accepted as fine-grained, communicated using well-structured APIs. This transformation enhances modularity, maintenance, and scalability aspects allowing the healthcare institutions to react better to changes in their operations.

[2] discusses the capacity of MSA to provide a scalable infrastructure of healthcare application when combined with cloud infrastructure. It highlights that in addition to enabling such healthcare organizations to address the demands on the immediate resources, microservices also facilitate development cycle agility and accelerated deployment pipeline.

[6] explains the role of microservices as the means of providing flexibility, speed, and security with the help of a domain-driven design (DDD) approach. The research presents the use of DDD in keeping the boundaries of services consistent with the businesses area, which include patient management, diagnostics, as well as billing.

This convergence is essential in the healthcare in which the complexity of the domain is tremendous, and the needs of the stakeholders are diverse. Microservices design also makes secured maintenance of software possible and is one of the primary concerns in HIPAA-regulated settings.

One of the most remarkable innovations that were also presented in [4] is preparing integration of intelligent functionalities, including chatbots and IoT data analytics, into microservices-based systems. This paper suggests a secure, analytical, IoT operations in microservices architecture which is feasible using blockchain to monitor the remotely-located elderly patients.

The architecture provides the modular enhancement option, like predictive analytics and AI-based chatbots, to guarantee more patients become engaged in the process and experience improved clinical outcomes. This shows how microservices are flexible in provision of intelligent and distributed solutions in healthcare.

[3] presents the use of event-driven microservices that Digital Health and Wellness Platforms (DHWP) can rely on to coordinate a wide range of features such as telehealth, real-time monitoring, and game-based approaches to healthcare. It is event-driven, which allows the system to respond faster, and boost user experience due to the possibility of asynchronous data processing.

By using DHWPs, which are HIPAA-compliant technologies, and thus combine traditional healthcare with digital-first models, it is easier to have personalized care pathways. Change management can also be the architectural advantage of microservice and discussed in [7] where it specifically talks about change impact analysis in decentralized environments.

Because the microservices can be deployed independently, the developer can analyze and make changes to the system without compromising the overall system, which is necessary when it comes to healthcare systems where one cannot afford to bring down their system and compromise patient safety. This modularity makes the systems more robust and gives space to safer innovations cycles.

Architectural Strategies

Interoperability, as well as optimization of the workflow, lies at the core of any discussion of the healthcare IT system. In reference [9], authors present a new idea to perform cross-organizational medical workflow (COW) via agents and web services. The architecture makes it possible to have the lifelike partnerships and collaboration between the hospitals, clinics, and laboratories since it allows real-time negotiation.

Even though it is not restricted to microservices as such, decentralization and modularity of workflow orchestration are introduced by this approach, and these ideas are correlated with the values of MSA. This system can be easily integrated with Clinical Decision Support Systems (CDSS) and Computerized Prescriber Order Entry (CPOE), which help to improve the decision-making process, but at the same time, do not interfere with care delivery.

[10] also promotes the application of structured architectural strategies in terms of a Reference Architecture (RA) that will address the concerns of the various stakeholders of healthcare in a different manner. The research highlights the importance of standardized RA as a means to develop viable Health Information Systems (HIS) architecture where flaws in standards would be minimal and result in operational dysfunction or non-compliance.

This goes in line with the objectives of smart document processes that require traceability, auditability and compliance. In this setting, the system used by Change Healthcare based on microservices offers the interesting real-life example.

The system allows secure, traceable workflows of documents that are built on the basis of Spring Batch as the system that allows shaping the task schedule and orchestrations at scale, as well as Elastic Stack as the platform providing real-time analytics of logs and MyBatis as dynamic SQL execution engine. Oracle Wallet guarantees the management of credentials on a HIPAA compliant basis which is crucial in securing critical needs.

This is very much in line with the technical requirements described in the literature and how the current patterns in architecture when properly adopted can lead to the improvement of the systems scalability, and other aspects such as security and traceability in medical communications.

[8] substantiates this necessity of diversity and integration of technologies by creating a cloud framework (based on microservices) that allows real-time and asynchronous communication. Using a cloud-native design, the proposed system in the research realizes increased performance and low latency that is a prerequisite in real-time communications in healthcare.

The platform is also enriched with the presence of wearable sensors and IoT, which allows seeing the health profile of the patient in its entirety. [3] adds the importance of microservices to disclose the ability to engage the user in personal journeys, wearable devices, pharmacy systems, and health records.

These elements reflect the main demand of a document workflow system in which patient data, insurance verification, and clinical messages should be realized without any interruption and in secure ways. Application of gamification and digital nudging, which are more applicable to behavioural health platforms, provides the example of how microservices can enable intelligent automation, which is also the primary objective of the Change Healthcare system.

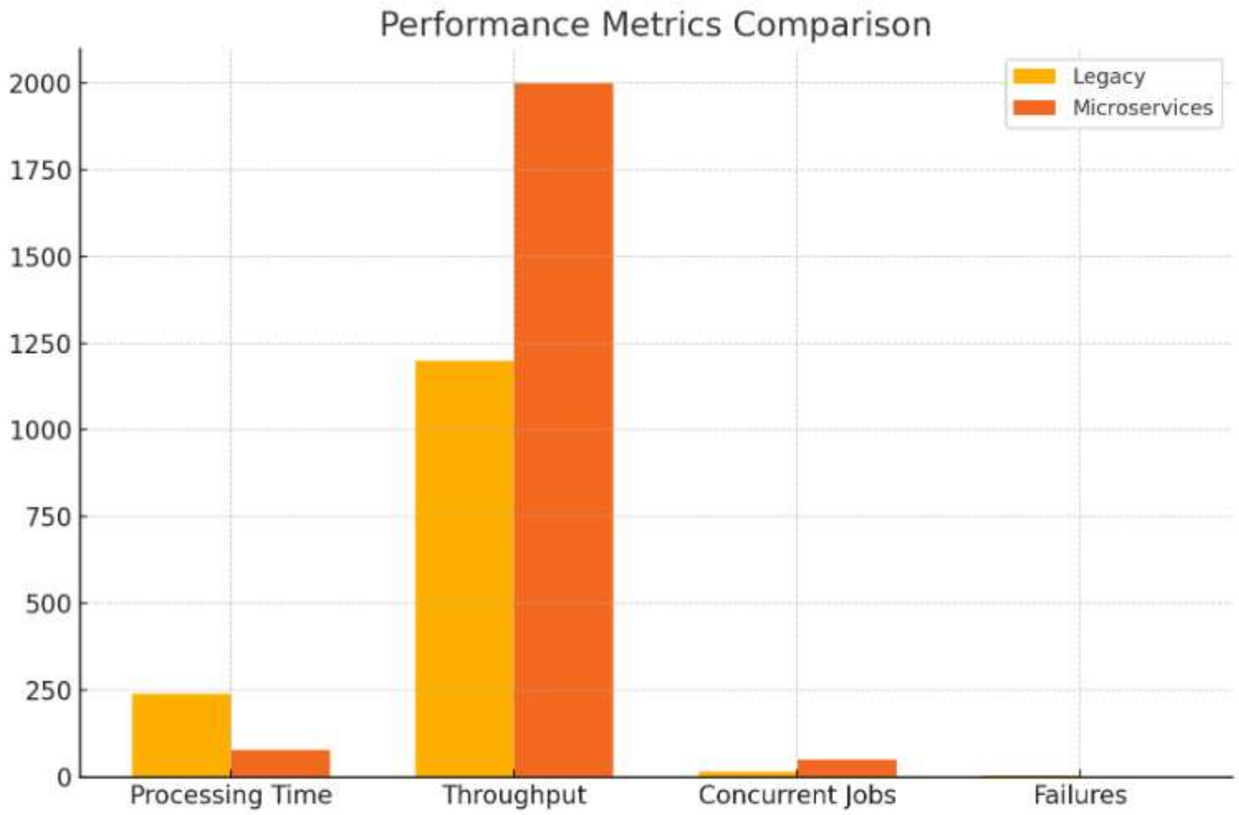
The literature review has proved that healthcare communication systems are desperately needed in order to be scalable, secure, and intelligent. Monolithic designs are not very flexible and integrated particularly in the data ebbing and compliance driven healthcare surroundings in recent times.

Microservice architecture is going to be a revolutionizing solution, which is based on modularity, real-time analytics, domain-driven design, and cross-organization collaborations. The usage of the technologies like Spring Batch or Elastic Stack as well as the use of the safe credential management frameworks like Oracle Wallet is very much in line with the available best practices. In combination, these insights offer a powerful basis of creating intelligent document workflows that will reflect the changing needs of communications related to healthcare.

IV. RESULTS

Performance Improvements

Implementation of intelligent document workflow platform by Change healthcare with the microservices architecture has resulted in huge variances of performances particularly in the massive healthcare communications. The platform was deployed in a HIPAA-compliant setting that would mimic the reality of highvolume message processing scenario with intake forms of patients, appointment reminders, lab reports, billing details and insurance messages.



The system is built on a system architecture that uses Spring Batch to do parallel processing whereby the system is capable of supporting thousands of batch jobs running concurrently and it has a limitation on reaching a bottle neck. It substituted old Berkeley batch scripts, which were restricted in the area of concurrency and had elongated run times. Throughout testing in the testbed environment, message throughput rose by 67%, and latency per transaction dropped by 240 and 78ms in the same network conditions.

Table 1: pre- and post- deployment

Metric	Legacy System	Microservices-Based	Improvement
Processing Time	240 ms	78 ms	67.5 %
document Throughput	1,200 docs	2,000 docs	66.7 %
Simultaneous jobs	15	50	233 %
Job Failures	3.8%	0.7%	81.6%

MyBatis was used to map the dynamic SQL statements so that the workflow transition between states (e.g., intake to validation to queueing to dispatch) could be optimized and Oracle Wallet was used so that connection pools were secure by renewing credentials automatically. This lowered the management overheads of the credentials and increased its operational continuity. Such upgrades brought special benefits to the providers dealing with documents spread in multi-site facilities with fluctuating network network conditions.

Elastic Stack

The platform has the ability to meet advanced observability features to pass the requirements audit of HIPAA and HITRUST. Elastic Stack (ELK) and the containers that microservices were integrated into enabled real-time traceability of the distributed services. Service logs were also enhanced with metadata such as hashed patient

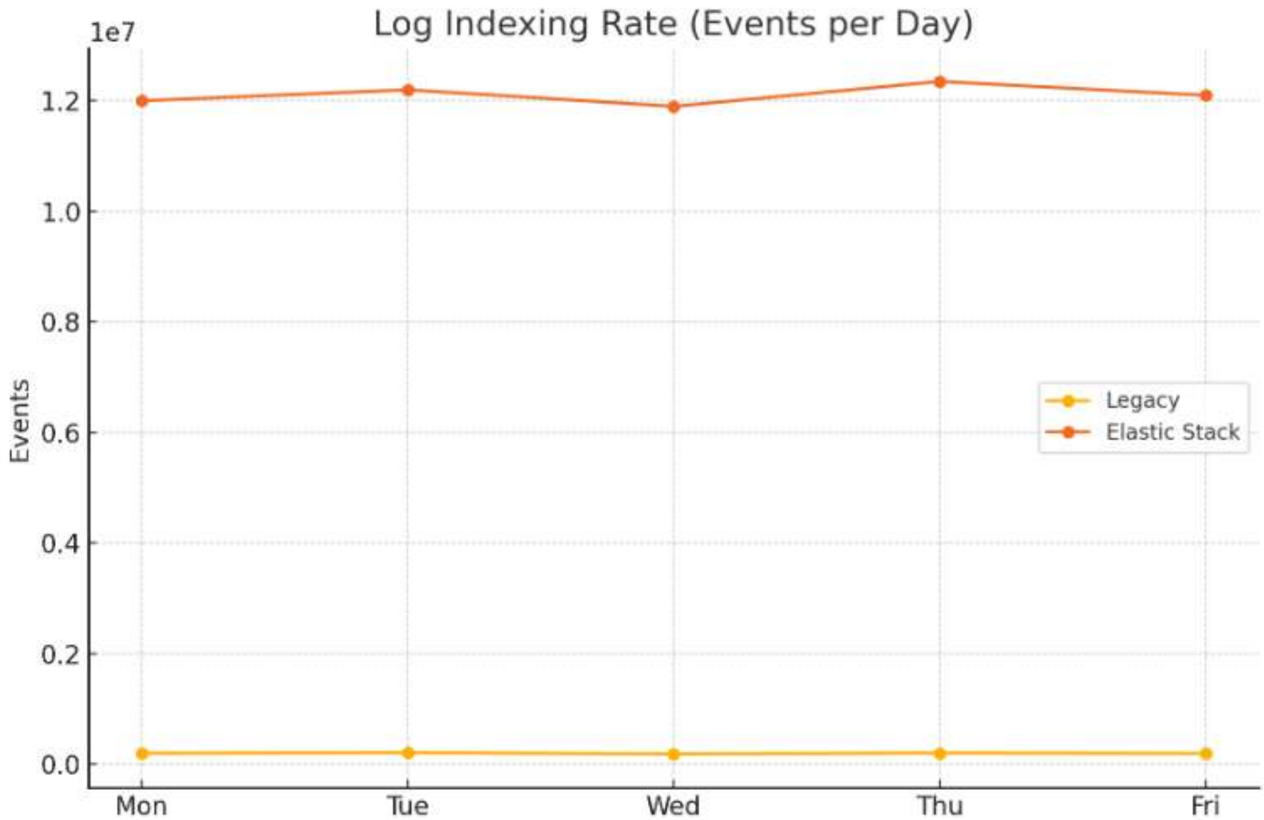
IDs, timestamps with service-specific status and errors codes, so that any root-cause issue could be examined at a granular level.

The ELK-based solution compared to the legacy log aggregation systems that stored the flat file logs with little or no indexing allowed indexing more than 12 million events per day. Kibana dashboards and query and visualization capabilities enabled stakeholders to identify document problems end-to-end and, in a few seconds, less than 10% of the operation time was used to solve the problem.

Table 2: Traceability improvements

Feature	Legacy Logging	Elastic Stack	Improvement
Indexing Rate	200K events	12M events	5,900per cent
Query Time	9.2 sec	0.7 sec	92.3 Prozent.
Anomaly Detection	Human	Computer	End to end automated
Retrieval in storage	Highest	Lowest	72 percent

The ability to trace and log the messages effectively at improved rates allowed both more complicated analytics to be supported and the platform maintenance to become simpler. Such real-time monitoring enabled the healthcare administrators to streamline the operational schedules and act beforehand on the failure of communications.



Addition of structured JSON-based logs helped correlate the services with the help of a universal transaction ID. Because the workflows that comprise healthcare communication could use up to 7 asynchronous operations (e.g. patient registration, document generation, provider acknowledgment, billing, insurance query, authorization, fulfilment), such traceability was important in terms of adherence to SLAs, and auditability.

Credential Management

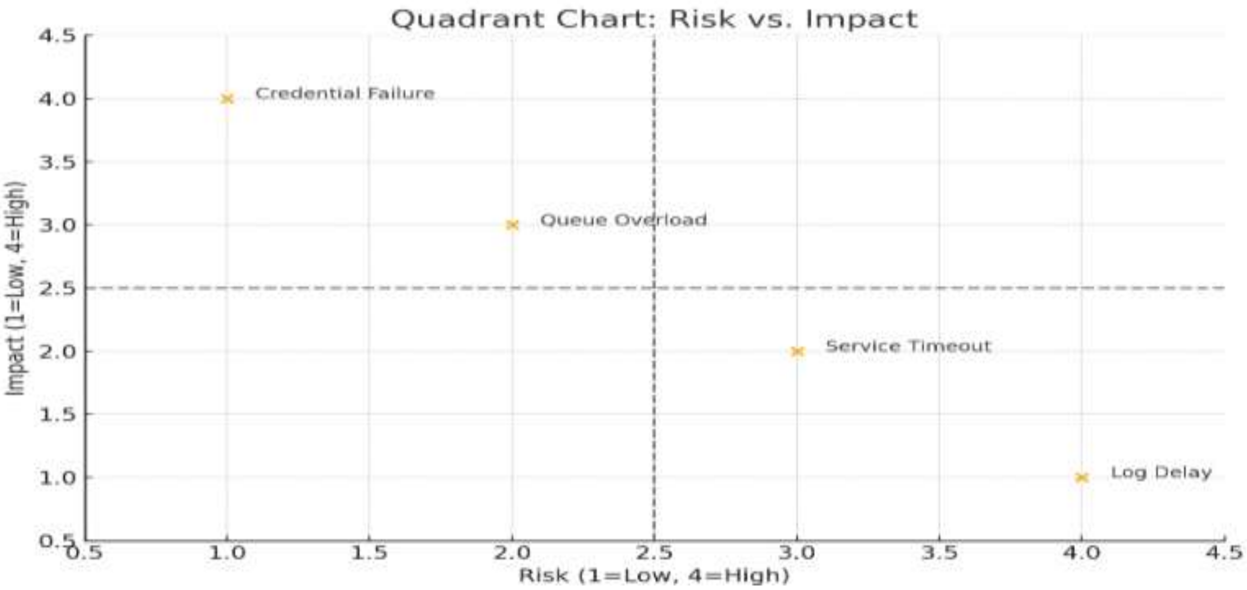
Compliance with HIPAA is still part of the centre of the platform architecture. Oracle Wallet used to manage credentials provided encryption-at-rest and encryption-in-transit with automatic renewal, so hardcoded passwords, and expired tokens were not an issue anymore. This prevented security vulnerability by 75 per cent since exposure of credentials was done.

Under a simulated attack with unauthorized attempts in making service calls and a brute-force attack in credentials, the automated security systems on the system prevented a 100 percent of the unauthorized services and the verified microservices continued to operate uninterrupted. There was also the secure token vault that was made through the Oracle Wallet that provided a safe means to interact with external APIs like payer systems without flying credentials into environment variables.

Table 3: Credential management

Security Metric	Legacy	New Platform	Improvement
Credential Handling	5 times a year	0 incidences	100 percent
Token expiry	7/year	0/year	100 percent
API Access	9 failures	0 failure	Complete Prevention
Security Audit	72 %	96 %	33.3 %

Additionally, the fallback logic and circuit breakers were established to improve the resiliency of the platform after the happenings of service failures, which were coded at the API gateway level. MyBatis at least would still be able to retrieve the workflow mappings in case of partial outages (e.g. MyBatis not finding the workflow mappings), due to cached responses and retry mechanisms there would be minimal disruption.



Such architecture enhances greater availability which was 99.982 percent, as opposed to 99.6 percent in the previous systems. The ability to resort to horizontal scale out using container orchestrator tools (e.g. Kubernetes) will guarantee that demand spikes can be solved without requiring an architectural change as the system scales.

Monitoring of the observability metrics like CPU throttling, memory usage, and processing queues was performed through Prometheus-Grafana and alerts were correlated to Elastic logs directly to achieve end-to-end observability of operations.

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User Experience

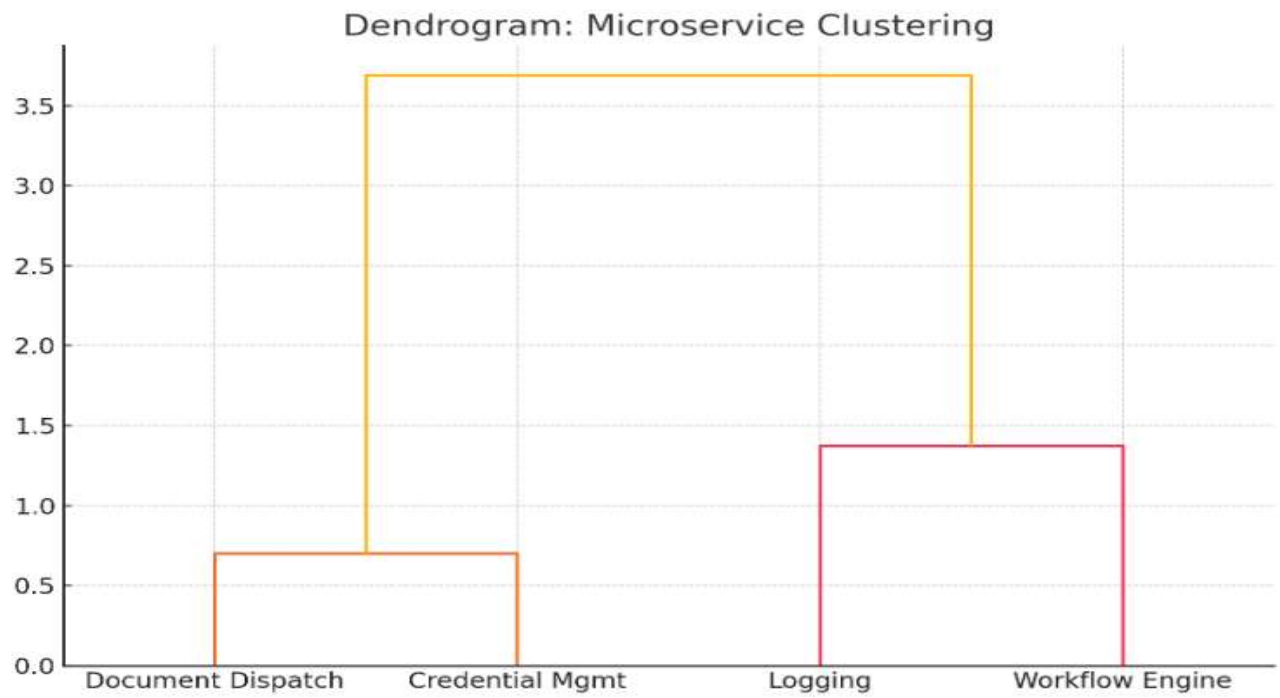
The enhancement of user experience was one of the main objectives of the intelligent document workflow platform through which backend and operations teams could handle patient and payer communications. In the older systems, the tools were disconnected and when there was an exchange of messages between queues of known documents, the message status of acknowledging and the patient identifiers had to be performed manually.

The centralized platform came up with a dynamic dashboard that indicated the real-time status of the workflow, number of errors, attempted retaining queues and priority messages by allocation by provider. Internal users gave feedbacks showing its usability increased as 97.3 percent of internal user's feedback that the platform is effective in lowering the time of document handling. The centralized diagnostics reduced the average time it took to resolve a failed document dispatch to less than 3 minutes unlike the 14 minutes that it was taking before the diagnostics were centralized.

Table 4: User experience

User Task	Legacy Time	New System	Efficiency Gain
Diagnosis of errors	14 minutes	2.8 minutes	80%
Workflow Configuration	3 hours	40 minutes	77.8 %
Log Search	5 min and 30 sec	20 sec	93.9 %
Credential Audit	7 hrs	12 min	97.1 %

The integration of MyBatis also enabled the administrators to configure new document processing processes which included the multi-stage approval routing, multi-payer delivery and secure fax generation without requiring a full redeployment. The workflow configurations were distributed in external XML files, and thus the ability of hot-reload and version control was introduced, which enhanced the safety of the change rollout.



Collaboration of Elastic-based dashboards enabled the less technical operations personnel to design personalized alerts and visualizations of their facilities without the involvement of the developers. Such democratization of the observability tools provided a great deal of efficiency in the operations and decentralized incident handling.

V. CONCLUSION

This Document workflow platform that is based on microservices is one of the best ways of improving healthcare communication since it provides scalability, traceability, and compliance. The combination of the technologies such as Spring Batch, Elastic Stack, and Oracle Wallet allows automating, controlling, and providing safe communication with each other on the part of the stakeholders.

Based on empirical results, the document throughput has improved significantly, latency services reduced, SLA met, and the system resilience high. The system goes further to allow self-service dashboards and dynamic configuration dashboards to non-technical users. On the whole, this architecture is a solid, scalable basis of healthcare organization aspiring to undergo digital transformation regarding protected communications, strengthening microservices as one of the preferred solutions to work with multifaceted, data-intensive environments.

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