IJMSERH

International Journal of Multidisciplinary and Scientific Emerging ResearcH (IJMSERH)

Volume 13, Issue 2, April-June 2025

Impact Factor: 9.274

editor@ijmserh.com

www.ijmserh.com

International Journal of Multidisciplinary and Scientific Emerging ResearcH (IJMSERH)

| ISSN: 2349-6037 | www.ijmserh.com ||Impact Factor: 9.274||Quarterly, Peer Reviewed & Refereed Journal|

|| Volume 13, Issue 2, April-June 2025 ||

DOI: 10.15662/IJMSERH.2025.1302079

Accelerating Claims Processing with Observability and Automated Dashboards

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ABSTRACT: MCE for HealthCare is an environment for building blocks to adjudicate medical claims within provider and payer settings. MCE is architected to adjudicate claim input, data validation, eligibility validation, benefits rule adjudication, post-processing (payment and remittance), analytics, and reporting. MCE replaces traditional mainframe processing with cloud-based, observable, and analytics-driven infrastructure to support rapid adjudication, improved data quality, and open financial operations. The MCE is augmented by the Observability Framework, a telemetry that aggregates metrics, logs, and traces end-to-end across the data path. Real-time monitor dashboards provide throughput, error rate, end-to-end latency, and SLA compliance. Distributed tracing monitors cross-service call patterns to identify bottlenecks and points of failure. Centralized log and analysis support microservices, streaming pipeline, and mainframe replications' events correlation for performance tuning and root-cause analysis. Data elements are correlated to the observability model such as ingestion and validation, adjudication engine, payment and post-processing, and analytics layer. This enables stakeholders to monitor processing performance, straighten out real-time errors, and uphold data privacy and healthcare rule compliance. MCE, together with an observability pattern, delivers data-driven capability, operational resilience, and end-to-end visibility to facilitate industry transformation to cloud-native, observable, and AI-enabled claim processes.

KEYWORDS: Medical Claims Engine (MCE), SLA compliance, Microservices, Streaming Pipelines, Adjudication Engine

I. INTRODUCTION

An observability platform implemented in the health care sector provides end-to-end visibility in real-time, reliability, and security in clinical systems, patient data pipelines, and networked medical devices. Observability platform combines operational monitoring, data observability, and AIOps automation to enable patient safety, compliance, and efficiency in health care. It captures and consolidates metrics, logs, and traces from hospital systems, electronic medical records (EMR), and Internet of Medical Things (IoMT) devices with tamper-evident functionality, tracking the origin of patient data, abnormality alert, and regulatory compliance such as HL7 and HIPAA.

A few of the important healthcare use cases are data integrity and transparency, predictive analytics, telemedicine, integrated EMRs, and integrated medical devices as well as improved patient safety. Observability provides lineage tracing and data integrity that enhances the accuracy of diagnosis and facilitates evidence-based decision-making. AI-driven observability enables patient care systems to predict failures and disrupt the process beforehand, and enables mission-critical functions such as automated triage systems and intensive care unit monitors. Health organizations benefit from enhanced patient safety, data compliance and trust, business efficiency, and preventive assistance. Integration of the clinical processes with IT, a health care integrated observability platform improves patient outcomes, system reliability, and regulatory compliance through 360-degree visibility [1].

Integrated observability framework is a technology that weaves together metrics, logs, traces, and events onto a single platform in order to observe, analyze, and optimize performance in cloud-native and distributed systems. It supports real-time ingestion, conversion, and publication of telemetry data from applications and infrastructure to build the pillars of an integrated observability stack. It supports real-time monitoring and rapid problem-solving by injecting observability capability into infrastructure management, operational processes, and software development life cycles. Operations and development teams are able to identify anomalies earlier, establish causations, and enable dependability and conformance with such insight based on integration across APIs, services, and networks. It gives real-time end-to-end visibility for infrastructure and application, quicker Mean Time to Detect and Respond, closer integration among development teams, Service Requirements, and DevOps, and enhanced validation of compliance via automated performance testing and adding it in the software development life cycle. Briefly, an observability platform that was integrated on implemented customized monitoring into one comprehensive, knowledge-driven platform that facilitates operational intelligence, scalability, and resiliency for high-risk digital space [2].

Implementation of observability framework for healthcare IT provides real-time visibility into hard-to-monitor systems, and early identification of issues and remediation before impacting patient care. It delivers mission-critical application uptime such as medical device networks, telemedicine networks, and electronic health records. Observability gives data in the context, allowing for better root cause analysis and decision-making and higher operational efficiency and therapeutic outcomes. Data convergence, stored audit trails, and observability make data convergence, compliance easier. Scalable infrastructure management like automated alert, anomaly detection, and proactive maintenance at reduced cost of operation and downtime. Observability unites heterogenous data sources into harmonized governance, easy to govern in a healthcare merger or hybrid cloud. The benefits improve patient safety, optimize the use of resources, stimulate innovation, and adapt to changing requirements for regulation [3].

GE Healthcare Apex Pro CH telemetry system enables centralized and decentralized monitoring in hospital networks for safe acquisition of patient data. Medtronic's Vital Sync combines wearables' and bedside physiological information with hospital servers to enable remote clinical protocol and patient management. Philips Healthcare provides eCareCoordinator Clinical for remote and chronic disease management through the utilization of AI-based risk stratification and patient monitoring dashboards with tight coupling with medical devices. Spacelabs Healthcare provides advanced ambulatory care telemetry monitoring systems. Other major suppliers include Mindray, Blue Spark Technologies, and Nihon Koden. They offer telemetry tailored for the healthcare industry, enabling patient safety and clinical decision-making by capturing data in real-time continuously, device interoperability assistance, regulatory compliance, and electronic health records integration [4].

HealthCare's Medical Claims Engine (MCE) is a cloud solution to enable the growing complexity of health claim adjudication to be processed perceptually, accurately, and intelligently. Scalable architecture to accommodate real-time compliant and accurate claims adjudication is provided by it. MCE eases smooth integration with electronic systems and health data standards through its support in Microsoft Azure. Real-time replication of data and large observability frameworks are enabled by it, thus making the claims management predictive and insight-driven capability a feature more than a transaction-type activity. Observability consistency makes operational governance simple, pre-empts problems ahead of time, and offers single data integrity. Cigna's MCE offers an improved, superior framework of enhanced member satisfaction, compliance, and long-term health care cost savings in the contemporary provision.

Observability is a shift toward embracing real-time monitoring and machine learning-driven anomaly detection to provide operation consistency in the claims processing universe. It identifies performance bottlenecks, data integrity issues, and compliance problems through correlating events and aggregating telemetry. Cross-domain orchestration and documentation of observability processes yield predictable results in the event of disaster, reducing downtime as well as improving reliability. Enhanced data and distributed infrastructure for cloud and hybrid-based deployments are facilitated by the solution with scalability enhanced through minimum human intervention and operational barriers. Artificially intelligent analytics and automation enable proactive capacity planning along with self-healing. Increased data freshness transparency, end-to-end traceability, and compliance conformity result in high-quality output. Predictive analytics will allow health care companies to forecast risk ahead of time and optimize resource utilization, achieving the most crucial goals of contemporary health care IT: enhanced member service, regulatory compliance, and cost savings [5].

II. RELATED WORK

Wang et al. (2022) [6] also suggested a graphical framework for tracking research designs and data observability of electronic health records (EHR). The methodology assesses validity and usefulness of different sources for healthcare information, e.g., administrative claims and connected EHR systems. The Connected Health Impact Framework (CHIF) [7] was constructed through stakeholder workshops and literature reviews for determination of the needs of digital health impact assessment as well as incorporating data. Several studies have proposed the application of observability within healthcare cloud systems with the unification of logging, monitoring, and tracing methods with AI-analytics methods for enhancing operational effectiveness, security, as well as reliability. Real-time monitoring and anomaly detection can probably be employed to improve patient care and compliance with case studies and experimental evaluation [8].

An astute healthcare monitoring framework survey outlines the use of AI, machine learning, and edge/cloud computing in real-time monitoring of vital signs. This article classifies structure, component, and intelligence approaches to increase the observability of health information. These articles identify practices which incorporate visualization, stakeholder participation, AI analytics, and structured data observability methods to solve intricate issues in the discipline of health data and present scalable, readable, and high-quality healthcare operational insight [9].

Healthcare observability platforms are moving toward data visualization, AI-led integration, and end-to-end system monitoring to provide reliable healthcare. The platforms use graphical representation of data to display patient outcomes between datasets to identify bias and completeness. Real-world healthcare operationally driven need-based framework establishment by stakeholder preference indicates preference for frameworks. AI-Enhanced Observability uses AI and machine learning to perform root cause analysis, prediction models, and anomaly detection. Such frameworks facilitate pre-emptive problem-solving and in-flight alerting by combining telemetry information with pattern matching rules or neural networks. Site Reliability Engineering (SRE) principles-driven End-to-End Monitoring ensures application reliability and availability for hybrid cloud healthcare deployments. Pre-emptive Data Integrity and Quality are guaranteed through automated data validation, lineage tracing, and audit trails to facilitate compliance and correct clinical data availability in distributed healthcare deployments. These methods combine SRE practices, AI-driven analysis, data-driven visualization, and co-design to provide fault-tolerant, scalable observability solutions reacting to the intricate data and regulatory health landscape [10].

Hospital and clinics observability models vary in size, complexity, and orientation based on differences in the infrastructure and patterns of service delivery. Hospital observability models emphasize extensive monitoring, for example, systems such as EHRs, PACS imaging, laboratory systems, and critical care devices. They are experts at providing customers with proactive anomaly detection, end-to-end traceability, and predictive analytics in hybrid cloud and distributed microservices. They possess advanced dashboards for real-time root-cause analysis and interact with ITSM tools to provide auto-response issue and continuous service-level objective optimization. Hospital observability provides data accessibility, clinical workflow efficiency, scalability, high availability, and HIPAA compliance. Observability systems in clinics are interested in patient flow, resource usage, and straightforward operating processes. They are interested in accurate field observation approaches, targeted telemetry acquisition, and comprehending patient paths, workflow constraints, and data integrity from combined clinical products and EHR components. Clinics find value in low-cost monitoring, real-time insight into provider-patient interactions, and usability-friendly applicability [6].

Hospital case studies demonstrate the effectiveness of observability for improved patient care. A healthcare organization on the West Coast implemented a full-stack observability platform to reverse its delays in the EHR system, preventing downtime and enhancing patient care quality. CDW worked with a hospital to implement ServiceNow's Metric Intelligence observability solution with AIOps capabilities, automating trouble tickets and identifying inactive or malfunctioning devices for maintenance. New York City-based Community Care Physicians substituted network monitoring with eG Enterprise in order to have comprehensive Citrix service performance and virtual application information for 1,800 end users across 75 clinics. EMEA and APAC's large healthcare provider, Bupa, combined monitoring tools with LogicMonitor, which interacts with ServiceNow to accelerate trouble fixing and automate creating incidents for over 500 medical devices. Successful observability solutions in healthcare settings are defined by end-to-end visibility, detection of anomalies with AI, automation of incident handling, and scalability. Such solutions have contributed directly to patient care outcomes, minimized downtime, and improved reliability in healthcare settings [11].

Bupa, the West Coast healthcare organization, has introduced an AI-based analytics-driven full-stack observability platform and real-time telemetry collection. The solution, leveraging tools like Dynatrace, New Relic, and Datadog, issue identifies and resolves automatically for equipment like wheel-based workstations. Community Care Physicians chose eG Enterprise to gain end-to-end visibility, issue automation, and extensive insight into Citrix service performance and virtual apps across different clinics and hospitals. Bupa also leveraged LogicMonitor, a hybrid observability platform built with ServiceNow integration, to automate incident creation and maximize operational efficiency. Cisco Full-Stack Observability is given as a strategic observability solution for healthcare, providing infrastructure and application monitoring, digital experience monitoring, and AI-driven insights to support safe and effective clinical systems [12]. Specialized tools like SolarWinds NTM and Paessler PRTG excel at network topology and device mapping, while full-stack observability solutions like Dynatrace and LogicMonitor track cloud resources and EHR apps. eG Enterprise and ServiceNow solutions automate the identification of devices for clinical workflow continuity and patient safety, delivering end-to-end visibility into all hospital IT systems are depicted in below Table 1:

Systems Monitored	Observability Tools Used	Record
Electronic Health Records (EHR)	Dynatrace, New Relic, Datadog, ServiceNow Metric Intelligence, LogicMonitor	Full-stack platforms capable of monitoring application performance, transaction tracing, and compliance monitoring.
Network Infrastructure	SolarWinds Network Topology Mapper, Paessler PRTG, Zabbix Network Monitoring, Cisco Full-Stack Observability	Tools that provide automated discovery, real-time network topology mapping, device status, traffic analysis, and bottleneck identification.
Medical Devices & IoT Devices	eG Enterprise, LogicMonitor, ServiceNow Metric Intelligence, OpManager	Monitoring device telemetry, connectivity, uptime, and integration status with hospital systems. Emphasis on critical medical equipment and clinical workstations.
Virtualization & Cloud Services	eG Enterprise, LogicMonitor, Cisco Full-Stack Observability	Monitoring performance and availability of virtual applications, Citrix sessions, and cloud infrastructure supporting healthcare systems.
Storage and Database Systems	Dynatrace, New Relic, LogicMonitor	Monitoring database query performance, replication status, and ensuring data consistency.

Table 1: Observability Tools used in the Hospital Implementations

III. SYSTEM OVERVIEW

The Medical Claims Engine leverages AI-based automation and real-time telemetry to enhance claim processing accuracy, efficiency, and transparency. It optimizes the claims life cycle, reduces error, and improves payers' and providers' financial outcomes. Optimized reimbursements and enhanced claim status notices increase patient satisfaction. The real-time system of claims adjudication is a fault-tolerant and extensible system that uses a streaming platform like Apache Kafka for processing claims. Kafka states data is then processed using an engine for stream processing like Apache Flink or Apache Spark Streaming, which does rule and eligibility evaluations based on metadata. Adjudication examines cost-sharing arrangements, provider agreements, and benefits and decides claims to adjudicate manually or qualify to auto-adjudicate. Claim status and financial liability are determined via adjudication.

Remittance instructions and advice are produced by adjudicated claims with payment and post-processing. Near-real-time downstream transfer to payment and accounting systems allows for faster reimbursements. Observability technology takes metrics, logs, and traces at all layers to track latency, throughput, error rates, and SLA compliance. Analytics and Reporting Layer The Change Data Capture technology asynchronously replicates claims data to data warehouses or cloud storage and provides reporting, fraud protection, and operations insights to providers and internal teams. The architecture illustrates the feasibility of near-instant claims processing by leveraging real-time streaming, automation, and end-to-end integrated observability while preserving data correctness, compliance, and operating transparency.

DOI: 10.15662/IJMSERH.2025.1302079

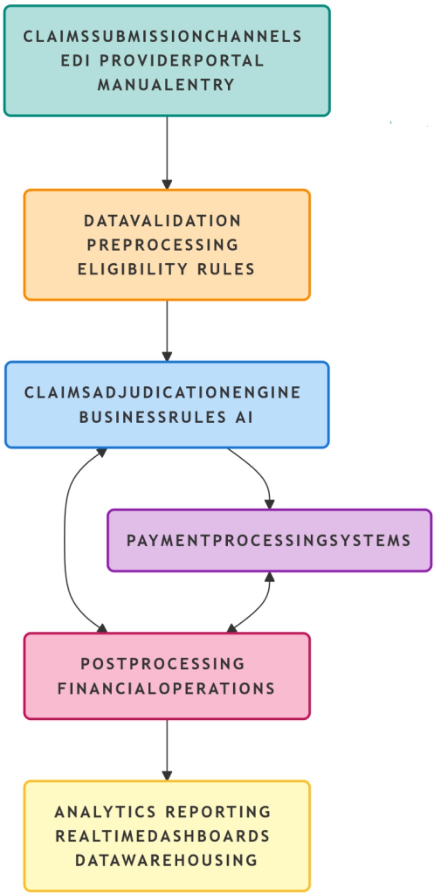

Figure 1: Medical Real-Time Medical Claims Adjudication System

- Real-Time Capture and Validation: Claims are submitted electronically multiple channels for effective clean and safe consumption.
- Automation for Pre-processing and Eligibility Verification: Automated eligibility and quality verification leading up to adjudication.
- AI-based adjudication: Employs rule-based reasoning during the claims process leading to reducing decisions and time.
- Telemetry Post-processing: Batch processing for real-time observation and financial support payment; limits lag and dynamic performance optimization.
- Data Analytics and Near Real-Time Reporting: Mainframe claims and member data will be moved to relational databases and cloud storage, giving transparency with certainty to the patient with financial communication.

The project redesigned Cigna Medical Claims Engine as a robust end-to-end solution architectural pattern built on agile and DevOps best practices. The architecture was structured in five functional domains: acquisition, pre-processing, adjudication, post-processing and analytics/reporting. Amazon Web Services cloud computing, Apache Kafka, IBM Classic Change Data Capture, and microservices were the providers of elastic compute and elastic storage. Observability technology provided fault correction and performance optimization of ahead of time by real-time telemetry dashboards. Governance model with dense controls provided an a high level of consistency of quality control and conformance to healthcare laws. Agile delivery discipline architectures were in place, with effectively collaborating clients and stakeholders providing risk mitigation and co-alignment to business needs. The initiative was the Cigna corporate transformation gold standard, planning and designing an observability-driven, cloud-based claims platform that minimized processing time time, provided operational transparency, and made key decisions based on data. The solution can be employed in your background and Medical Claims Engine transformation project instance, with best practices and solution architecture patterns documented as:

- Identify Business Objectives and Requirements: Meet stakeholders to identify operational objectives such as accuracy, time-to-adjudication, and transparency.
- Identify Functional and Non-Functional Requirements: Performance, security, scaling, and compliance.
- High-Level Architectural Design: Create a high-level architecture for analytics, claim acquisition, pre-processing, adjudication and post-processing.
- Interaction and Technology Adoption Design: Identify appropriate tools such as observability tools, microservices, APIs, Kafka, AI/ML engines.
- Roadmap Implementation Planning and Planning: Create staged implementation plan, build deployment plans, automated testing, and CI/CD pipelines.
- End-to-End Monitoring, Governance, and Improvement: Establish governance policies, monitor system health, data flow, and performance metrics, analyze system metrics, and make design choices.

As depicted below in figure 2, Medical Claims Engine was revolutionized by adopting a disciplined, iterative enterprise software delivery lifecycle that focused on agile practices, DevOps, and observability-driven operations. This approach reduced risk and increased business value realization with incremental feature release and regular deployment balanced with regular integration. Implementation stages were planning and analysis, development and testing, and deployment and monitoring. Stakeholders were employed in order to identify functional and non-functional requirements, and domain-specific modules for claim collection, pre-processing, adjudication, post-processing, and analytics were modeled in modular way. Mainframe and cloud platform integration cycles were built with focus on elastic microservices, Apache Kafka data streaming-based, and IBM CDC data replication-based. Scrum cycles were used with support from automated testing, code quality gates, and continuous integration pipelines. Release was containerized on AWS cloud infrastructure and system reliability and SLA adherence became feasible. Support frameworks post-implementation and large-scale user training were envisioned. The strategy facilitated smooth implementation via effective governance, risk management, and communication with stakeholders [13].

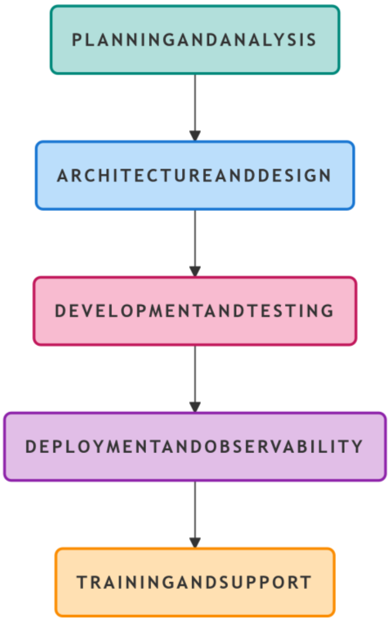

Figure 2: Implementation Methodology for the Medical Claims Engine

The most important measures for the deployment process of the Medical Claims Engine are in measuring its effectiveness and efficiency. The Clean Claim Rate (CCR) is a measure of how percent of claims are received and settled for the first time and should be at least 95% to reflect successful claims processing and prevention of rework. Claim Processing Time is the interval between date received and date decided, and shorter times support cash flow and member satisfaction. Denial Rate, about 5%, is the number of claims paid by payers as a percentage, and lower rates reflect accurate coding and compliance. Days in Accounts Receivable (AR) reflect payment speed in receiving payments, with smaller days showing an improved revenue cycle. Claims Throughput and Volume measures the amount of claims processed over a period, reflecting operating capacity and scalability.

Also, Error and Exception Rate monitoring helps decrease operations friction by identifying claims with data or adjudication mistakes. System Availability and Uptime monitor steady operations of the claims engine, which is vital to servicing. API Response Times and SLA Compliance are quantified to measure latency and service-level agreement compliance, while Root Cause Analysis and Incident Resolution Time quantify the effectiveness of system defect detection and repair with observability tools. All five metrics combined give an overall impression of financial effect, business efficiency, and quality of service of the claims engine and are considered helpful in strategic planning and continuous improvement [14]. Five of the main observability metrics can be helpful for Medical Claims Engine to gain insights into data reliability, claims processing effectiveness, and system health in general in relation to the "four golden signals" methodology and healthcare-specific data observability best practices.

The first metric is latency, which is the average time the claims take to go through each stage of adjudication and validation to have responsive times and timely payments. The second, errors rate, monitors failed claims transactions and data validation errors to identify recurring issues in terms of data mapping as well as adherence to HIPAA and ICD-10 standards. Throughput, the third performance metric, measures the number of claims processed within any given period of time so as to verify that high volume submission is supported by the platform and that system capacity and throughput are optimized. The fourth is utilized for measuring data consistency and freshness by observing data replication synchronization and timeliness across different nodes and analytics systems, which plays an important role in the preservation of predictive analytics and audit integrity.

Finally, resource utilization, such as CPU, memory, and I/O, is being observed in order to ensure high availability and to avoid performance degradation, resulting in capacity planning and improving cloud operation cost-effectiveness. These collectively form an end-to-end observability framework that links system performance to data quality, operational resilience, and compliance in the Medical Claims Engine environment [15]. Holt's linear trend model or simple exponential smoothing can be applied to smoothen trends and determine patterns in 2018-2024 data. The method enhances trend visualization and forecasting as it estimates level and trend, with increasing data losing weights and smoothness being programmed variables. The approach eliminates noise resulting from erratically changing values and enables the analysis of progress or declines in a more appropriate manner, thus being most suitable to time series measures such as Clean Claim Rate and Denial Rate. Smoothed trend lines courtesy of Python solutions through statsmodels might be useful plots for meaningful comparisons is shown in the following Figure 3:

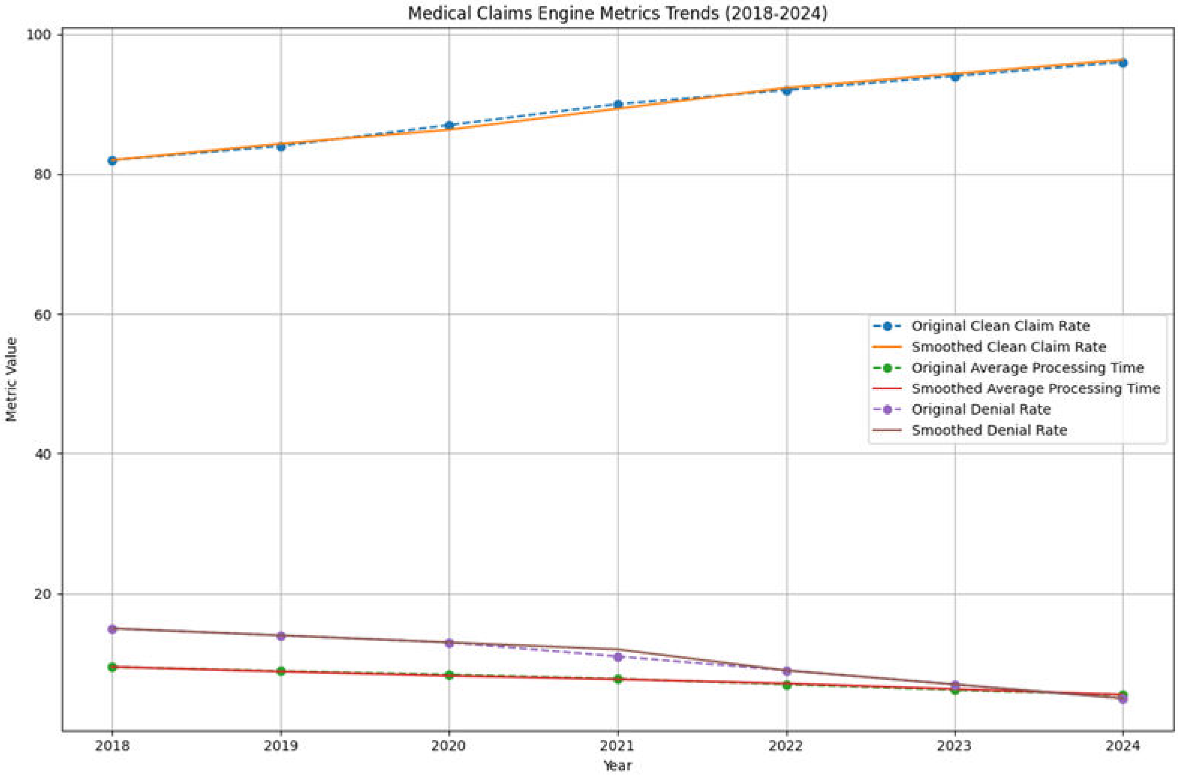

Figure 3: Medical Claims Engine yearly metrics Trends (2018 to 2024)

IV. CONCLUSION

Medical Claims Engine has been redeveloped as an observability-facilitated, analytics-enabled, cloud-native platform with faster claims adjudication, increased data transparency, and better end-to-end data synchronization from operational to analytical use cases. Telemetry and observability dashboards enable proactive issue detection, accelerated root-cause analysis, and quantifiable reductions in incident time to resolve. Modular microservices-based architecture enables elastic capacity to process increasing claim volumes, reduced maintenance, and accelerated iteration. Real-time replication to cloud data warehouses and single, unifying dashboards support data-driven decision making. Governance and compliance are enabled by governance, risk, and compliance controls throughout the lifecycle.

The future-looking platform encompasses AI-based appeal processing and denial prediction, advanced predictive analytics, event-driven near-zero-latency processing, blockchain for trust and provenance, and cost optimization and cloud-first approach. It also provides medical coding and documentation with AI, self-service analytics to stakeholders, and continuous review of cloud-native services, scalability choices, and cost control. Risks and mitigants include model drift and deteriorating data quality, imposing strict identification, access, and encryption controls, complex integration and vendor lock-in, and change management challenges. The roadmap sets the Medical Claims Engine up for future value in AI, interoperability, and cloud-first innovation, in support of the highly-established advantages of observability-driven modernization.

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