REDUCING LATENCY IN SMART MANUFACTURING SERVICE SYSTEM USING EDGE COMPUTING

[1*]S.Vimal, [2]Jesuva Arockiadoss S, [3]Bharathiraja S, [4]Guru S and [5]V.Jackins

Abstract

In a smart manufacturing environment, more and more devices are connected to the Internet so that a large volume of data can be obtained during all phases of the product life cycle. The large-scale industries, companies and organizations that have more operational units scattered among the various geographical locations face a huge resource consumption because of their unorganized structure of sharing resources among themselves that directly affects the supply chain of the corresponding concerns. Cloud-based smart manufacturing paradigm facilitates a new variety of applications and services to analyze a large volume of data and enable large-scale manufacturing collaboration. The manufacturing units include machinery that may be situated in different geological areas and process instances that are executed from different machinery data should be constantly managed by the super admin to coordinate the manufacturing process in the large-scale industries these environments make the manufacturing process a tedious work to maintain the efficiency of the production unit. The data from all these instances should be monitored to maintain the integrity of the manufacturing service system, all these data are computed in the cloud environment which leads to the latency in the performance of the smart manufacturing service system. Instead, validating data from the external device, we propose to validate the data at the front-end of each device. The validation process can be automated by script validation and then the processed data will be sent to the cloud processing and storing unit. Along with the end-device data validation we will implement the APM(Asset Performance Management) to enhance the productive functionality of the manufacturers. The manufacturing service system will be chunked into modules based on the functionalities of the machines and process instances corresponding to the time schedules of the respective machines. On breaking the whole system into chunks of modules and further divisions as required we can reduce the data loss or data mismatch due to the processing of data from the instances that may be down for maintenance or malfunction ties of the machinery. This will help the admin to trace the individual domains of the smart manufacturing service system that needs attention for error recovery among the various process instances from different machines that operate on the various conditions. This helps in reducing the latency, which in turn increases the efficiency of the whole system

Keywords*: SmartManufacturing, CloudComputing, Edge Computing, Resource management, APM, product life cycle*

[1*Corresponding Author] *Associate Professor, Department of Computer Science and Engineering, Ramco Institute of Technology, Rajapalayam (svimalphd@gmail.com)*

[2] *Graduate Student, Department of Information Technology National Engineering College, Kovilpatti, Tuticorin,India (1715017@nec.edu.in)*

[3] *Graduate Student ,Department of Information Technology National Engineering College, Kovilpatti, Tuticorin,India (1715008@nec.edu.in)*

[4] *Graduate Student ,Department of Information Technology National Engineering College, Kovilpatti, Tuticorin,India (1715012@nec.edu.in)*

[5]*Assiatant Professor(Senior Grade), Department of Information Technology National Engineering College, Kovilpatti, Tuticorin,India (Jackins.silves@gmail.com)*

Received: Feb. 26, 2021, Revised: Mar. 16, 2021, Accepted: Mar. 25, 2021

I. INTRODUCTION

1.1. Introduction to Smart Manufacturing

In the modern production technology, most of the industries are rushing to get their product out of the production unit as soon as possible to maintain the market value of the product that may be either the global market or regional market. So, the production units in the industries are automated to maintain the flow of the production units, in this scenario there are numerous sensors to detect the state of the product at that instance and report the status of the product to the centralized system to actively maintain the constant flow of the production unit. The concept of smart manufacturing includes the manipulation of huge data that are processed along with the various sensors, accumulators and process machines. So, it may become a tedious task to maintain all the data and abiding the data manipulation rules such as Data Integrity. It utilizes all the components, addressing the complexities of security, interoperability and intellectual property for manufacturing. It is helpful to integrate the data and information from various sources such as the applications that include the product warehouse management system that have the data of different products which can be composed to form a new solution using the smart manufacturing service system. Not only that, but it is applicable to the industries or companies that have either a single production line or across a network of suppliers and customers. The linking and integrating across all of these can be carried out in synchronized time. These enhancements make it efficient to manage the manufacturing operations with more precision and better collaboration among the production line, suppliers and business partners. SM will create an environment where fact based decisions can be made and decision makers will have trusted data whenever it is needed in a most useful form.

1.2. Resource Management Computing

In the smart manufacturing service system, the coordination of the production line can be achieved using the data communication between the client and server but the other whole concept that is essential to make the smart manufacturing environment as an efficient and elegant one is the resource management computing. The resources in the manufacturing includes the human, material, equipment, environment, supply chain, and other assets used in the production. These data are deeply integrated through data, models, algorithms. The various data from all aspects of the manufacturing environment can be collected with the help of IoT and the internet technologies. These data can be continuously converged to the cloud from the terminals. The cloud computing and the big data processing helps in processing the original data with the analysis and other operations to exploit the value of data. By using the statistical data from the cloud, the manufacturing companies can understand the requirements of the customers and the trend of the supply chain in a better way. The information obtained from the smart manufacturing service system will further help the manufacturers to understand the status of production capacity. SMs that have these functional qualities can be more extensive to connect all things, more intelligent to capture and analyze data, and more efficient to provide production services.

1.3. Data Sources in Manufacturing

The manufacturing system consists of a huge data from various resources some resources are,

1. The data collected from the equipment in the smart factories by the industrial IoT technologies corresponds to the real-time performance of the factory and operating conditions.
2. The data collected from the services' system that includes the material and product data which will give information about the performance and the inventory of the smart factories
3. Environmental data that includes the temperature, humidity, air quality etc.

The data that are analyzed by the production environment to know market value of the product is known as Internet data, this data includes,

1. User data collected from the e-commerce platforms (e.g., Amazon, Walmart, and Taobao) and social networking platforms (e.g., Twitter, Facebook, LinkedIn, and YouTube)
2. Public data from open websites (e.g., governments and public service websites), and so on.

1.4. Big Data Process

In the manufacturing environment, the real time data is enabled for the manufacturing process monitoring, so that the manufacturer could keep on analyzing the smart manufacturing service system performance to develop the optimal operational control strategies. Besides the product quality control and improvement are embedded into each and every step of the manufacturing process, that is from the raw material to the finished product. The early warning of quality defects and rapid diagnostics of root causes of malfunctions can also be alarmed to the production line which would be accomplished in real time to guarantee the high quality.

II. LITERATURE REVIEW

F. Tao and Q. QI, have proposed that The researches on the manufacturing big data capturing and integration architecture, the big data analytics algorithms and platforms, and the predictive analytics models for manufacturing should be continually concerned[1]. So the process of monitoring the data flow in the manufacturing system may lead to the latency in the system performance which may eventually affect the production unit and decrease the production rate of the industry or company. M. S. de Brito, S. Hoque, R. Steinke etc, have proposed that the current solutions and methods do not tend to realize smart interconnection between the cloud server and the client system[2]. Due to the lack of implementation methods for smart interconnection, the implementation cycle of smart interconnection is beyond the acceptable time of users that's, the latency of the system. Q. Qi and F. Tao[3], have proposed that the system efficiency will not be boosted to compensate with the big data that the smart manufacturing system needs to manipulate. The similarities and differences between big data and Digital twin in manufacturing are compared from different aspects, including the general and data perspectives. The complementarity of digital twin and big data is discussed. Abulazizalarift Kalka Dubey, Mohammed Moon, Torki Altameem, etc have proposed that [4], there should be a hybrid framework for computing the big data in the smart manufacturing system, which considers the time-based power consumption model, after the research work on the green cloud computing framework it is concluded that the 5 framework will be applicable to only the small scale industry that need not be administered using the big data. Muhammadhameed Siddiqi Madallahalruwaili, Amjadali, etc, have proposed that in the smart manufacturing system the data associated with the machines and the process can only be processed whereas the data related to the transportation and the supply chain cannot be processed since the data may vary by time and market values[5]. This becomes the major disadvantage when the production data should be analyzed against the market data to control the production rate for the better profit and product capacity. Hou, Shoulu,Wang, T., Ke, H., have proposed a new distributed optimal online approach to the smart manufacturing system based cloud platforms[6]. The approaches are able to instantly dispatch raw data and aggregate results, adapting to the instantaneous availability and capability of data. But this will affect the performance of the server and thus leads to the latency. Zheng, X., Wang, KSangaiah, have proposed that designing new data cleaning techniques becomes essential to eliminate meaningless or abnormal data and enables related networks to operate as long as possible[7]. Zhao, Dongfang, MohamedMohamed, etc, have proposed the emerging containerized cloud services for the better scalability of the system[8], the Docker and docker images concept are used to extend the operability of smart manufacturing system to process the big data sets and produce the result without latency but the containerized cloud servers needs huge configuration that are complex to interconnect with the cloud servers and the client application. Liang, Junbin, Min Zhang, and Victor CM Leung, have proposed that the trust computing system [9] can be used for the scalability issue of the system, but this computing process will be used only with the dedicated servers that have the centralized data which is irrelevant to the cloud database cluster that 6 we have enhanced to store and manipulate the data in the smart manufacturing system. Qi, Qinglin, and Fei Tao, have proposed that the smart manufacturing system has various levels through which the data should be processed. The computing, storage, and networking capabilities in the near-end nodes [10], edge computing and fog computing reduce the data sent to the cloud, and the probabilities of service downtime, ensuring the robustness of smart manufacturing systems. Edge computing, fog computing and cloud computing cooperate with each other, better meeting the requirements of smart manufacturing applications, but these layers should be processed at each stage of the production which will increase the data processing time and may lead to decreased production rate

III. PROPOSED MODAL

3.1. Data Modeling

The manufacturing unit will have numerous machines that have various processes and the process instances. It will be a tedious task to track down the machines or processes that need the attention of the production admin to check for the quality assurance. In our proposed model, we have designed the architectural data model to ensure the easy track down of the machines or processes or even the process instances in such a way that the whole manufacturing system will be divided into three major categories such as the Commencing, Intermediate and Finishing stages. Each stage can be fed with the corresponding machine data and process data. So it will be easy for the production admin to trace the data flow of each stage in the production.

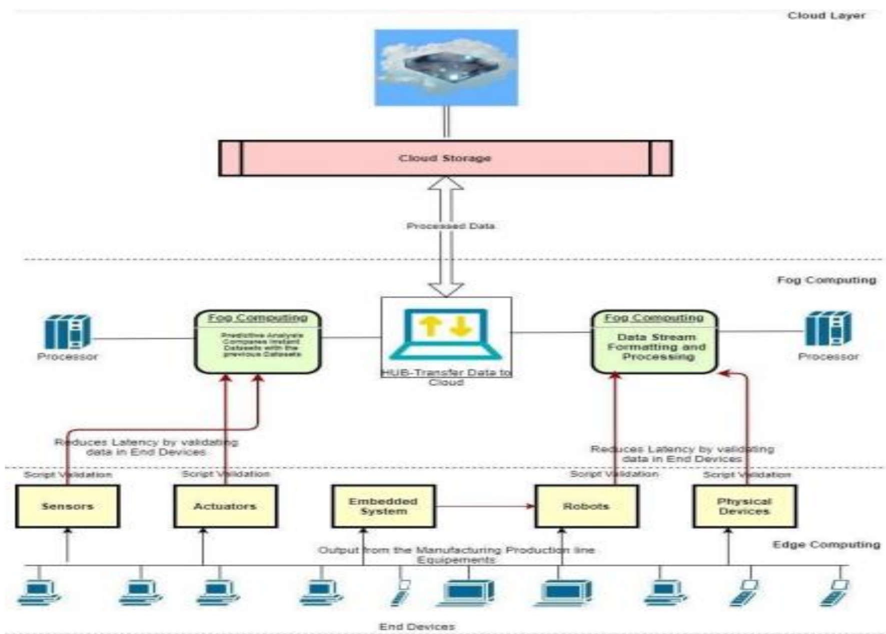

Figure 1. Proposed Modal

3.2. Data Preprocessing

Instead of validating data from the external device, we propose to validate the data at the front-end of each device. The validation process can be automated by script validation and then the processed data will be sent to the cloud processing and storing unit. Along with the validation at the edge devices we have planned to develop a Predictive Analytics Algorithm to check the data stream with the possibilities of the error occurrence by comparing the data generated at the instant with the data that is in the correct format. This method will prevent the fog computing layer from wasting its computing time with the wrong data sets, which in turn reduces the time delay by sending the wrong data to the cloud for processing and returning the error message to the fog layer and then to the edge device. This helps in reducing the latency, further needs to be researched for the effect of the idea on the various parameters.

3.3. Cloud Data Management.

All the data generated from various machines will not be uploaded to the cloud, since it will lead to latency in the whole system. The preprocessed data from the edge layers only are allowed to transfer to the cloud database. We have acquired the cloud database cluster in the Amazon Web Services having Mumbai as the main cluster availability zone. The database will have two replicated datasets for the backup and recovery process if the main instance goes down due to maintenance or technical errors or due to disasters. The preprocessed data for every machine and process will be stored in the different collections to maintain the Data Integrity.

IV. IMPLEMENTATION

4.1. Technology

The technology we used to create the smart manufacturing service system is node JS along with the cloud computing environment on the Heroku and AWS. We have used the MongoDB clusters for the data storage purpose. The web application will be initiated with the load balancer depending upon the test results from the developed system.

4.2. Framework

The framework that we have used to build the application if Express framework which is efficient for the production environment as well as for the development environment

4.3. Project Skeleton

The basic functionalities that we have implemented are Dashboard for overall performance Monitoring Machines, Process and Process Instances Modules Adding data to the Machines, process and Process Instances for new Machinery Categories and schedule modules for differentiating the machines and its processes based on their time of production or ideal, Data controlling and Manipulation Module

4.4. Project Flow

Initially we have created the project skeleton by dividing the overall project into individual working modules so that the development process will be progressive. The app.js file holds the defaults that are used in the project and the server.js contains all the code that are used to connect the application to the cloud server and mongo server. On initiating the application, the application will be automatically connected to the cloud and MongoDB instance, the application URL direction is carried out by the route module in the application. All the operational functions are defined inside the controllers that are responsible for rendering the data from the server and database; it works as the communication bridge between the server and the database. The JavaScript code here is modeled for each category of the application. We have used the handlebars to dynamically display the data from the server making the UI function light weighted by using the MVC structure to display the data in each corresponding page, these files are grouped under the view folder. The purpose of creating the overall performance dashboard is to let the user know about the overall productivity of the manufacturing system. Here we have used the Handlebar pages to dynamically load the content from the database to the user. The Machines, Process and Process Instance data are displayed in the corresponding individual handlebar pages.

V. RESULT

We have implemented the basic functionalities of the smart manufacturing service system and tested by launching the application in the Heroku cloud Instance and the EC2 of AWS, the application seems to run better in the Heroku cloud instance thus the application is launched in the Heroku cloud. The overall performance of the application is optimized by the optimal algorithms used in the development process at every stage of the project thus the application runs smoothly without any interruption in the cloud servers and node servers. The web application that we have created using the node JS is light weighted and can run in any process environments, the dependencies of the application will be automatically installed in the cloud servers when the server code starts its process, then the data will be rendered from the MongoDB cloud instance. The initial page of the smart manufacturing service system is the dashboard that displays the overall functioning of the system and its data flow. The create New Machine, category, process and process instances are enabled only for the super admin who can manage the overall production Process, they are able to add the new machines or the updating the process or process instances of the existing machinery. The data given in these pages will be automatically updated to the cloud database instances. The data manipulation in this application will probably take less time as we have mentioned in the data process methods in the proposed modal section.

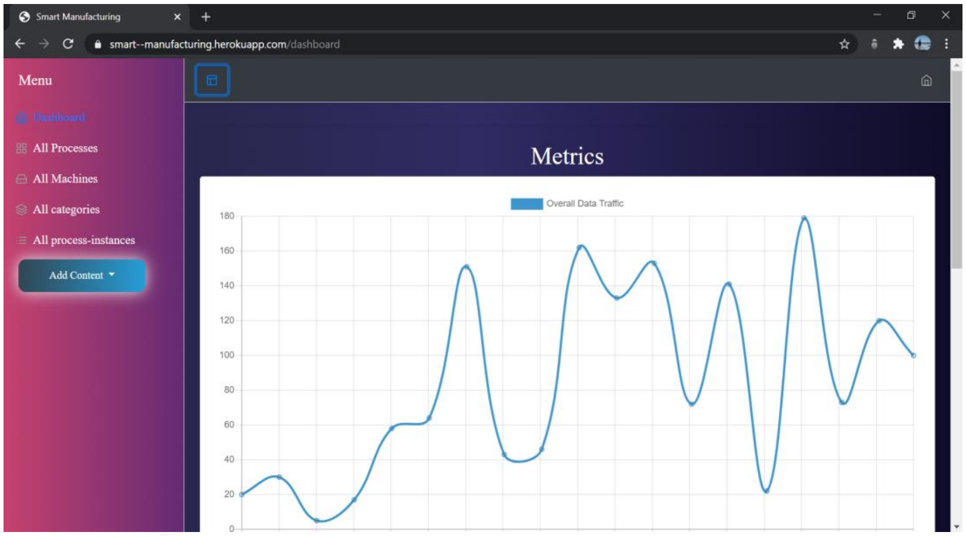

Figure 2. Application Homepage.

VI. CONCLUSION

The smart manufacturing service system application that we have designed and developed will reduce the latency in the data processing in the cloud environment. The data stream from the node server will be processed asynchronously, leading to the increased efficiency in the data rendering methods used in the controllers and the handlebar pages. The basic functionalities of the smart manufacturing service system is developed and implemented by considering the results from the unit test of the application. The area that needs further improvement is the UI of the application and creating the visualization of the large statistical data. We have planned to enhance the present UI of the application with the more efficient material designs and also designing a module for displaying the large statistical data to the user which makes the application more user-friendly.

VII. References

[1] F. Tao and Q. Qi, ‘‘New IT driven service-oriented smart manufacturing: Framework and characteristics,’’ IEEE Trans. Syst., Man, Cybern. Syst., vol. 49, no. 1, pp. 81–91, Jan. 2019

[2] M. S. de Brito, S. Hoque, R. Steinke, A. Willner, and T. Magedanz, Application of the Fog computing paradigm to smart factories and cyber physical systems,’’ Trans. Emerg. Telecommun. Technol., vol. 29, no. 4, p. E3184, 2018.

[3] Q. Qi and F. Tao, ‘‘Digital twin and big data towards smart manufacturing and industry 4.0: 360 degree comparison,’’ IEEE Access, vol. 6, pp. 3585–3593, 2018.

[4] Alarifi, Abdulaziz, et al. "Energy-Efficient Hybrid Framework for Green Cloud Computing." IEEE Access 8 (2020):115356-115369.

[5] Siddiqi, Muhammad Hameed, et al. "Dynamic Priority-Based Efficient Resource Allocation and

Computing Framework for Vehicular Multimedia Cloud Computing." IEEE Access 8 (2020): 81080-81089.

[6] Hou, Shoulu, et al. "Frequency-Reconfigurable Cloud Versus Fog Computing: An Energy-Efficiency Aspect." IEEE Transactions on GreenCommunications and Networking 4.1 (2019): 221-235

[7] Wang, T., Ke, H., Zheng, X., Wang, K., Sangaiah, A. K., & Liu, A. (2019). Big data cleaning based on mobile edge computing in industrial sensor-cloud. IEEE Transactions on Industrial Informatics, 16(2), 1321- 1329.

[8] Zhao, Dongfang, Mohamed Mohamed, and Heiko Ludwig. "Locality Aware scheduling for containers in cloud computing." IEEE Transactions on Cloud Computing (2018)

[9] Liang, Junbin, Min Zhang, and Victor CM Leung. "A Reliable Trust Computing Mechanism based on Multi-source Feedback and Fog Computing in Social Sensor Cloud." IEEE Internet of Things Journal (2020).

[10] Qi, Qinglin, and Fei Tao. "A smart manufacturing service system based on edge computing, fog computing, and cloud computing." IEEE Access 7 (2019): 86769-86777.

[11] Zhang, Yongmin, et al. "Efficient computing resource sharing for mobile edge-cloud computing networks." IEEE/ACM Transactions on Networking 28.3 (2020): 1227-1240.

[12] Ren, Jinke, et al. "Collaborative cloud and edge computing for latency minimization." IEEE Transactions on Vehicular Technology 68.5 (2019): 5031-5044.

[13] Wang, Xiaofei, et al. "Convergence of edge computing and deep learning: A comprehensive survey." IEEE Communications Surveys & Tutorials 22.2 (2020): 869-904.

[14] Lin, Bing, et al. "A time-driven data placement strategy for a scientific workflow combining edge computing and cloud computing." IEEE Transactions on Industrial Informatics 15.7 (2019): 4254-4265.

[15] Wang, Haoxin, et al. "Architectural design alternatives based on cloud/edge/fog computing for connected vehicles." IEEE Communications Surveys & Tutorials 22.4 (2020): 2349-2377.

저자 소개

S.Vimal

2021 : Associate professor in Dept. Of Computer Engineering, Ramco Institute of Technology,Rajapalayam,Tamilnadu,India

Research Interests : AI, Wireless Communication and Big Data Analytics

Jesuva Arockiadoss S

2017 : Undergraduate , Dept. of Information Technology, National Engineering College, Kovilpatti, Tamilnadu, India

Research Interests : Data Analytics, Cloud Computing

Bharathiraja S

2017 : Undergraduate, Dept. of Information Technology, National Engineering College, Kovilpatti, Tamilnadu, India

Research Interests : Data Analytics, Cloud Computing

Guru S

2017 : Undergraduate, Dept. of Information Technology, National Engineering College, Kovilpatti, Tamilnadu, India

Research Interests : Data Analytics, Cloud Computing

V Jackins

2010 : Assistant professor (SG) in Dept. of Information Technology, National Engineering College, Kovilpatti, Tamilnadu, India

Research Interests : Network security, Data mining, Analytics