Enhanced Real-Time Monitoring and Visualization System for Efficient Data Analysis: A Case Study on Public Distribution System Data in Assam, India

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Keywords: RDBMS, Big Data, Real-Time, Visualization, Elasticsearch, Kibana, Flask, PostgreSQL.

Abstract: Modern software produces large amounts of log files or data. The exponential growth of data in modern software poses significant challenges for organizations in efficiently managing and extracting insights from this vast amount of information. This paper presents a user-friendly monitoring system that integrates Elasticsearch's search engine with Kibana's visualization tools, aimed at simplifying real-time data management. By streamlining processes for retrieval, monitoring, searching, analysis, and visualization, the system addresses the challenges associated with handling large volumes of data. Through testing with data from Assam's Public Distribution System (PDS), the research demonstrates the system's efficacy in creating an efficient solution for monitoring and analyzing PDS data. The strategic alignment of this system underscores its potential to significantly enhance the effectiveness of data management in critical domains such as public distribution. This study contributes to advancing the understanding and implementation of streamlined data management solutions in complex operational environments.

1 INTRODUCTION

Managing the rapid increase in log files from modern applications poses difficulties in real-time data access and search, with high usage leading to potential system failures. Handling substantial real-time data is challenging for Relational Database Management System (RDBMS). Addressing these issues requires complex infrastructures, relying on specialized monitoring systems like DevOps and big data management tools. However, continuous human monitoring of these systems proves to be a challenging task. In their study, Konig et al.(König and Steffens, 2018) explored how integrating machine learning techniques can significantly enhance monitoring systems. Despite the complexity involved in building such systems, they opted for Elasticsearch as the foundational big data technology for their proposed DevOps framework.

Elasticsearch (Shukla and Kumar, 2019) serves as an open-source distributed analytics engine, capable of handling a wide range of data types, including text, numerical, geospatial, unstructured, and structured data. Some examples of big data are transportation, government, media, entertainment, and advertising and marketing data. Ration Card Data[1] in Public Distribution System (PDS) is one of them.

In June 1997, India's government introduced the Targeted Public Distribution System (TPDS) with a primary emphasis on supporting the economically disadvantaged. Under the TPDS, countries are required to develop and implement a comprehensive evidence based system for grain delivery through the identification of the poor and transparent and accountable distribution system through the Fair Price Shop (FPS). The Targeted Public Distribution System (TPDS) operates collaboratively with both the central and state governments sharing responsibilities. The state is tasked with identifying families below the poverty line, issuing ration cards, overseeing and regulating the operation of the FPS, and managing interactions with the state government.

Since December 2015, Assam has implemented

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[1]The ration card data set. (2022) [Online]. Available: https://pds.assam.gov.in/ , 2022

Bhattacharjee, N., Gogoi, A. and Nath, S.
Enhanced Real-Time Monitoring and Visualization System for Efficient Data Analysis: A Case Study on Public Distribution System Data in Assam, India.
DOI: 10.5220/0013304500004646

In *Proceedings of the 1st International Conference on Cognitive & Cloud Computing (IC3Com 2024)*, pages 5-12
ISBN: 978-989-758-739-9

the National Food Security Act (NFSA'13), offering highly subsidized food grains to 2.52 crore individuals in accordance with Article 13 of the NFSA. Efficient monitoring and quick searching of ration card-related information have become essential, necessitating the adoption of new technology for real-time data retrieval. Elasticsearch, coupled with Kibana[2] as its monitoring and visualization tool, emerges as a suitable solution, enabling faster and optimized performance compared to traditional RDBMS systems.

The study aims to evaluate and analyze the real-time performance of Elasticsearch compared to an RDBMS system. The development of a web-based application facilitates the easy retrieval of PDS-related ration cards through Elasticsearch indexing. Additionally, a dynamic dashboard incorporating Key Performance Indicator (KPI)-based data visualization using Kibana has been created. The proposed system's objectives include systematically recording and maintaining ration cardholder details for Assam on a unified website. Furthermore, the system aims to expedite the generation of detailed reports for ration cardholders whenever required.

2 RELATED WORK

Big data analysis serves various objectives, including the classification of conversation topics to identify trending discussions. Given that the main aim of this research is to devise a text search and big data analysis system within the DevOps framework, it is crucial to establish a clear definition. Wahaballa et al.(Wahaballa et al., 2015) described this approach as a software development methodology designed to enhance communication, collaboration, and integration between development and operations teams, aiming to address critical challenges such as the fear of change and the risks associated with development.

Historically, the separation between teams dedicated to swift feature delivery and those responsible for ensuring system stability has led to discord and decreased productivity. DevOps emerged to address conflicts, offering swift and continuous assessment through the facilitation and integration of collaboration among development, operations, and teams responsible for quality assurance. But building, logging, and monitoring tools are essential to automating the DevOps process. Akshaya et al.(Akshaya et al., 2015) introduces several monitoring tools commonly employed in DevOps practices. Some of them are briefly described as follows.

- Splunk serves as a tool for analyzing and storing big data, providing support for numerous related applications and plugins.
- Loggly offers logging and log data management through its cloud-based software-as-a-service (SaaS) solutions. Unlike other similar tools focused on identifying system issues, Loggly emphasizes pinpointing the source of the problem.
- Graphite proves to be a scalable solution for storing data, generating graphs from time-lapse data, and real-time monitoring of performance parameters.
- Sumo Logic stands out as a cloud-based SaaS security platform designed to process logs and derive real-time insights, proving valuable for promptly analyzing and addressing challenges within the infrastructure.
- Cacti is designed as an application capable of storing system data and presenting real-time graphics derived from it.
- Logstash, a component of the Elastic Stack, excels in processing extensive volumes of log files and extracting valuable insights from them.
- Kibana, an integral component within the Elastic ecosystem, provides interactive visualization of data on dashboards that users can customize according to their needs.

Bangnasco et al.(Bagnasco et al., 2015) in their work, describes ELK stack, comprised of Elasticsearch, Logstash, and Kibana, as a monitoring system utilized for Infrastructure as a Service (IaaS) and scientific applications in the cloud, leveraging the Elasticsearch ecosystem. The monitoring system is used to display data from a cloud-based system and store it in a SQL database, then feed it to an Elasticsearch node via the Logstash plugin. Each application possesses its unique Kibana dashboard for monitoring and visualization. Nevertheless, the success of the elastic stack-based solution prompted the team to contemplate the elimination of the SQL middleware layer from the system. Zamfir et al.(Zamfir et al., 2019) in their paper described the development of an Elasticsearch monitoring system that uses machine learning techniques to effectively identify and stop errors at scale. Takase et al. (Takase et al., 2017) in their work, present a solution based on the strategy used by the CERN cloud group. This solution comprises developing an Elasticsearch plugin to control data access based on user identity, allowing individual users to see personalized Kibana dashboards for monitoring

[2]Getting Started with the elastic stack technology (2022) [Online]. Available : https://www.elastic.co/guide/en/elastic-stack/7.17/installing-elastic-stack.html

cloud usage. Hamilton et al.(Hamilton et al., 2018) in their paper, elaborate on a SCADA (Supervisory Control and Data Acquisition) statistics monitoring system developed at CERN, employing the Elastic Stack. Shah et al.(Shah et al., 2022) in their paper, present a solution based on Elasticsearch, which includes a customized search engine, distributed structure, pre-defined indexing, and a standardized framework designed for broad text mining. Modern industrial gear generates large amounts of log data, but manually examining it takes a long time. Nezhmetdinov et al.(Nezhmetdinov et al., 2023) provide an information system that uses the ELK software stack to automate log file analysis for industrial equipment. Calderon et al. (Calderon et al., 2023) in their study, demonstrate the implementation and performance assessment of an Internet of Things (IoT) platform that integrates Apache Kafka with Elastic Stack tools (Elasticsearch, Kibana, and Beats). The Elasticsearch cluster for data storage and search, the Edge Nodes for communication with IoT devices and networks, the Data Streaming module with Apache Kafka, the Cloud Server for device interaction and data storage in Elasticsearch, and the Visualization module with Kibana comprise the architecture of the IoT platform. Karmalkar et al.(Karmalkar et al., 2021) in their work developed a web application that serves as a data analytics based search engine for Twitter data based on Elastic search. Tscharf et al.(Walter-Tscharf, 2022) in their work describe a system design for indexing, clustering, and searching scientific text using Elasticsearch and Kibana. Bhosale et al.(Bhopale and Tiwari, 2024) in their paper mentioned the Elasticsearch engine as an efficient document matching and retrieval mechanism for their transformation-based information retrieval system. Famous companies like Facebook, Uber, Udemy and Netflix have used Elastic Stack as a monitoring tool. CERN also uses Elastic Stack as a control solution for more than 210 control applications.

This study explores challenges associated with handling and analyzing vast real-time data, highlighting the expertise required in specific database and visualization tools. We introduce a simple monitoring system that integrates Elasticsearch and Kibana features. Our method demonstrates superior text search performance compared to current approaches. The remaining sections of this document are organised as follows: Section 3 provides a brief review of Elasticsearch and Kibana concepts. In Section 4, we introduce our new proposed architecture methodology for real time text searching and monitoring, along with a brief explanation of the experimental setup . Finally, Section 5 discusses the conclusions drawn from our findings.

3 STATE OF THE ART

This section highlights the present status of Elastic Stack technology utilized in this study.

3.1 ELASTICSEARCH

Elasticsearch, an openly accessible distributed and open-source search tool, furnishes an analytical engine that facilitates text, numeric, geospatial, structured, and unstructured search capabilities. Elasticsearch, formerly known as Elastic Research N.V. and now referred to as Elastic, is constructed on the foundation of Apache Lucene. Its popularity stems from the simplicity of its REST APIs, distributed nature, speed, and scalability. Elastic search(Kathare et al., 2020) is the central component of the Elastic Stack. Other notable examples of websites and applications leveraging Elasticsearch include Wikipedia, which utilizes it for text search and recommendations, Stack Overflow for location-based queries and similar searches, and GitHub for code searches, showcasing the versatility of Elasticsearch across different domains.

The system architecture is built on the following concepts:

- **Documents** - In a basic Elasticsearch repository, a document comprises fields of a specified type, each having a unique identifier, and it needs to be included in an index.
- **Index** - Documents' logical storage location. It uses the inverse index model. It is distributed across numerous points and subdivided into one or more spheres.
- **Node** - a single Elasticsearch instance that is active.
- **Cluster** - cooperative grouping of interconnected nodes.
- **Shards** - Splitting one index into multiple subshards allows for parallelization, which boosts efficiency. It is possible to store the shards on various servers.
- **Replicas** - replicas of the broken pieces. Replicas are used to boost throughput, obtain data redundancy, and achieve high availability.

3.2 KIBANA

The Elastic search community created Kibana, a visualization tool, in 2013. With its intuitive and user-

friendly interface, it offers real-time capabilities for analysis, summarization, charting, and debugging. Sharing of log snapshots is also permitted. With Kibana (Srivastava, 2019), we can manage several dashboards with an easy-to-use browser-based interface and save the dashboard.

4 PROPOSED ARCHITECTURE

This section outlines the methodology and dataset employed in the experimental setup.

4.1 METHODOLOGY

The system design architecture employed in this research is depicted in Fig. 1. There are two servers server1 and server2. The specifications of both servers are exactly the same. Server 1 installs Elasticsearch with a PostgreSQL input, while Server 2 uses the PostgreSQL input directly. The client can access the servers through the localhost network connection.

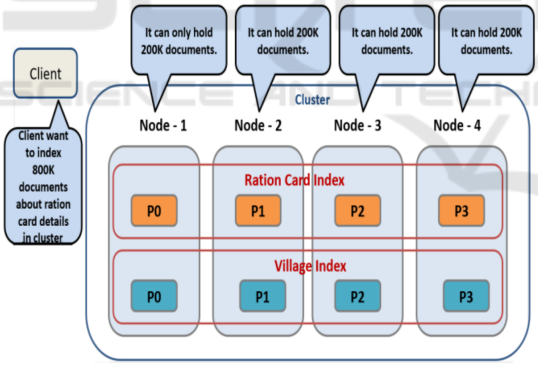
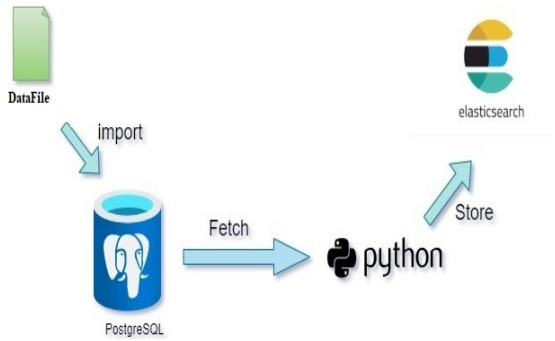


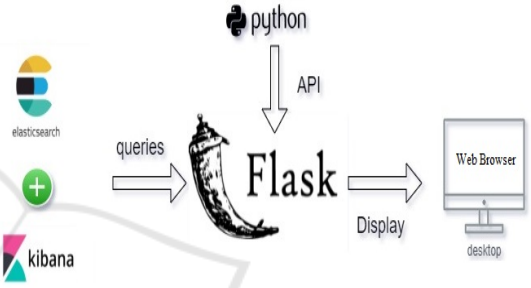
Figure 1: System Design Architecture

A server is configured as a node. There is “Elastic Node-1” for server 1 and “PostgreSQL database” for server 2. Elastic Node is configured in a cluster named “elasticsearch”. Each node will have indices inside them for storing data. The software system architecture is shown in Fig. 2(a).

The collected data is ration card data that is taken from the PDS Assam website and is stored into PostgreSQL database. This data is stored into Elasticsearch index using python code and Kibana is used to visualize Elasticsearch data using graphs, tables or charts and analyze this data easily from a browser. The system data flow design is illustrated in Fig. 2(b).



(a) System Design Architecture



(b) Software Data Flow Design.

Figure 2: Software Architecture and Design.

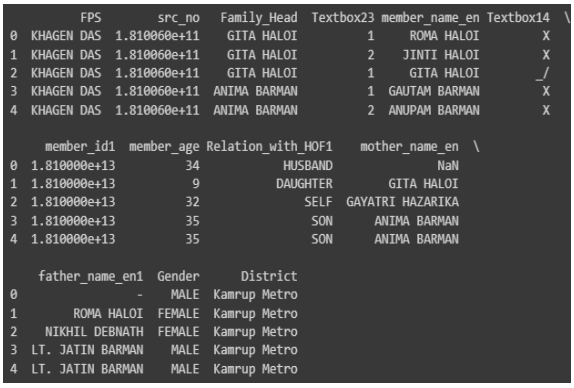
4.2 DATASET

A dataset comprising 58,437 ration card holders has been chosen for import into Elasticsearch from PostgreSQL using Python code. The dataset includes various fields such as FPS (Fair Price Shop), ration card number, holder name, member serial number, member name, member detector, age, relationship, mother’s name, father’s name, gender, and district. This dataset is the result of aggregating individual FPS dealer details from different districts.

To validate the accuracy of the data import, multiple search queries were executed on the Elasticsearch node using a comprehensive Query Domain Specific Language (DSL). All these queries returned accurate and expected responses. Fig. 3 is an illustration showcasing a sample of the dataset.

4.3 EXPERIMENTAL SETUP

To become acquainted with the Elastic Stack technology and examine its potential, a simple experimental



	FPS	src_no	Family_Head	Textbox23	member_name_en	Textbox14
0	KHAGEN DAS	1.810060e+11	GITA HALOI	1	ROMA HALOI	X
1	KHAGEN DAS	1.810060e+11	GITA HALOI	2	JINTI HALOI	X
2	KHAGEN DAS	1.810060e+11	GITA HALOI	1	GITA HALOI	_/
3	KHAGEN DAS	1.810060e+11	ANIMA BARMAN	1	GAUTAM BARMAN	X
4	KHAGEN DAS	1.810060e+11	ANIMA BARMAN	2	ANUPAM BARMAN	X

	member_id1	member_age	Relation_with_HOF1	mother_name_en
0	1.810000e+13	34	HUSBAND	NaN
1	1.810000e+13	9	DAUGHTER	GITA HALOI
2	1.810000e+13	32	SELF	GAYATRI HAZARIKA
3	1.810000e+13	35	SON	ANIMA BARMAN
4	1.810000e+13	35	SON	ANIMA BARMAN

	father_name_en1	Gender	District
0	-	MALE	Kamrup Metro
1	ROMA HALOI	FEMALE	Kamrup Metro
2	NIKHIL DEBNATH	FEMALE	Kamrup Metro
3	LT. JATIN BARMAN	MALE	Kamrup Metro
4	LT. JATIN BARMAN	MALE	Kamrup Metro

Figure 3: Raw Data.


```
{
  "name" : "DESKTOP-0TLBB6H",
  "cluster_name" : "elasticsearch",
  "cluster_uuid" : "AirhCfgySz-3ZViSz7jKXg",
  "version" : {
    "number" : "7.17.1",
    "build_flavor" : "default",
    "build_type" : "zip",
    "build_hash" : "e5acb99f822233d62d6444ce45a4543dc1c8059a",
    "build_date" : "2022-02-23T22:20:54.153567231Z",
    "build_snapshot" : false,
    "lucene_version" : "8.11.1",
    "minimum_wire_compatibility_version" : "6.8.0",
    "minimum_index_compatibility_version" : "6.0.0-beta1"
  },
  "tagline" : "You Know, for Search"
}
```


Figure 4: Elasticsearch Cluster.

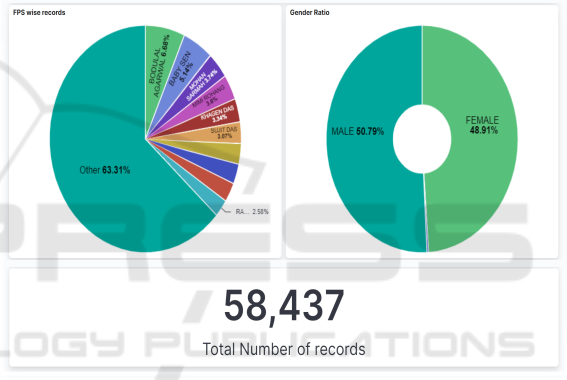
Elasticsearch with Kibana infrastructure was built up.

To begin, Elasticsearch version 7.17.1 was installed on a local PC with the following specifications: 2 cores CPU, 4 threads, 4 GB RAM, 500 GB hard disk, 256 GB SSD, and Microsoft Windows 10 Professional. Installation instructions from the official manual [3] resulted in a simple and rapid setup. Subsequently, the Elasticsearch node was initiated in the background using its default settings automatically. A sample request was submitted to elastic search to assess the node's health, and the results showed proper execution. In a similar manner, the Elastic node operating in the system was located and setup using Kibana version 7.17.1.

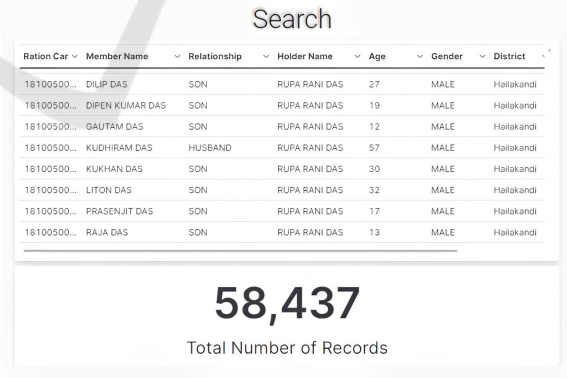
5 RESULTS AND DISCUSSION

Once Kibana is launched, the Kibana server identifies the Elasticsearch node and establishes a connection to it. Utilizing the web interface, it presents a summary of the system's infrastructure, as illustrated in Fig. 4.

For visualization purposes, pie charts, graphs, and tables were generated using Kibana, utilizing the stored data to explore the range of functionalities provided by the Kibana tool. For instance, Fig. 5(a) displays two charts and total number of records available in elastic search. First chart represent all the FPS dealers with number of ration card holder enrolled under them with the percentage of occurrences and second chart displays the gender ratio between male, female and trans-gender. Fig. 5(b) shows a searchable datatable representing all the fields present in the given data in an efficient organized manner. Kibana datatable supports three types of searching mechanism as: Lucene Search (Full Text Normal Searching), KQL (Kibana Query Language) Search and Filter Search. It has been noted that Kibana provides a wide range of visualization options, with graphs refreshing rapidly upon any parameter change.



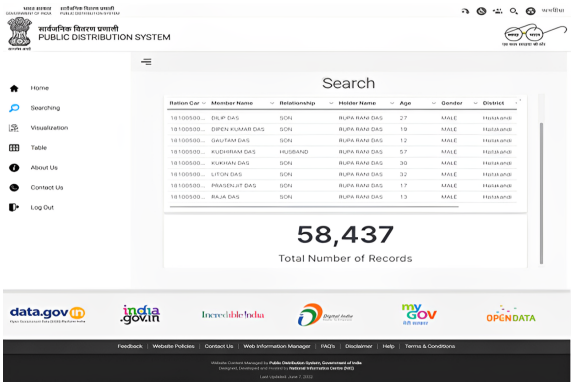
(a) Kibana Charts.



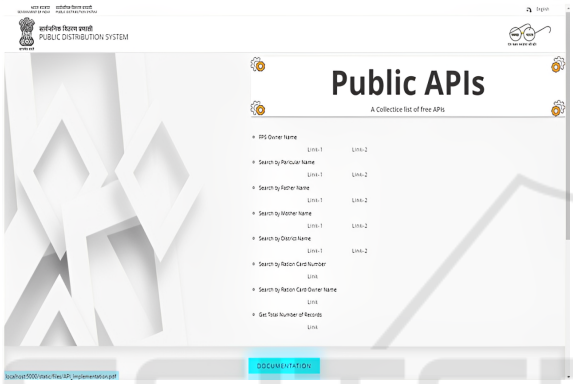
(b) Kibana Searchable data table.
Figure 5: Data display using Kibana.

Using Flask, and Kibana's short URLs we have created a monitoring dashboard or a website as shown in Fig. 6(a) for easy monitoring and quick searching of big data (PDS Data). The dashboard has been designed with a special page for API handler that supports more than 15 various APIs as shown it Fig. 6(b)

[3]Getting Started with Elastic Stack Technology (2022) [Online]. Following the instructions at https://www.elastic.co/guide/en/elastic-stack/7.17/installing-elastic-stack.html



(a) Dashboard for PDS Data.



(b) Public APIs handler page.

Figure 6: Website Overview.

and Table 1. It can be utilized for additional research endeavors and integrated with any system, as depicted in Fig. 6(b). It can also be used for easy retrieval of ration card-related information in real-time.

The developed web application software fulfills the following specific requirements:

i) The system displays the basic details of each Card Holder details including name, Card Number, Family Member Name, Age, District, and FPS dealer name.

ii) The system allows faster access, and searching of PDS data in real-time, allowing downloading of results in CSV file format as shown in Fig. 7.

iii) The system allows the generation of dynamic Dashboards containing KPI-based data visualization using Kibana in real-time and allows downloading of results in CSV file format.

iv) The system allows district-wise monitoring of the PDS records via interactive charts and graphs.

Based on the data presented in Table 2, it is evident that the proposed method outperforms PostgreSQL in terms of data rendering time across different numbers of records. For instance, when handling 58,437 records, the proposed method demonstrates a rendering time of 2-4 minutes compared to PostgreSQL's 5-7 minutes. Moreover, for larger datasets containing 269,548 records, the proposed method shows significant improvement with a rendering time of 5-7 minutes compared to PostgreSQL's greater than 10 minutes. These results highlight the effectiveness of the proposed approach in achieving faster data rendering, making it a promising solution for real-time data analysis and management tasks. In conclusion, we've incorporated an ELK panel into the system to assist in dataset analysis. This feature allows for the creation of aggregations and basic visualizations for each data field. This addition enhances the system's ability to thoroughly explore and interpret data, contributing to better insights and decision-making.

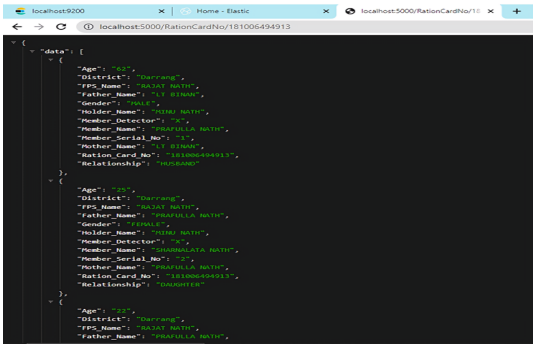


Figure 7: Result of a single API request.

6 CONCLUSION

The research culminated in developing a robust PDS data analysis monitoring system for the National Informatics Centre, Government of Assam. Utilizing Elasticsearch and Kibana, integrated with Flask and PostgreSQL, the objective was to establish a DevOps monitoring framework capable of handling extensive volumes of big data and real-time events. The initial phase involved immersing into the technological landscape to explore possibilities and establish Elasticsearch as the cornerstone technology, chosen for its scalability, speed, and simplicity tailored to the provided dataset. This strategic choice aligned with the overarching goal of creating an effective solution for PDS data analysis and monitoring system. Future work could focus on exploring opportunities to integrate emerging technologies such as blockchain for enhanced data security and transparency could further bolster the robustness of the monitoring system.

Table 1: API Endpoints and Descriptions

API Endpoints	Description
http://localhost:5000/#home	Used to display the dashboard of the proposed system.
http://localhost:5000/API	Used to display the entire available API to the proposed system.
http://localhost:5000/fpsName/<fpsName>	Used to fetch 10 records of the ration cards holders that come under the particular FPS dealer.
http://localhost:5000/fpsName/<fpsName>/<records>	Used to fetch required amount of the ration cards holder records that come under the particular FPS dealer.
http://localhost:5000/memberName/<memberName>	Used to fetch 10 records of the ration cards holders that come under the given member name.
http://localhost:5000/memberName/<memberName>/<records>	Used to fetch required amount of the ration cards holder records that come under the given member name.
http://localhost:5000/fatherName/<fatherName>	Used to fetch 10 records of the ration cards holders that come under the given father name.
http://localhost:5000/fatherName/<fatherName>/<records>	Used to fetch required amount of the ration cards holder records that come under the given father name.
http://localhost:5000/motherName/<motherName>	Used to fetch 10 records of the ration cards holders that come under the given mother name.
http://localhost:5000/motherName/<motherName>/<records>	Used to fetch required amount of the ration cards holder records that come under the given mother name.
http://localhost:5000/districtName/<districtName>	Used to fetch 10 records of the ration cards holders that come under the given district.
http://localhost:5000/districtName/<districtName>/<records>	Used to fetch required amount of the ration cards holder records that come under the given district.
http://localhost:5000/RationCardNo/<rationCardNumber>	Used to fetch at max 20 records of the ration cards holders that come under the given ration card number.
http://localhost:5000/familyHead/<rationCardOwnerName>	Used to fetch at max 20 records of the ration cards holders that come under the given ration card owner name.

Table 2: Time required for data rendering (in min)

Number of Records	PostgreSQL	Proposed Method
58437	5-7 min	2-4 min
269548	>10 min	5-7 min

ACKNOWLEDGMENT

This research is done for National Informatics Centre, Assam State Unit. The authors are grateful to Pranab Chakravarty, Scientist E (Technical Director) of NIC, Department of Computer Science and Information Technology Cotton University, and Department of Computer Science and Engineering, Tezpur University for giving us the opportunity to carry out this work.

REFERENCES

Akshaya, H., Vidya, J., and Veena, K. (2015). A basic introduction to devops tools. *International Journal of Computer Science & Information Technologies*, 6(3):05–06.

Bagnasco, S., Berzano, D., Guarise, A., Lusso, S., Masera, M., and Vallero, S. (2015). Monitoring of iaas and scientific applications on the cloud using the elasticsearch ecosystem. In *Journal of physics: Conference series*, volume 608, page 012016. IOP Publishing.

Bhopale, A. P. and Tiwari, A. (2024). Transformer based contextual text representation framework for intelligent information retrieval. *Expert Systems with Applications*, 238:121629.

Calderon, G., del Campo, G., Saavedra, E., and Santamaría, A. (2023). Monitoring framework for the performance evaluation of an iot platform with elasticsearch and apache kafka. *Information Systems Frontiers*, pages 1–17.

Hamilton, J., Gonzalez Berges, M., Tournier, J.-C., and Schofield, B. (2018). Jacow: Scada statistics monitoring using the elastic stack (elasticsearch, logstash, kibana).

Karmalkar, V. et al. (2021). Twego trending: Data analytics based search engine using elasticsearch. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, 12(1S):246–251.

Kathare, N., Reddy, O. V., and Prabhu, V. (2020). A comprehensive study of elasticsearch. *International Journal of Science and Research (IJSR)*.

König, L. and Steffens, A. (2018). Towards a quality model for devops. *Continuous Software Engineering & Full-scale Software Engineering*, 37:37–42.

Nezhmetdinov, R., Kotyrova, S., Nezhmetdinova, R., and Kovalev, I. (2023). Automating log analysis for industrial equipment maintenance using elastic stack. In *E3S Web of Conferences*, volume 389, page 01064. EDP Sciences.

Shah, N., Willick, D., and Mago, V. (2022). A framework for social media data analytics using elasticsearch and kibana. *Wireless networks*, pages 1–9.

Shukla, P. and Kumar, S. (2019). *Learning Elastic Stack 7.0: Distributed Search, Analytics, and Visualization Using Elasticsearch, Logstash, Beats, and Kibana*. Packt Publishing Ltd.

Srivastava, A. (2019). *Kibana 7 quick start guide: visualize your elasticsearch data with ease*. Packt Publishing Ltd.

Takase, W., Nakamura, T., Watase, Y., and Sasaki, T. (2017). A solution for secure use of kibana and elasticsearch in multi-user environment. *arXiv preprint arXiv:1706.10040*.

Wahaballa, A., Wahballa, O., Abdellatief, M., Xiong, H., and Qin, Z. (2015). Toward unified devops model. In *2015 6th IEEE international conference on software engineering and service science (ICSESS)*, pages 211–214. IEEE.

Walter-Tscharf, F. F. W. V. (2022). Indexing, clustering, and search engine for documents utilizing elasticsearch and kibana. In *Mobile Computing and Sustainable Informatics: Proceedings of ICMCSI 2022*, pages 897–910. Springer.

Zamfir, V.-A., Carabas, M., Carabas, C., and Tapus, N. (2019). Systems monitoring and big data analysis using the elasticsearch system. In *2019 22nd International Conference on Control Systems and Computer Science (CSCS)*, pages 188–193. IEEE.