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Research Article

A Decentralized Blockchain-Node-Red-Cloud Architecture for Secure EHR Management and Novel Disease Prediction

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ABSTRACT

In today's healthcare landscape, where data is the backbone of effective care and seamless supply chains are essential, system inefficiencies and data vulnerabilities can seriously impact patient safety. This paper introduces a novel, integrated framework that combines Blockchain technology, Node-RED, and cloud computing to transform how healthcare data is managed and how emerging diseases are detected. A private Blockchain acts as the backbone for securely storing electronic health records (EHRs) and tracking supply chain activities, ensuring data integrity and traceability. To streamline real-time operations, Node-RED provides a user-friendly, visual programming interface that automates critical processes like prescription verification and inventory synchronization among healthcare stakeholders. Cloud infrastructure complements the Blockchain by handling high-volume data processing and analytics, helping the system scale without compromising performance. At the core of the framework lies the Enhanced Supervised Learning Chain Model (ESLCM), a machine learning model designed to analyse patient symptoms and regional health data. This model can identify unusual patterns that may signal the onset of novel diseases, making it a vital tool for early detection and pandemic preparedness. By combining transparency, automated workflows, and intelligent analytics with a strong commitment to data privacy, this integrated system empowers healthcare providers to respond faster, collaborate more effectively, and deliver smarter, more secure care in a world where every second matters.

Keywords: Blockchain, Node-Red, EHR, Healthcare Supply Chain, Infectious Disease, Viral diseases.

INTRODUCTION

Many hospitals accumulate extensive patient data, yet only a fraction of this wealth of information is utilized for making informed treatment decisions. The healthcare industry receives huge amount of patient-related data, encompassing clinical test results, vital signs, investigative reports, treatment follow-ups, prescription choices, and more. However, both medical practitioners and scientists often disregard the importance of these invaluable records. A computerized decision support system emerges as a pivotal tool to facilitate precise diagnoses and cost-effective healthcare. This repository of data can be found either in extensive paper archives or residing on server databases. The trajectory of automated systems' growth and refinement is poised to shape the future of healthcare, promising profound enhancements in disease management strategies, encompassing surgical procedures, medical testing, and pharmaceutical interventions.

The current global landscape is grappling with one of the most devastating and widespread pandemics in recent history—Covid-19. Upon the discovery of this illness, medical facilities and personnel swiftly organized, mobilizing all available resources to combat its relentless spread. However, the existing model proves inadequate in safeguarding users' information. Recognizing this vulnerability, Blockchain-based decentralized systems emerge as a robust solution, enabling even the most skeptical nodes to securely and reliably share a unified transaction record with decentralized authority. Nevertheless, recent circumstances expose vulnerabilities in numerous systems spanning various companies [6][7][8][32]. It has become evident that there is an urgent need for enhanced healthcare and pharmaceutical supply chain management and traceability. Amidst the depletion of critical medical supplies, including masks, protective gear, and ventilators crucial for intensive care units, Blockchain technology stands out for its ability to introduce transparency to the supply chain [10][11][12][32]. Healthcare supply chains grapple with logistical challenges as governments work tirelessly to meet escalating demands, extending across cities, hospitals, warehouses, and production facilities. The imperative for improved information security in the face of a global health crisis underscores the significance of transitioning to Blockchain-based decentralized systems. These systems not only address the current shortcomings but also offer a resilient framework for enhancing transparency and traceability in critical supply chains, ultimately contributing to more effective pandemic response measures.

After the epidemic has passed, it becomes necessary to examine the flaws in the inventory monitoring and supply levels. Here, Blockchain technology stands out as the perfect remedy. Blockchain solutions offer transparency, auditability, and security, simplifying their adoption by organizations [23] [32]. The medical and pharmaceutical supply chains struggle with substantial logistical challenges, such as real-time shipment tracking, transportation disruptions, quality assurance, customs reporting, and intricate invoicing processes. In stark contrast, a Blockchain-managed supply chain documents each step in the process for individual items, ensuring immutability, transparency, and efficiency. Significantly, developments in Enhanced Random Forest Supervised Learning on Blockchain technology have revolutionized precision in network activities, including data transmission throughput, latency, and energy consumption [13][14][15]. Implementing a distributed ledger strategy across the network's capabilities with a focus on achieving high performance accuracy can effectively address the challenges outlined above. In contrast to conventional machine learning methods, it is imperative to prioritize and fortify data privacy concerns. To tackle this, we have developed cutting-edge data management systems rooted in behavioural effects [16][17][18]. In this approach, a majority of users contribute to a public Blockchain system within the application, and the existing machine learning system updates tasks based on the uploaded data. This exemplifies an advanced form of Random Forest Supervised learning, a widely adopted mechanism. The Enhanced Supervised Chain not only ensures the confidentiality of all user information but also monitors the overall network efficiency by closely tracking user behaviour. This innovative system presents a solution that not only addresses privacy concerns but also enhances the overall performance and adaptability of the network.

LITERATURE SURVEY

A disease analysis framework called FIDA was introduced by Madhav Erraguntla et al. for infectious disease analysis [27]. FIDA employs a multi-modelling strategy to accommodate the many analytical needs that arise at various stages of a disease's lifecycle, such as among a reservoir population, among transmission vectors, among infected individuals, and across a community [24]. Joshua Feldman et al. employed machine learning to look at the effectiveness of extracting information on infectious disease activity from online news sources. They assembled a database of tagged news stories indicating if they include fresh information on disease outbreaks. These records were classified using this dataset as training. To validate the accuracy of the system, a concealed test set was employed to compare the articles against those featured in the World Health Organization's Disease Outbreak News service. The proposed classifier demonstrated commendable performance, achieving scores of 88.8 for recall and 86.1 for accuracy [25].

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Published in The Lancet in October 2020, The Global Burden of Disease Study 2019 presents a comprehensive analysis assessing the impact of diseases and injuries on a global scale. Encompassing data from 204 countries and territories spanning the years 1990 to 2019, the study's primary goal is to offer insights into the global burden of diverse diseases and injuries, serving as a crucial resource to inform healthcare policies and decision-making processes. The study meticulously categorizes and analyses 369 different diseases and injuries, evaluating their prevalence, mortality rates, disability, and overall impact. This extensive undertaking proves invaluable in comprehending the health challenges faced by diverse regions and populations, enabling the formulation of evidence-based strategies to enhance public health outcomes [26]. The input data set for the study is robust, compiled from various sources such as census records, surveys, civil registration and vital statistics, sickness registries, health care utilization data, air quality monitors, satellite imagery, disease warnings, and more. The methodology employed includes calculating rates and proportions of deaths attributed to various causes using the Cause of Death Ensemble Model and spatial-temporal Gaussian process regression. All-cause mortality rates, integral to the Global Burden of Disease estimates, were generated, with cause-specific mortality rates adjusted accordingly. Years of Life Lost (YLLs) were determined by multiplying the number of deaths by the expected lifespan at each age. This meticulous approach ensures a comprehensive and nuanced understanding of the global health landscape, facilitating informed policy decisions and targeted interventions.

In a study conducted by Yuki Furuse (2020), the analysis focused on infectious illnesses and their disease burden, shedding light on which infectious diseases have been overlooked by researchers [27]. Across the globe, infectious diseases inflict significant suffering and death, yet the effectiveness of the limited human, financial, scientific, and temporal resources allocated to disease management research remains unclear. The study delves into the correlation between the number of publications (as a surrogate for research activity) and the number of disability-adjusted life years (a measure of disease burden), adjusting research intensity for 52 infectious illnesses on a global and national scale. The research reveals that, in comparison to other major infectious diseases like influenza, HIV/AIDS, hepatitis C, and TB, research on paratyphoid fever is notably less intense. This highlights the disparities in attention given to various infectious diseases. The study identifies both the infectious diseases that researchers have focused on and those that have generally gone unnoticed. Interestingly, despite the label of being "neglected," not all tropical diseases showed little or no burden-adjusted research effort. Moreover, the research findings unveil varied tendencies in countries' levels of infectious disease research. These insights open the door for further discussions on how to effectively prioritize funding for research into infectious diseases, offering valuable considerations for allocating resources to address global health challenges.

A study by Wei Liu et al. analyses factors associated with hospitalised patients with the 2019 novel corona virus disease's health outcomes [28]. In this research author adds the growing body of evidence that shows high C-reactive protein and reduced albumin are variables related with a poor prognosis of COVID-19 illness. Protein levels in the blood, as measured by albumin, are a good proxy for overall dietary health. When albumin levels drop, the body is less able to fight against the virus, which speeds up the course of sickness. Inadequate blood clotting capability and an elevated C-reactive protein level together constitute a significant inflammatory index. Keeping a close eye on the new dynamics in these metrics has a major predictive influence on learning about the patient's state. Additionally, research has demonstrated that lymphocytes are the main cell type that viruses infect. The immune system takes the brunt of the damage caused by viruses, and this is shown as a decline in lymphocyte count. More research is needed to determine why these indicators were not useful in determining the outcome of COVID-19 patients in the current study.

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1. TECHNOLOGY UTILIZATION & RESEARCH GAPS

1.1. NODE-RED

Node-RED stands out as an open-source visual programming tool explicitly crafted for IoT (Internet of Things) and diverse flow-based applications. Tailored to provide an intuitive interface, it excels in the seamless connection and automation of devices and systems. Leveraging Node.js as its foundation, Node-RED boasts a web-based flow editor empowering users to effortlessly create, edit, and deploy flows comprised of nodes representing distinct functions and devices [33].

It's crucial to note that Node-RED isn't a Blockchain platform; rather, it stands as a powerful flow-based development tool for visual programming. In the intricate web of the healthcare supply chain, which involves a myriad of interconnected stakeholders, Node-RED emerges as a transformative solution. The primary aim is to foster coordination and connectivity across all facets of the supply chain, encompassing hospitals, manufacturers, distributors, suppliers, customers, and the organization itself. Choosing Node-RED to implement a supply chain solution presents numerous advantages. This flexible, open-source, visual programming tool has the potential to streamline and automate diverse supply chain processes. By leveraging Node-RED, the healthcare supply chain can benefit from enhanced efficiency and coordination, ultimately contributing to a more agile and responsive ecosystem.

Here are some benefits of using Node-RED for healthcare supply chain management [4][30][31][33]:

- **Integration of Diverse Data Sources**: Node-RED allows you to easily integrate data from a wide range of sources, including IoT devices, sensors, databases, and external APIs. This enables real-time monitoring and tracking of supply chain activities.
- **Customization and Flexibility**: Node-RED provides a visual programming environment, making it relatively easy to design custom workflows that meet your specific supply chain needs. This adaptability is crucial in supply chain management, as requirements can vary greatly between industries and organizations.
- **Real-time Visibility**: With Node-RED, you can create dashboards and visualizations that provide real-time insights into your supply chain operations. This can help identify bottlenecks, optimize routes, and improve overall efficiency.
- **Automated Processes**: Node-RED allows you to automate various tasks within your supply chain. For example, you can set up automated alerts for low inventory, automatic reordering of stock, or predictive maintenance for equipment.
- **Enhanced Data Security**: Blockchain integration is possible with Node-RED, which can provide an added layer of security for your supply chain data, ensuring data integrity and traceability.
- **Cost Savings**: By streamlining and automating supply chain processes, Node-RED can help reduce manual labour and errors, resulting in cost savings over time.
- **Scalability**: Node-RED is scalable and can accommodate the growth of your supply chain operations. As your supply chain expands, you can easily extend your Node-RED-based system to handle increased data and tasks.
- **Rapid Prototyping**: Node-RED's visual interface and extensive library of nodes make it ideal for rapid prototyping. You can quickly test and iterate on new supply chain management ideas.
- **Interoperability**: Node-RED supports a variety of communication protocols and data formats, making it compatible with existing systems and devices in your supply chain.
- **Open Source and Community Support**: Node-RED is open-source, and it has an active and supportive community. This means you have access to a wealth of contributed nodes and community knowledge to help you develop your supply chain solutions.

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Node-RED can be a valuable tool for building workflows and integrating systems, but it may have limitations when it comes to handling security issues, especially in complex applications. Blockchain can complement Node-RED by enhancing security.

1.2. BLOCKCHAIN TECHNOLOGY

Blockchain technology represents a paradigm shift in data storage and transaction recording by operating as a decentralized and distributed ledger system. It meticulously records transactions across numerous computers, ensuring their immutability, security, and transparency. At its core, Blockchain serves as a revolutionary technology, fundamentally altering the landscape of decentralized network data management. The system, inherently a distributed ledger, guarantees transparency, security, and immutability [9].

Transactions are methodically organized into blocks, interconnected through cryptographic links, and disseminated across a network of computers. Once a transaction is enshrined on the Blockchain, it becomes an indelible part of the ledger, impervious to any form of tampering or deletion. This unique attribute reinforces trust and data integrity, propelling Blockchain into a pivotal role in diverse industries. Its potential to reshape the future of data management and digital interactions is a driving force behind ongoing innovation [1] [32]. In essence, Blockchain stands as a transformative force, promising a new era in secure, transparent, and trustworthy data handling across a variety of sectors.

Combining Node-RED with Blockchain technology can provide a powerful platform for the development of innovative applications. Let's discuss the positive implications of Blockchain technology for dealing with node-red security concerns [1] [2][29][31][34]:

- *Access Control*:
  - Node-RED provides basic access control features, but it may not meet the stringent access control requirements of certain security-sensitive applications. It may lack robust role-based access control (RBAC) mechanisms.
  - Overcoming with Blockchain: Blockchain can enforce access control through cryptographic methods. Each participant in a Blockchain network has a cryptographic identity, and permissions to access data and perform actions are controlled by smart contracts. This ensures secure and fine-grained access control [22].
- *Data Security:*
  - While Node-RED can process data, it may not provide built-in encryption and data protection features to secure sensitive information adequately.
  - Overcoming with Blockchain: Blockchain uses cryptographic techniques to secure data at rest and in transit. Data entered into a Blockchain ledger is tamper-proof and encrypted, enhancing data security [30].
- *Authentication*:
  - Node-RED relies on traditional authentication methods, which may be vulnerable to password-related security issues, such as password breaches.
  - Overcoming with Blockchain: Blockchain networks often use public-private key pairs for user authentication. This eliminates the need for traditional usernames and passwords, reducing the risk of password-related vulnerabilities [14].
- *Auditability*:
  - Node-RED does not offer native features for maintaining an immutable audit trail, which is crucial for forensic analysis and compliance purposes.
  - Overcoming with Blockchain: Blockchain's inherent immutability ensures that all transactions are permanently recorded and cannot be altered. This feature provides a robust audit trail for security and compliance purposes [3].
- *Secure Smart Contracts:*
  - Node-RED does not inherently support smart contracts, which can automate and enforce business logic securely.

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  - Overcoming with Blockchain: Blockchain platforms, such as Ethereum or Hyperledger, support smart contracts that execute code in a trust-less and secure manner. These contracts can automate supply chain processes while maintaining security [3][21].
- *Data Tampering:*
  - In Node-RED, data may be vulnerable to tampering if not adequately protected and verified.
  - Overcoming with Blockchain: Blockchain's consensus mechanisms ensure that data once recorded cannot be altered without consensus from the network participants. This provides data integrity and resistance to tampering [5][18].
- *Third-Party Nodes:*
  - Node-RED allows the use of third-party nodes, which may introduce security risks if not carefully vetted.
  - Overcoming with Blockchain: Careful auditing and validation of third-party smart contracts and nodes before deployment on a Blockchain network can mitigate this risk. Blockchain networks often have mechanisms for reviewing and approving third-party code [22].

In summary, while Node-RED provides a user-friendly and flexible platform for developing applications, it may require additional measures and integrations to address security concerns adequately. Combining Node-RED with Blockchain technology can enhance security by providing cryptographic authentication, data integrity, access control, and tamper-proof auditability, making it a robust solution for secure supply chain management.

Additionally, despite its strength, Blockchain technology has several limits that can be complemented and addressed by combining it with cloud technology.

1.3. CLOUD COMPUTING

Cloud technology is a revolutionary paradigm offering on-demand access to a shared pool of computing resources and services via the internet. These encompass computing power, storage, databases, networking, software, and more. Users benefit from accessing and utilizing these resources without the burden of owning or managing the underlying infrastructure. The integration of Blockchain and cloud technologies presents an opportunity for organizations to leverage the unique strengths of both, effectively addressing challenges and limitations [24][25].

Here are some common problems with Blockchain that can be mitigated by using cloud services.

- *Scalability*: Blockchain networks, particularly public ones like Bitcoin and Ethereum, encounter scalability challenges. Leveraging the cloud offers a scalable infrastructure solution to manage growing transaction volumes and data storage needs. Organizations can effectively address scalability issues by deploying Blockchain nodes on cloud servers, enabling flexible scaling of their Blockchain networks as required.
- *Latency and Performance*: Blockchain, due to their distributed nature and consensus mechanisms, can introduce latency in transaction processing. Cloud solutions can optimize network connectivity and processing power to reduce latency and improve the performance of Blockchain applications. This is particularly important for real-time applications and industries like finance and gaming.
- *Storage Costs*: Storing data on the Blockchain can be expensive, especially for large volumes of data. By utilizing cloud-based storage solutions, organizations can reduce storage costs significantly. Cloud providers offer scalable and cost-effective storage services, making it feasible to store large amounts of data off-chain while maintaining data integrity on the Blockchain.
- *Energy Efficiency*: Blockchain networks like Bitcoin rely on energy-intensive mining processes. By using cloud resources, organizations can optimize energy consumption for Blockchain nodes

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and reduce the carbon footprint associated with mining. This is essential for sustainability initiatives and eco-friendly Blockchain applications.

- *Rapid Deployment:* Deploying a Blockchain network can be time-consuming and complex. Cloud services provide easy-to-use interfaces and automation tools that accelerate the deployment process. Organizations can spin up Blockchain nodes and networks on the cloud quickly.
- *Resource Efficiency*: Cloud environments allow for better resource utilization and energy efficiency compared to traditional Blockchain mining operations, which can be energy-intensive. Organizations can take advantage of cloud infrastructure to reduce their carbon footprint.
- *Interoperability*: Integrating Blockchain with existing systems and services can be challenging. Cloud platforms provide APIs and integration tools that facilitate the interoperability of Blockchain applications with other cloud-based services and legacy systems.
- *Cost Management*: While Blockchain transactions can be expensive, cloud providers offer cost management tools and pricing models that allow organizations to optimize their cloud spending. This can help control overall operational costs.

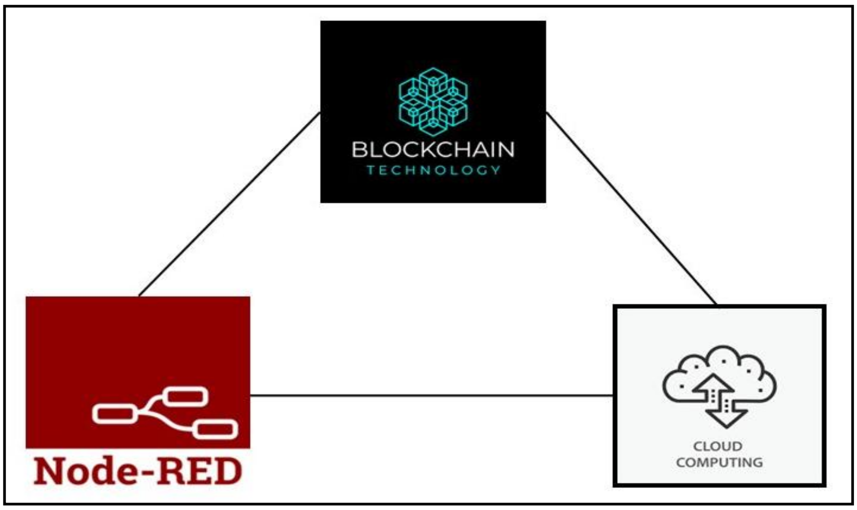

Figure 1. Technology Integration

Combining Node-RED, Blockchain, and cloud technology as shown in figure 1, represents a convergence of powerful capabilities in the world of application development. Node-RED's intuitive visual programming interface streamlines workflow automation and real-time data processing, while Blockchain ensures data integrity and security. The cloud, with its scalability and accessibility, provides the infrastructure needed to support these applications on a global scale. Together, this trio of technologies offers a dynamic platform for building innovative and trustworthy applications that can automate processes, secure data, and adapt to changing demands, making it a compelling solution for industries ranging from supply chain management to healthcare and finance, where data integrity and scalability are paramount.

1.4. RESEARCH GAPS

While Blockchain technology has numerous advantages, it also presents several programming related disadvantages and challenges for developers:

- *Handling Busy Networks:* When too many transactions hit a Blockchain, it's like a crowded store with long lines—things slow down fast. Cloud computing jumps in like extra cashiers, adding resources to keep things moving. Node-RED acts like a store manager, automatically organizing resources to handle the rush, so the network stays quick and reliable [4] [14] [24].
- *Managing Power-Hungry Nodes:* Running Blockchain nodes, especially for Proof-of-Work systems, is like keeping a big air conditioner on all day—it uses tons of energy and costs a lot.

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Cloud platforms offer a cheaper, flexible alternative, like a smart thermostat. Node-RED fine-tunes these resources, helping nodes run smoothly while cutting down on expenses [5].

- *Simplifying Smart Contracts:* Creating smart contracts is like building a delicate model—one mistake can ruin everything and cost big. Node-RED provides a simple, visual tool, like a guidebook, to help developers design contracts without errors. With cloud tools, it makes building safe, reliable smart contracts much easier [8] [25] [30].
- *Linking Different Systems:* Connecting Blockchains to each other or to older systems is like trying to get two different video game consoles to play together—tricky! Node-RED works like a universal controller, making it easy for systems to share information. Running on the cloud, it keeps data flowing smoothly between Blockchains and old-school setups [12][24].
- *Making Sense of Blockchain Data:* Turning Blockchain data into useful insights for analytics or AI is like solving a tough puzzle. Cloud platforms provide powerful tools to crack the code, while Node-RED acts like a puzzle guide, funneling data into analytics systems. This helps developers find trends and make predictions easily [4][25][30].
- *Reducing Energy Use:* Some Blockchains, like those using Proof-of-Work, eat up energy like a big bonfire, worrying people about the environment. Cloud providers often use green energy, like solar or wind, to power their servers. Node-RED helps optimize nodes on these platforms, cutting energy use and making Blockchain projects more eco-friendly [12] [24].

Combining Blockchain, Node-RED, and cloud computing can lead to more efficient, secure, and versatile applications. These technologies complement each other, enabling the development of advanced solutions for a wide range of use cases, from supply chain management to healthcare data management and more.

PROPOSED METHOD

1.5. SYSTEM ARCHITECTURE

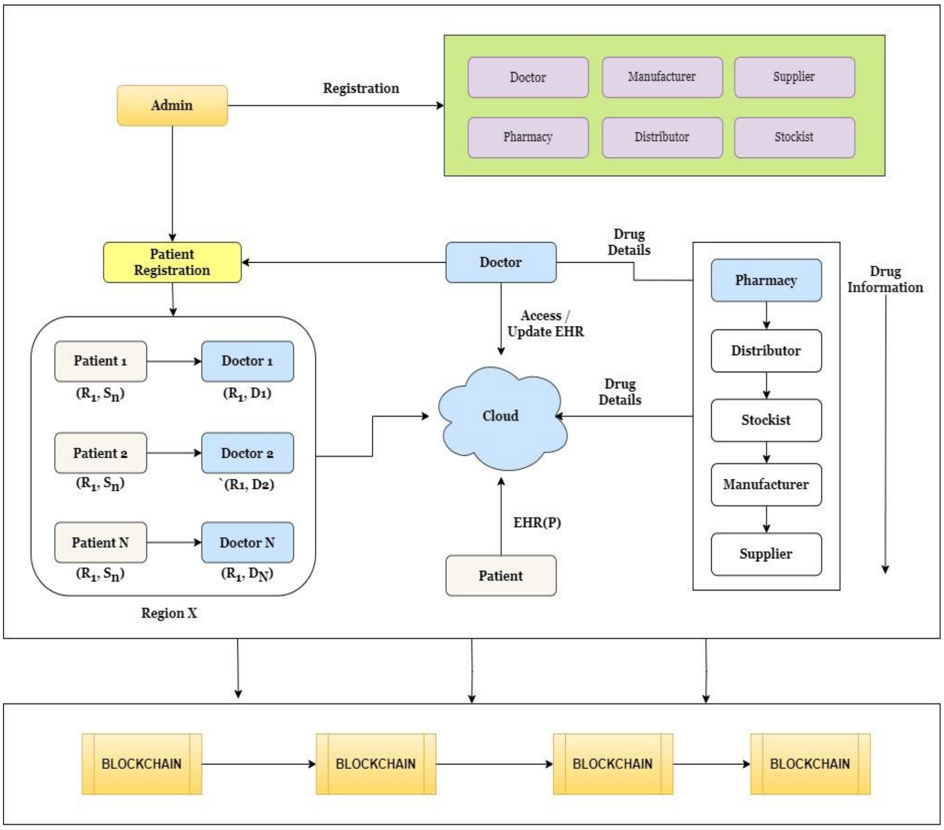

Figure 2. System Architecture

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The system's architectural flow is illustrated in Figure 2. In order to begin the process and become an affiliate in a chain, the network administrator or system administrator must authorize all the participants, including the doctor, supplier, manufacturer, distributor, etc. If a patient (R_N, S_N) is being seen for the first time, the doctor will register them. The doctor (R_N, D_N) will create an electronic health record for the patient that contains information such as address, present symptoms, allergies, any ongoing diseases, etc. Once the patient's EHR is established by the system, the patient will be given a unique patient identification number that can be used to trace the patient's mobility or for further treatment. The EHR is stored in the cloud since a Blockchain system might have scalability problems [28]. The system will use patient information, including the patient's region and symptoms (R_N, S_N), to identify any unprecedented disease situations [29]. Only drug or medication information is retrieved from an EHR and passed up the chain when a patient is diagnosed by the doctor. Chains contain stakeholder entities including pharmacies, distributors, suppliers, manufacturers, etc. [21] [30]. When a patient visits a linked pharmacy to purchase medicines, the pharmacy is responsible for incorporating drug information to the chain. The chain stakeholder may use this drug information to either increase or decrease the supply of a specific drug [22] [23].

1.6. SYSTEM MODEL

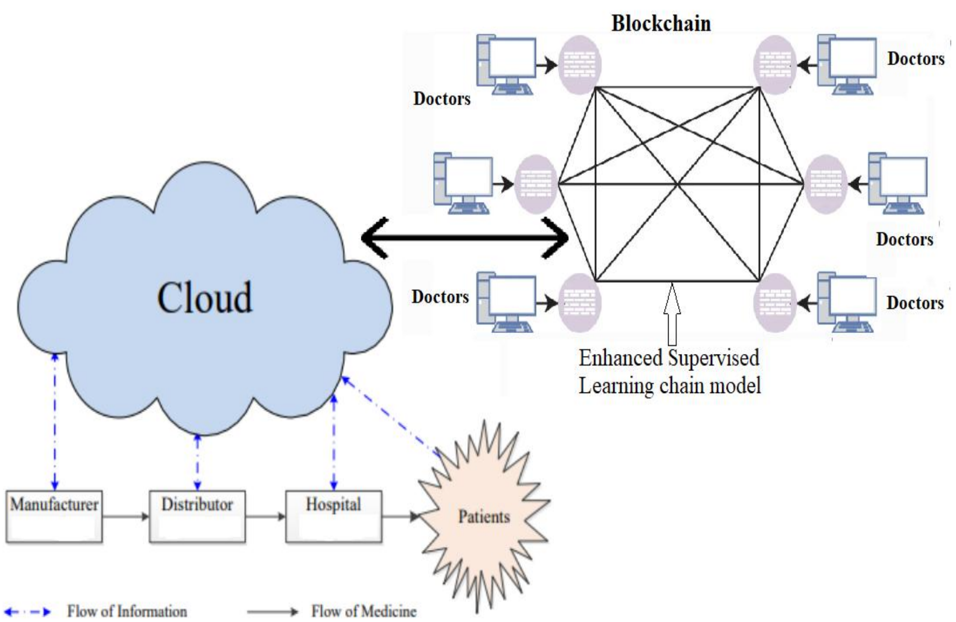

Figure 3. System Model

The proposed system model, illustrated in Figure 3, incorporates cloud storage, facilitating remote data access for both the admin group and clients. The Blockchain, stored in blocks, plays a crucial role in authenticating and verifying each transaction. Each block retains a comprehensive copy of the entire Blockchain, continuously updating as new transactions join the network. A pivotal aspect of the system is decentralized storage, where Blockchain-enabled cloud integration not only provides substantial storage capacity but also enhances privacy and data security [30].

The implementation section showcases block storage using a Node-Red cloud setup. Utilizing the Blockchain as a storage component is made possible by its encrypted mechanism for data storage and access. The fully decentralized nature of the Blockchain, complemented by cloud services, simplifies the online storage and retrieval of data [18][19][20]. Amazon oversees the Blockchain, offering a seamless platform for conducting analyses. This integration underscores the synergy between Blockchain and cloud technologies, promoting efficiency, security, and accessibility in data management.

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1.7. BLOCKCHAIIN UTILIZATION

Figure 4 depicts the Blockchain paradigm that is used to link the information from earlier blocks. The proposed system is connected to a number of field inputs, including patient, distributor, manufacturer, hospital, physician, and pharmacy. The Blockchain allows creating new blocks on the process. In the Blockchain, each hash has unique patient inputs and references to the previous hash. Each block has its own value and connected with previous blocks**.** The Blockchain system broadcast hash values to next block for linking**.** In the demonstration, the doctor prescribes medicines in accordance with the preceding block and the details of prescription will be broadcasted to pharmacy, hospital, admin and patient.

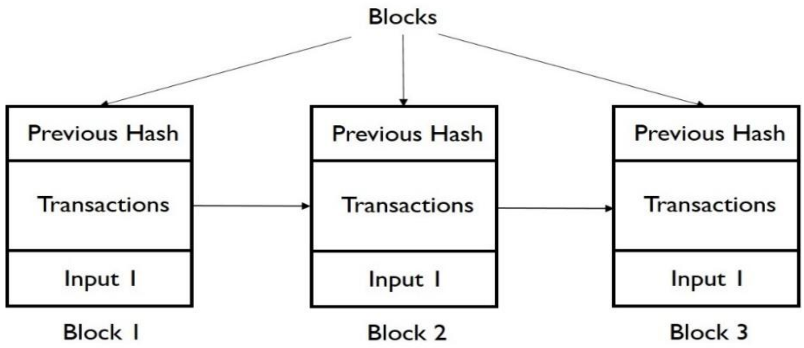

Figure 4. Blockchain Model

The healthcare department of an organization manages the transactions, which are handled and maintained employing private Blockchain technology. The block transactions are restricted to public access and only authorised users are allowed to access the same. The private Blockchain utilizes resources effectively.

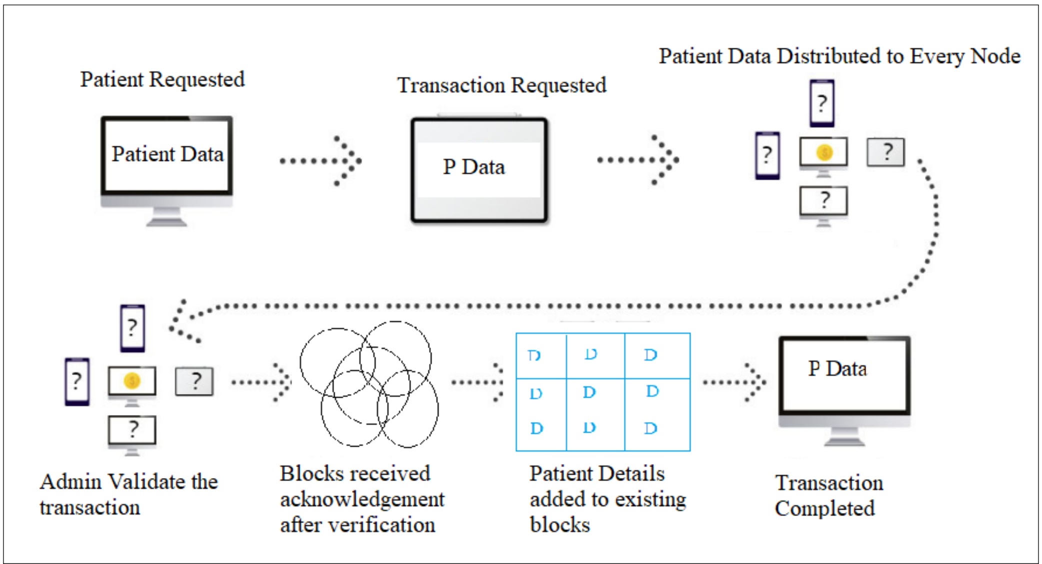

Figure 5. Patient transaction processing

Figure 5 illustrates the transaction processing of a patient in the Blockchain system. Doctors, hospitals, and pharmacy may commence a new transaction and it is validated by the network administrator. Once a block receives an acknowledgement after verification; patient details are added to the block. The transaction details are then stored and distributed throughout the network operations. The network is

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accessible from anywhere, and the transactional details are saved in the cloud. The Blockchain and cloud systems is coupled to store gathered data and make it accessible for analysis.

1.8. OUTCOME OF THE PROPOSED SYSTEM

The real-time cloud storage system supports multistate data collection, including data distribution. The Blockchain-based decentralized system analyses various departments, such as distributors, manufacturers, hospitals, doctor prescriptions, and labs. The data processing involves multi-state information for data processing. Unusual consumption, different prescriptions for the same issue, sudden surges in medical demand, and shortages due to overwhelming demand are among the critical situations addressed. The administrator can analyse the data and initiate notices to the relevant departments, assigning special teams to investigate the root causes. The processing time depends on the specific issues targeted. Identification of unprecedented diseases is achieved through data processing, with pattern and trend detection being the primary processes of distributed Blockchain techniques. In disease identification, data mining involves the systematic collection and analysis of patient data using Enhanced Supervised Learning Chain Model (ESLCM) algorithms, followed by the development of a distributed system for disease prediction or patient care [24]. While data mining has been practiced for many years, it has become more prevalent with the advancement of information technology. Cloud-based database management systems provide online access and storage. Historical disease knowledge and prediction algorithms, tailored to the current scenario and region, aid in complex data mining. The Enhanced Random Forest Supervised Learning Chain Model integrated with a Blockchain-based decentralized data management system verifies disease symptoms and updates them in a distributed ledger. The format above clearly outlines the structure of the disease identification system, focusing on disease behaviour as an index to monitor patient health and detect unprecedented diseases. The administrator receives a configuration of disease monitoring architecture to aid in unprecedented disease detection [24][25].

IMPLEMENTATION AND RESULTS

Node-red based experimental system is configured to gather information from pharmacy, doctor, hospital, manufacturer, stockists, and distributors. The provided solution accommodates various medicines with different dosage levels. The Patient information and doctor prescribed medicines are stored at decentralised system. Following are some important snapshots of the system.

1.9. Patient Mobile Interface – Personalized Entry Point

This screen shown in figure 6 represents the starting point of patient engagement within the healthcare network. Accessible via mobile, this interface enables hospitals or authorized admins to register new patients in real time, capturing crucial details like name, patient ID, and prescribed medication. What makes this interface powerful is its seamless connection to the Blockchain system: the moment the form is submitted, a digitally signed, immutable patient health snapshot is stored securely and shared with relevant nodes in the network. The interface exemplifies patient-centric design—mobile, minimal, and medically meaningful.

1.10. HOSPITAL ADMIN INTERFACE

Figure 7 shows the Hospital admin interface. The admin interface is the brain of hospital-side operations. From registering doctors to managing patient data and overseeing drug distribution logs, this panel provides complete visibility into hospital-level activities. Notably, it includes verification layers that ensure only licensed professionals enter the Blockchain. This figure reflects not just functionality but trust: admins act as gatekeepers of data integrity, ensuring each transaction is both medically valid and system-approved. The interface brings governance and transparency to a traditionally siloed environment.

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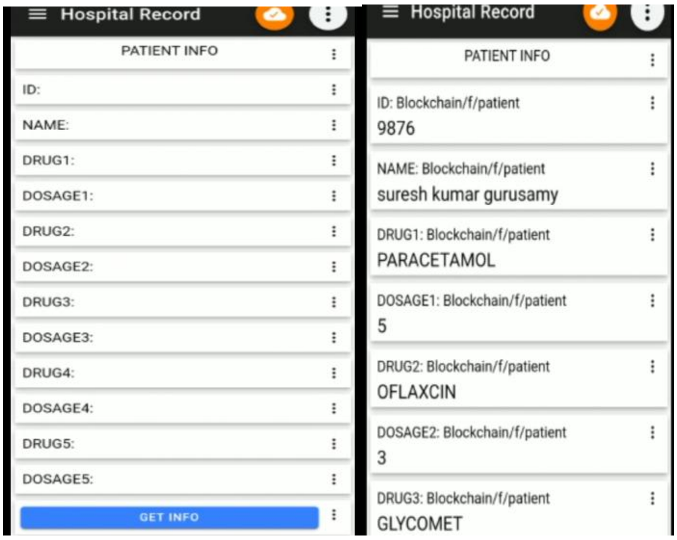

Figure 6. Patient Info & Medical Record

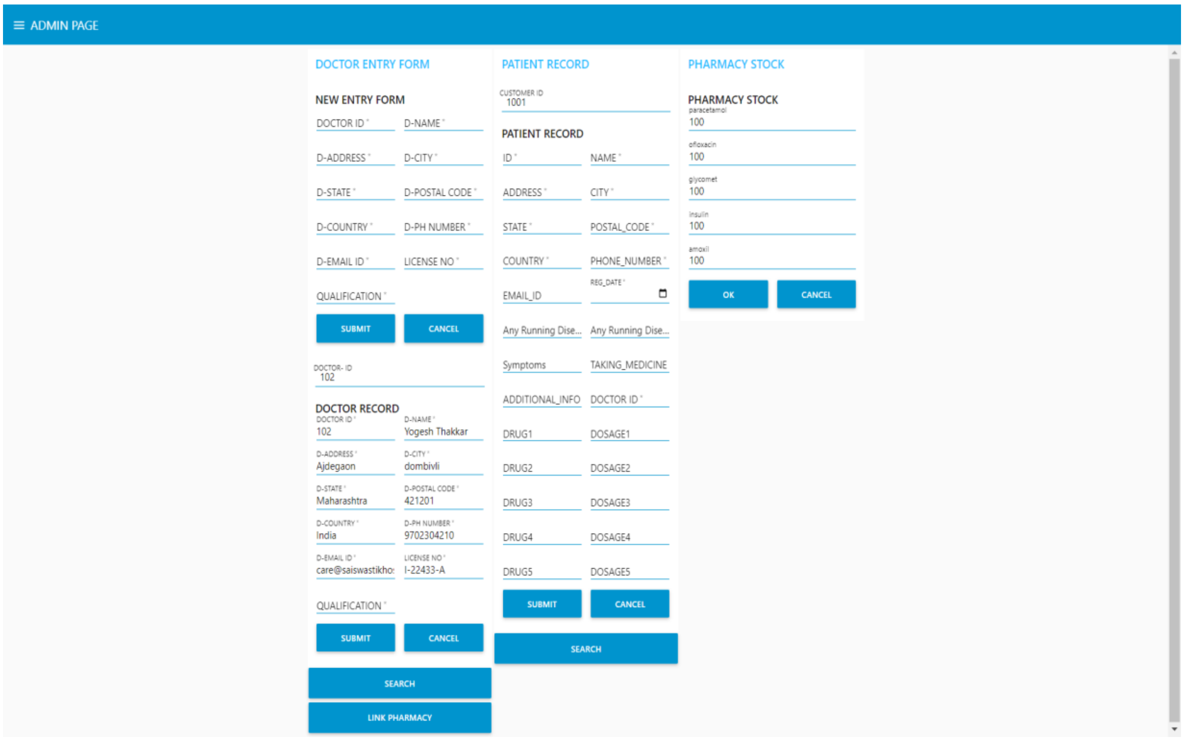

Figure 7. Hospital Admin Interface

1.11. DOCTOR INTERFACE

In Figure 8, doctors interact with a clean, purpose-built interface to create or update Electronic Health Records (EHRs) for patients. Designed to minimize cognitive load, it allows the practitioner to focus solely on the clinical process. Uniquely, only prescription-related data is extracted and published to the Blockchain, ensuring that patients' privacy is preserved while their care continues. Doctors also gain real-time visibility into medicine availability, bridging the gap between diagnosis and feasible treatment. This is more than a medical dashboard—it's a clinical decision tool.

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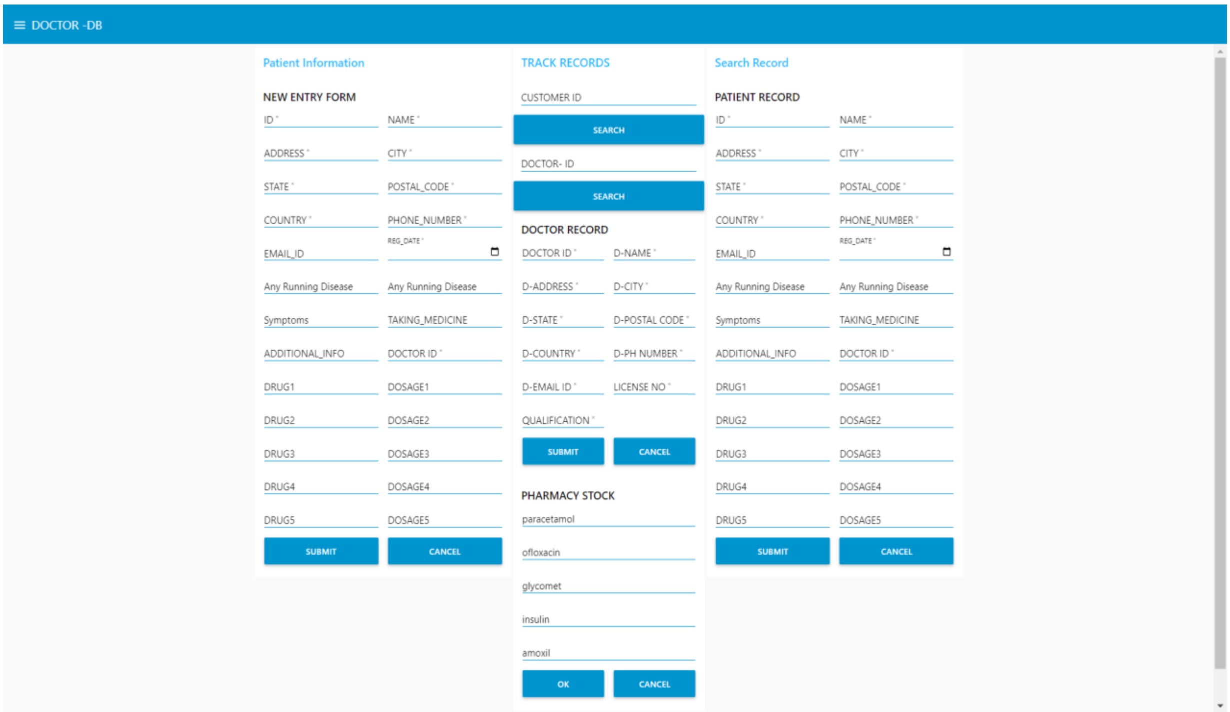

Figure 8. Doctor-DB

1.12. PHARMACY INVENTORY

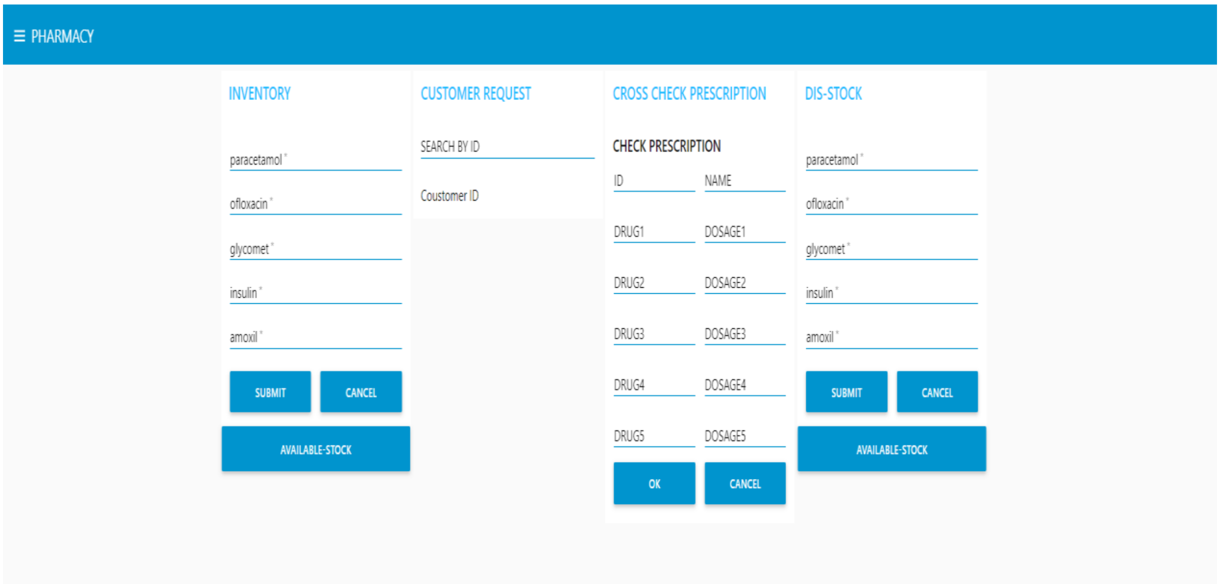

Figure 9. Pharmacy Inventory

Figure 9 brings the prescription to life. Once a doctor submits a medication plan, pharmacies use this interface to verify and dispense medications, all tied to the patient's unique ID. Inventory updates are instant and immutable, automatically triggering alerts for restocking or potential supply imbalances. This user interface is a living ledger—every interaction, whether dispensing or restocking, is captured on-chain. The result is a secure, traceable system where drug misuse, fraud, or miscommunication is virtually eliminated.

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1.13. DISTRIBUTOR INTERFACE

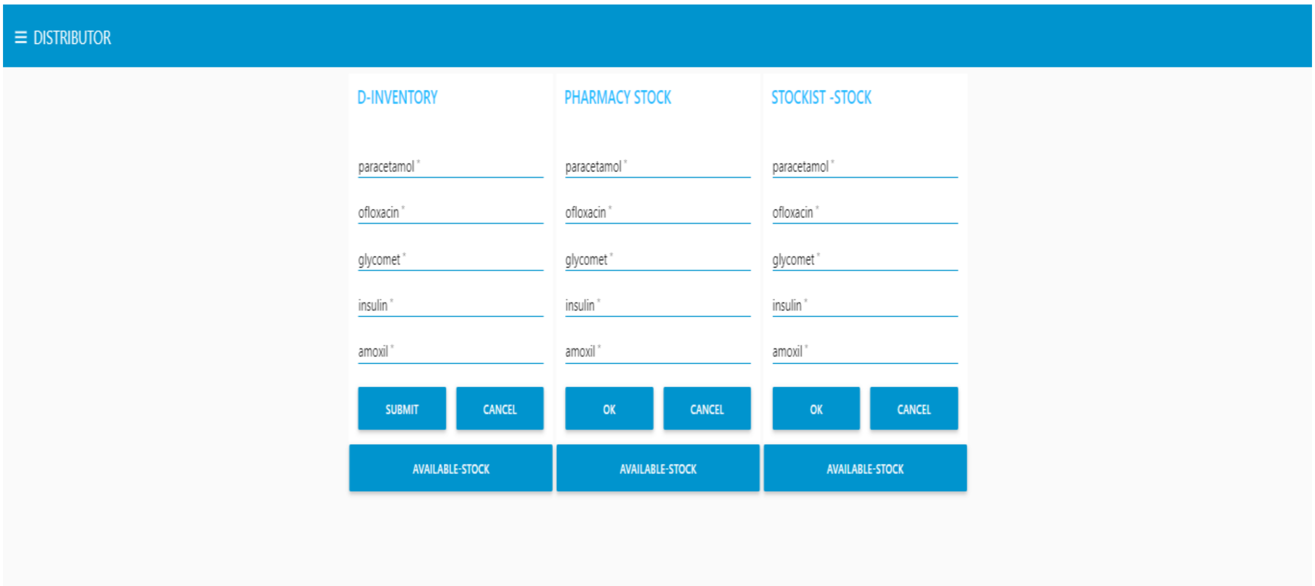

Figure 10. Distributor interface

Here, the supply chain starts flexing its muscle. Distributors use this UI to track medicine flows across stockists and pharmacies, dynamically adjusting to changes in demand. Figure 10 demonstrates how the system allows distributors to pre-empt shortages—an essential feature during health crises. The Blockchain's timestamped records ensure that supply anomalies or delays can be traced to the source, enhancing both responsiveness and accountability.

1.14. Manufacturer Interface

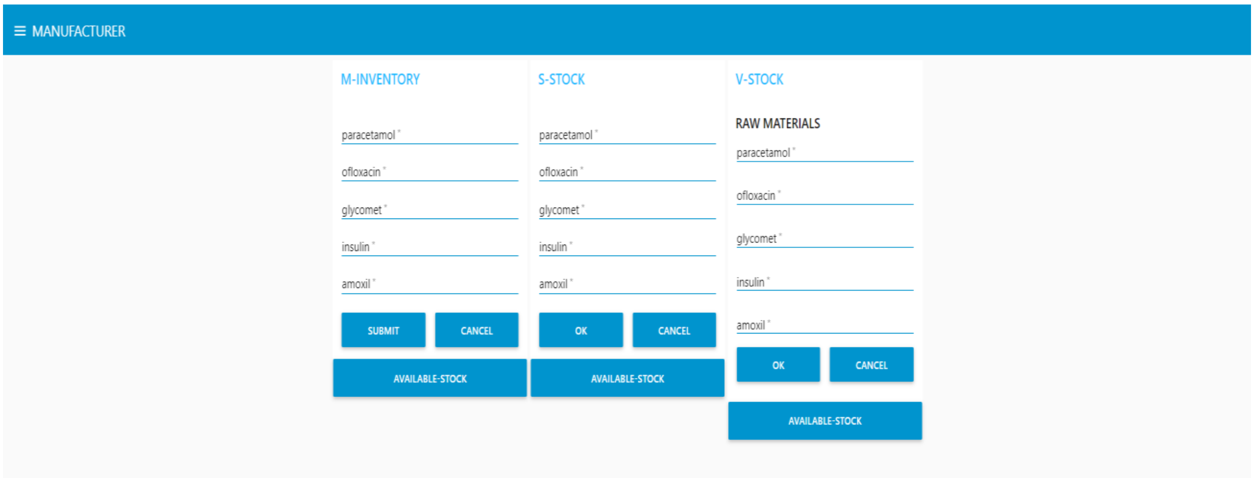

Figure 11. Manufacturers interface

Manufacturers rely on real-time market signals, and Figure 11 provides exactly that. This dashboard connects manufacturers directly with supply-side data, allowing them to adjust production volumes based on real-time demand. It's no longer guesswork—it's data-guided manufacturing. What makes this unique is its integration with Blockchain-led verification: only authenticated demand spikes trigger production workflows, avoiding waste and ensuring high-value resource utilization.

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1.15. STOCKIST INTERFACE

In Figure 12, the stockist acts as the balancing node of the entire chain. With access to both upstream (manufacturer) and downstream (distributor/pharmacy) data, this interface helps optimize storage capacity and flow planning. It also includes batch-level traceability, making it easy to flag expired or overstocked drugs. During pandemics or emergencies, this interface transforms into a response hub, making timely decisions that can literally save lives.

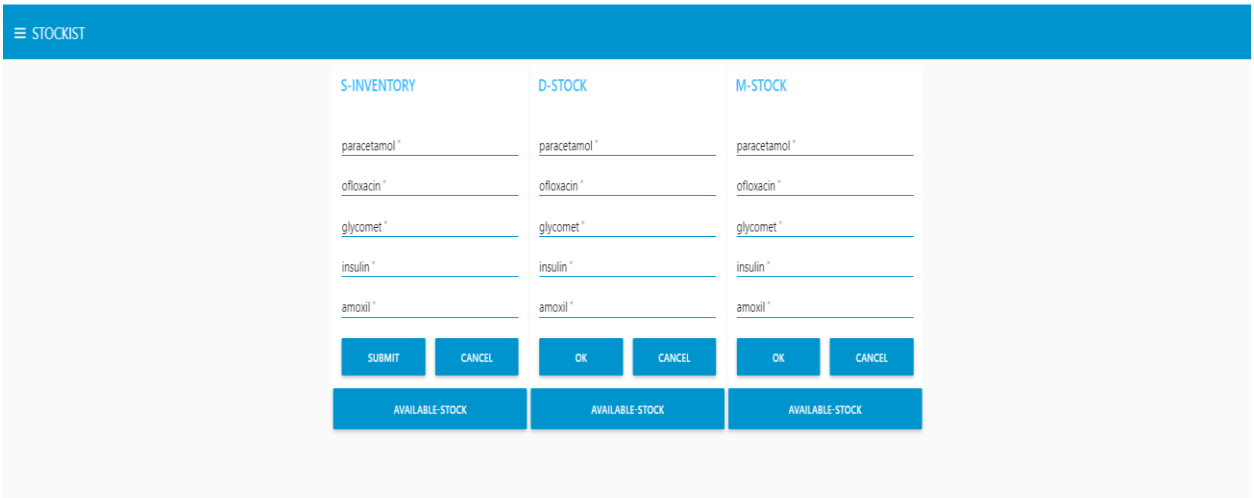

Figure 12. Stockist

1.16. SUPPLIER INTERFACE

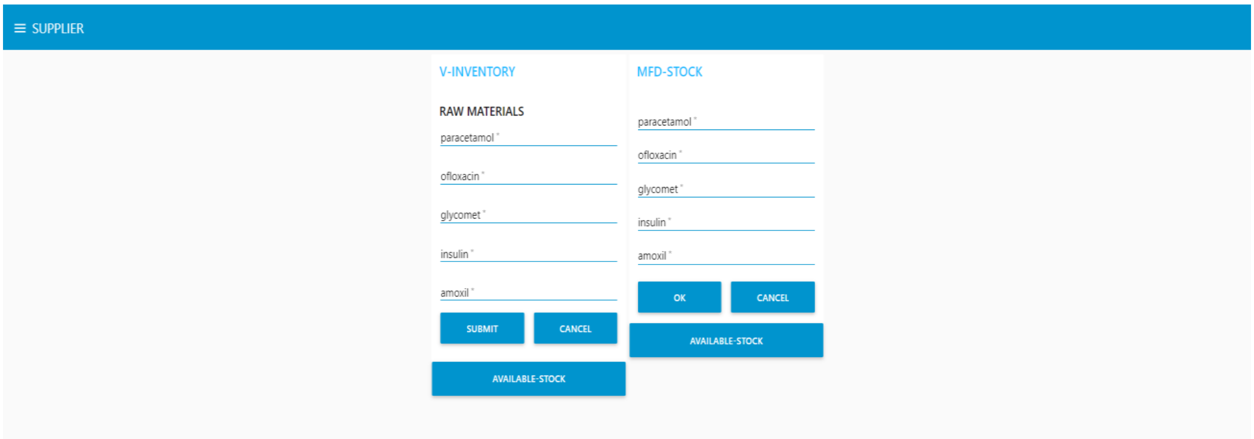

Figure 13 Supplier Interface

Suppliers form the very first link in the chain, providing raw materials for drug manufacturing. Figure 13 visualizes this connection, enabling suppliers to respond instantly to material demand from manufacturers. It closes the loop on upstream inventory planning. Unlike traditional procurement systems, this one is transaction-aware and blockchain-auditable, ensuring that only legitimate, verified orders trigger supply activity. This adds reliability at the molecular level of the healthcare supply system.

1.17. CLOUD INTERFACE

Finally, Figure 14 illustrates the Adafruit Cloud interface, where blockchain-backed transactions are mirrored for analytics and historical tracking. This is where the system scales beyond transactional

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workflows to become an AI-ready health intelligence platform. Using cloud infrastructure mitigates blockchain's storage limitations while enabling advanced analytics like trend detection, outbreak prediction, and drug utilization monitoring. It is where smart healthcare meets smart data.

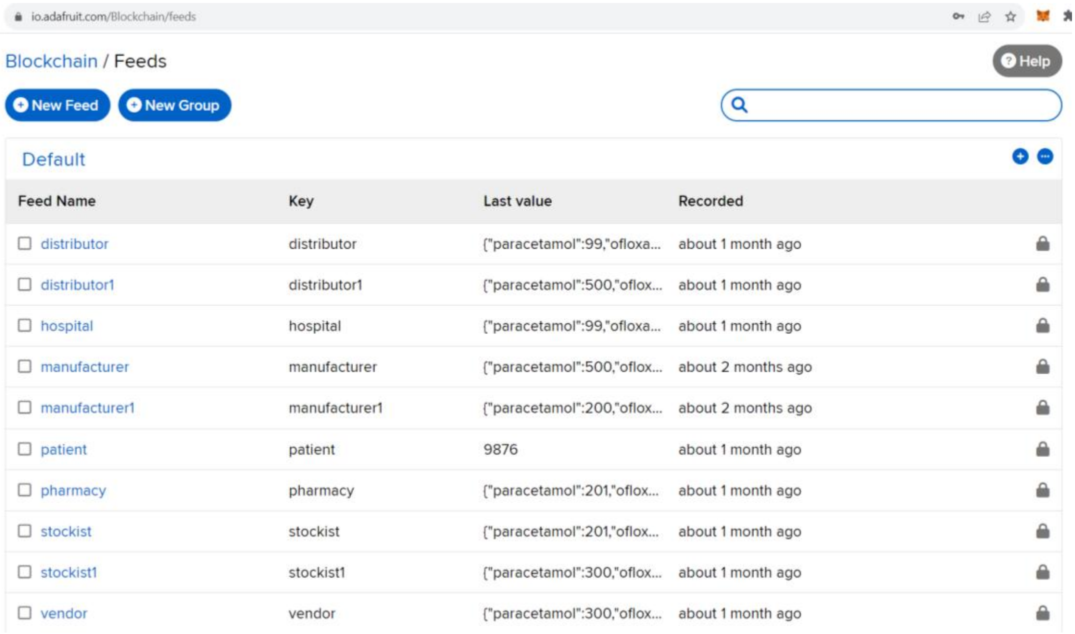

Figure 14. Cloud Interface

To bring our architecture to life, we present a sample Blockchain block representing a single transaction within the healthcare supply chain. This example illustrates how a patient's journey—from diagnosis to medication delivery—is digitally recorded, verified, and stored with security, transparency, and traceability at its core. Imagine a scenario where a patient arrives at a clinic exhibiting symptoms of fever, cough, and shortness of breath. The attending physician, after clinical evaluation, suspects a viral respiratory infection and prescribes Azithromycin and Paracetamol. Instead of writing a prescription on paper, the doctor enters this data into the system interface. Here's where the technology quietly takes over.

Once submitted, this interaction is captured as a digitally signed transaction, containing the anonymized patient ID, symptom profile, and precise medication details. This transaction is then passed through Node-RED, which performs intelligent checks—verifying medication availability, dose safety, and prescription rules. If approved, it is automatically pushed to the Blockchain ledger. This transaction, now time-stamped and validated, becomes a permanent part of a newly mined block. The block stores not only the prescription but also a detailed chain of interactions: the doctor's action, Node-RED's validation, the pharmacy's inventory response, and the final confirmation from the Blockchain network. Each step is cryptographically logged, leaving no room for ambiguity or tampering.

The patient then proceeds to a linked pharmacy. With a unique patient ID, the pharmacy retrieves the verified prescription, checks its own stock, and dispenses the medicine. The act of dispensing itself is recorded back to the system, closing the feedback loop. This seamless interaction not only prevents fraudulent prescriptions but also enables dynamic stock management, where pharmacies, distributors, and manufacturers receive real-time supply-demand cues. This sample block (Block #1021) becomes more than a technical artifact; it's a microcosm of digital trust in healthcare. It ensures that every actor—from physician to supplier—is synchronized in a shared, tamper-resistant, and ethically secure data environment. No more paper trails to lose, no more drug shortages to guess. Every decision is accountable. Every step is traceable. And every interaction—whether human or machine—is given equal significance in the ledger of care.

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Ultimately, this Blockchain-backed transaction framework humanizes technology, ensuring that healthcare is not only smarter but more dependable, inclusive, and patient-first.

2. FINDINGS & DISCUSSION

The combination of Blockchain technology, Node-RED, and cloud computing to identify unknown diseases represents a sophisticated and innovative approach to healthcare. Each component plays a distinct role in enhancing data integrity, processing efficiency, and overall system reliability. Let's delve into the key aspects of this integrated system:

- *Blockchain: Locking Down Patient Data:* Blockchain is like a digital safe deposit box for medical records, chaining each piece of data to the last with unbreakable encryption. This setup blocks unauthorized access, tampering, or data corruption, ensuring patient information stays secure and trustworthy. It's a vital tool for protecting sensitive health records [1], [14], [22]
- *Blockchain: Building Trust without a Boss:* By running on a network of computers instead of a single authority, blockchain is like a shared notebook everyone can see but no one can change alone. This openness fosters trust and ensures data accuracy, which is critical in healthcare where mistakes can't be afforded [5], [18], [32]
- *Blockchain: Giving Patients Control:* Blockchain hands patients the keys to their health data, letting them decide who gets access. It's like choosing who can read your diary, aligning with privacy laws and empowering people to share only what they're comfortable with [1], [23], [32]
- *Node-RED: Linking Health Gadgets:* Node-RED works like a digital bridge, connecting devices like fitness trackers, hospital sensors, and more. It's simple, visual interface lets developers easily pull together data from all these sources, creating a flexible hub for health information [30].
- *Node-RED: Sorting Data Smartly:* Node-RED acts like a data organizer, sifting through patient information to highlight what matters most for disease detection. It's like a chef prepping ingredients before cooking, ensuring only the right data moves forward for analysis [4], [30].
- *Node-RED: Creating Solutions Quickly:* With its drag-and-drop setup, Node-RED is like a set of quick-build Legos for developers. It speeds up creating and tweaking data systems, which is crucial in healthcare for adapting to new diseases or changing needs fast [30], [31]
- *Cloud: Storing and Sharing Data Anywhere:* The cloud acts like a global, secure vault for health data, letting doctors and researchers access it from anywhere. It's like a shared online folder that makes teamwork between hospitals and labs seamless and secure [25]
- *Cloud: Boosting Disease Detection with AI:* Cloud platforms power up AI and analytics tools that spot patterns in health data, like finding clues in a mystery novel. This helps doctors identify diseases and customize treatments, making care smarter and more personal [12]
- *Together: Catching Diseases Fast:* Combining Blockchain, Node-RED, and the cloud creates a system that processes health data in real time. Blockchain secures the data, Node-RED guides it smoothly, and the cloud analyzes it quickly, helping doctor's spot diseases as they emerge [4], [27].
- *Together: Teaming Up for Research:* This tech trio makes collaboration a breeze for healthcare pros and researchers. Blockchain's transparency builds trust for sharing data, while Node-RED and the cloud streamline teamwork across the globe, all while keeping patient privacy first [12], [14], [31].
- *Together: Staying Ready for New Diseases:* New health threats can arise suddenly, but this combo is built to adapt. Node-RED's flexibility lets developers add new tools or data sources fast, and the cloud's power handles the load, keeping systems ready for whatever comes next [4], [31].

However, it's important to consider challenges such as regulatory compliance, data standardization, and ethical considerations when implementing such a system. Additionally, the success of this integration relies on the collaboration of healthcare professionals, technology experts, and policymakers to ensure that it aligns with healthcare standards and practices.

CONCLUSION AND FUTURE WORK

This research unveils a transformative healthcare framework, harmonizing Blockchain, Node-RED, and cloud computing to forge a secure, scalable, and intelligent ecosystem. The private Blockchain, exemplified by a sample block (e.g., Block #1021, Section 23), cryptographically links transactions—like a doctor's prescription of Azithromycin validated by Node-RED in seconds—ensuring immutability and trust across hospitals, pharmacies, and suppliers. Node-RED's flow-based automation streamlines data integration, reducing latency in supply chain updates and enabling real-time analytics. Cloud storage, leveraging platforms like Adafruit Cloud, overcomes Blockchain's block size limitations, supporting the Enhanced Supervised Learning Chain Model (ESLCM) in detecting unprecedented diseases through pattern analysis of symptoms like fever and cough. This system not only fortifies supply chain resilience but also empowers clinicians with actionable insights, acting as a digital sentinel for patient care. Future work will focus on optimizing ESLCM's algorithmic efficiency, integrating offline transaction capabilities for resource-constrained regions, and enhancing interoperability with legacy EHR systems. By addressing regulatory compliance and energy efficiency, this framework aims to scale globally, ensuring equitable access to smarter, safer healthcare.

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