

Fog Based IIoT Architecture Based on Big Data Analytics for 5G-networked Smart Factory

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Abstract. Industrial IoT data analysis is an essential means of obtaining important information in efficient smart factory operation. IoT devices connected to Smart Factory produce large amount of data from variety of mechanical facilities that actually operate. Because the collected data can be analyzed in real time, optimizing plant operations can be optimized, predicting maintenance schedules for mechanical facilities or quickly replacing equipment with faulty ones. In addition, various information needed for efficient operation can be obtained, such as improving the quality of the products produced. Using 5G wireless network and fog node and cloud computing, this paper introduces a new platform that supports efficient analysis of big data collected in smart factories. Leveraging various resources of 5G wireless network, it provides an optimized environment for collecting IoT data such as size, speed, delay and variety. It also provides big data analytic services through fog nodes and cloud computing and addresses various requirements for data collection, processing, analysis and management. This paper describes the requirements and design components of the proposed platform. Introduce case studies using data sets obtained from smart factories to validate the platform and provide meaningful results. The experimental results clearly show the benefits and practicalities of the platform.

Keywords: Industrial IoT · 5G-networked Smart Factory · Big data · Fog computing · Cloud computing

1 Introduction

Many countries around the world are building smart factories as part of their manufacturing innovations. Due to advances in telecommunications networks, Internet of Things, and smart factory are generating large amounts of data from various devices connected to the IoT system. The collected data plays an important role in improving the quality of the products produced, reducing costs, and ensuring efficient operation and management of mechanical equipment. In this

© Springer Nature Switzerland AG 2019
S. Misra et al. (Eds.): ICCSA 2019, LNCS 11620, pp. 44–52, 2019.
https://doi.org/10.1007/978-3-030-24296-1_5

paper, we propose a new platform by combining IoT and big data analysis technology with 5G network, fog node and cloud. The proposed platform quickly processes large amounts of data generated by smart factories and provides reliable analysis and results. On this platform, the 5G wireless network handles large amounts of data collection and massive traffic, storing data on fog nodes and core networks, while fog computing provides fast analytics close to real-time of the collected data. Also, fog computing is highly resource efficient as it has virtual machine technology that can continuously process new IoT data. The 5G wireless network plays a critical role in handling big data due to ubiquitous coverage as well as storage and computing capabilities within the network. A 5G wireless network consisting of a wireless access network and a core network segment can transmit data to data storage on fog computing nodes. Thus, a 5G wireless network can serve as a bridge between data sources and fog computing. Cloud computing offers a variety of benefits, such as Infrastructure as a Service (IaaS), Platform as a Service (PaaS), Software as a Service (SaaS). To accommodate large amounts of data, network capacity must be greatly increased. To meet speed and diversity, the 5G wireless network provides differentiated networking by integrating appropriate network resources to meet various service requirements in terms of latency, security and reliability. The main contributions of this paper are as follows. 5G Wireless Network, Fog Node and Cloud Computing will present platforms for big data analysis at IoT Smart Factory.

The composition of this paper is as follows: Sect. 2 describes the related work. Section 3 introduces the requirements and components of the proposed platform. Section 4 introduces open challenges for 5G smart factory issues. Finally, Sect. 5 presents the conclusions of the study and gives directions to future work.

2 Related Work

Due to the development of Internet of Things, the number of devices connected to the device is expected to reach about 50 billion by 2020, with around 20% in the industrial sector to be connected to the IoT [1]. Based on the architecture of IoT, industrial sites can be monitored and large amounts of data can be collected and processed in real time. Until now, mobile telecommunication technologies have developed rapidly. The key meaning of 5G is to expand the benefits of mobile technology in new applications, to work together in an optimal way, connecting, controlling, exchanging and deploying everything, and to overcome the limitations of space and time to create new business modes. 5G communication network has made tremendous strides in many respects, including a 1,000x increase in communication capacity and less than 1ms in end to end delays [2]. [3]'s study focused on predictive analysis of data access that should be stored on cloud systems. The author of [4] has developed a new gateway system that automatically integrates and configures new IoT data for seamless analysis in cloud systems. [5]'s study proposes a system that supports various IoT protocols for data collection and analysis. [6] presents a real-time data analysis engine that facilitates data processing near the information source. The proposed analysis

engine ensures that data is processed before it is offloaded. [7]'s study develops mechanisms to predict this problem and the latency of cloud-fog-IoT continuum systems. For real-time analysis of IoT data in an uncontrolled environment, the work presented in [8] proposes universal IoT frame work that integrates wireless hub nodes to support analysis reliability and ensure real-time data collection. [9]'s study proposed a system for performing data analysis in a distributed manner. Use fog computing, IoT devices, edges, and central servers. The main approach is to optimize the decision-making of the analysis so that all IoT devices are treated fairly and satisfied. The results of this work show a promising solution that increases utilization of fog and cloud computing systems. To facilitate the intelligence of edge networks that provide a strong analysis of the IoT system, [10]'s work explained a new approach to dynamically automating the transition between central cloud systems and edges, taking into account the various conditions and requirements of the application. In this paper, the requirements and components of the platform architecture for IoT big data analysis platform for smart factories are presented.

3 Industrial IoT Platform for Smart Factory

Smart factories are spreading rapidly around the world, and are becoming a remarkable business opportunity in a variety of industrial environments. Smart factories supported by IoT generate a lot of useful data. This chapter describes the requirements necessary to collect, process, analyze and manage IoT big data using 5G wireless networks and fog nodes and cloud computing, and presents the components of the proposed platform.

3.1 Design Requirements

Designing innovative platforms suitable for handling large amounts of data generated by smart factories requires the following requirements

Resource Distribution. Large amounts of data generated by smart factories require cost-effective and resource-efficient analysis of large amounts of data that are close to physical systems. Delay times should be short because they are processed and analyzed almost in real time. Therefore, resource proximity helps overcome the high latency associated with provisioning cloud-based services. This requires an optimized scheduling mechanism and appropriately allocates resources between fog nodes and cloud computing.

Extensible Tools. Smart Factory Data Streams require a very high level of processing and analysis. These data streams are received from high volumes, from various sources, and the data is changed by different environments. Thus, these data require scalable tools to process and analyze in a variety of environments. These data also require additional cleaning and preprocessing to reduce the size of the data and better extract meaningful data.

Integration. Data collected from different devices in smart factories are not structured and cannot be processed using existing tools. Thus, IoT data from smart factories should deal with additional dedicated integration mechanisms in the integrated system. Automated adaptive data collection methods should be developed to integrate various data transfer speeds and volumes and accommodate diverse data source and application requirements.

Visualization. Another requirement for dealing with IoT big data in smart factories is related to data through visualization. This requirement is quite important because each application relies on recognized representations of data after processing and analysis to visualize and make decisions. Application-specific data visualization provides expertise by providing meaningful results based on data quality. The following topics describe the components required for the proposed platform.

3.2 Components of Industrial IoT Platform

Figure 1 shows the structure of the proposed platform. It consists of a 5G wireless network and of fog nodes and cloud computing, and the components of the platform support continued integration, processing and analysis of smart factory data. Fog computing extends the main function of cloud computing to network edges close to the physical location of smart factories, speeding up data processing that is only available within a specific time limit. Data collected from smart factories are generally delivered to smart factory IoT gateways from various sources. Data acquisition is usually performed by certain IoT protocols, such as MQTT, which communicate with smart factory devices and IoT gateways. The IoT gateway acts as an agent to mediate between smart factories and cloud systems. IoT gateway also provides local processing and storage functions, including automatic control and filtering of data streams. During this communication process, the task of acquiring data will go through a step until the data is stored in the cloud where further processing may be performed. The following are the details of the platform components.

Smart Factory Components. Figure 2 shows the components of the Smart Factory. The components of smart factories are generally classified into three layers: cyber physical, connectivity and context aware. The cyber physical layer consists of smart metering system, smart renewable system, smart sensor system, and smart energy management system. These elements are responsible for all actual operation of the plant and are installed within the factory. This interacts with the outside world through the connectivity layer and, as mentioned earlier in this section, uses multiple communication protocols to enable these devices to communicate with the cloud system through the IoT gateway. The connectivity layer is responsible for inbound and outbound communications at smart factories, and is communicated to administrators through mobile or Web applications. The context aware layer provides the intelligence of smart

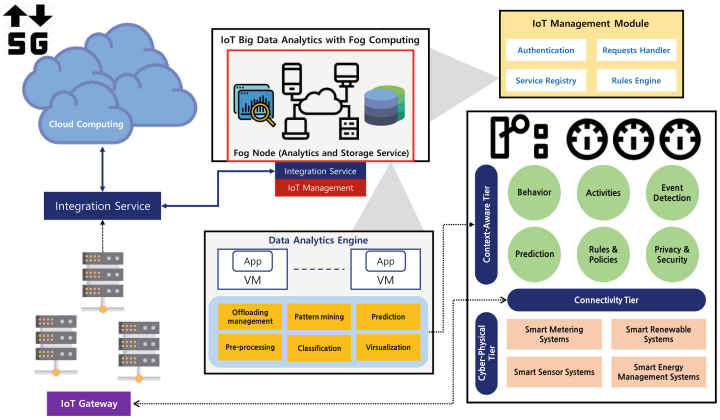

Fig. 1. IoT big data analytics with fog computing architecture.

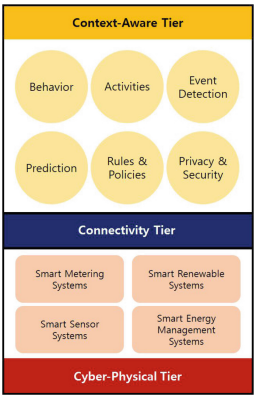

Fig. 2. Smart factory components.

factories, behavior, activity, event detection, prediction, rules policies and privacy security are performed by fog nodes, cloud computing systems and reported to smart factory applications.

IoT Management Service. IoT management service is a broker-based subsystem that processes IoT service requests from smart factory applications with cloud systems. Ensure that the approval rules are consistent with pre-configured policies in the rule engine and play an important role in providing certification services for these requests. Services that require access to smart factory-related data should be registered as IoT management brokers before using data from cloud systems. IoT management service is operated regardless of protocol and is responsible for maintaining continuity and flexibility of the entire IoT ecosystem.

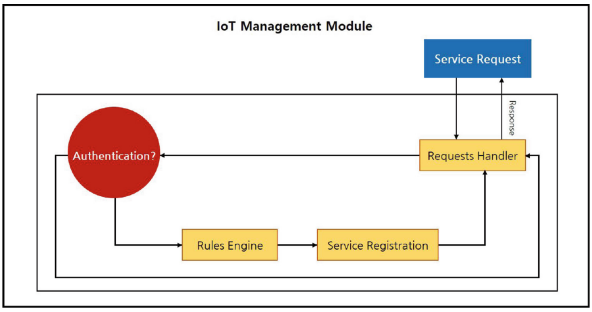

Fig. 3. The IoT big data management module.

Figure 3 shows the operation of the IoT management service. In this illustration, all services are first authenticated and registered before accessing the data. Integrated services ensure security as external applications cannot access the analytical engine directly. It also adds data visualization by enabling data to be used for a variety of user-specific applications, including mobile and desktop applications. Another key benefit is to provide interoperability for various channel technologies (Wi-Fi, Bluetooth, ZigBee and LPWAN) and data transfer protocols M2M, MQT and CoAP.

5G Wireless Network. 5G Wireless Network builds infrastructure such as various small cell base stations to support vast amounts of traffic and diverse services. With such a built-in wireless network, users can easily connect mobile devices and inaccessible devices, simplify line layout, and reduce costs. In addition, the 5G wireless network overcomes the limitations of existing communication technologies, providing an optimized environment for collecting IoT data such as high transmission speed, high coverage, low latency, large numbers of connections, high reliability and high security. Figure 4 shows the industrial 5G connectivity network architecture in a smart factory.

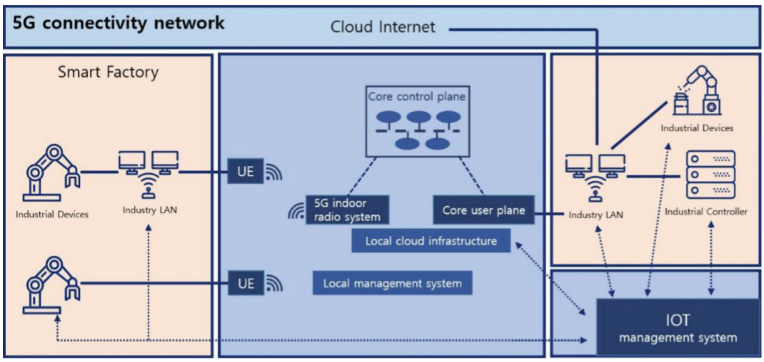

Fig. 4. 5G-networked Smart Factory Architecture.

Fog Computing Nodes. The fog computing nodes provide additional resources and computing services to support a variety of time-sensitive applications in smart factories. The Fog compute nodes provide a means to accelerate the analysis of collected data while increasing the responsiveness of the cloud infrastructure. Figure 1 shows the main functions of the fog computing nodes on the platform. It consists of several functions such as data preprocessing, pattern mining, classification, prediction and visualization. These functions are responsible for rapid analysis of smart factory data collected through the IoT system, and the aggregated results are transmitted directly to the cloud or service applications. The fog computing node performs all short-term analysis at the edge of the cloud system. The data that arrives at the fog compute node is not structured and there is no predefined model. Errors, duplication, and specificities are eliminated during the cleaning/preprocessing process to ensure consistency. In the pre-processing phase, all IoT data streams are filtered, analyzed and converted into an integrated data structure to perform further analysis. At this stage, raw data containing millions of data records is converted to predefined resolutions for each device.

Cloud Systems. In the proposed platform, cloud systems serve as key services for applications that include historical data analysis, extended storage capabilities, and core smart factory management infrastructure. Cloud services include smart factory device tracking, configuration, analysis, reporting, authentication and authentication services. These features provide value-added services that allow users to control and manage smart factories using mobile and Web applications and interact with third-party suppliers. Cloud systems also use large data mining resources such as Map Reduce, Spark, Storm, and others to deliver large-scale computing capabilities. Cloud systems use back-end computing to gain business insight and update fog computing nodes for new operational rules.

4 Open Challenges for 5G Smart Factory

In this paper, IoT data analysis for manufacturing equipment and devices of smart factory is presented through the proposed framework. SK Telecom introduced the 5G network artificial intelligence machine vision technology through Mobile World Congress 2019 (MWC19). When the product passes over the conveyor belt, high-resolution camera takes 24 pictures 5G network to the cloud server, and the server's high-performance artificial intelligence reads photos in real time to determine if the product is defective. Finally, when the results are sent to the machine, the robot arm distinguishes between normal parts and defective parts. Applying this technology to realistic auto parts companies has proven that productivity per worker is up to twice as much. In this case, deep runs have yielded meaningful data on defect detection in production products, which can help improve productivity and quality through defect detection in smart factories. In addition, a number of open issues are discussed in this section.

Balancing Between Communications, Caching and Computing. 5G wireless networks provide heterogeneous communications, calculations and caching resources. It is very important to efficiently utilize these heterogeneous resources to support heterogeneous big data applications. For example, additional computational resources may be exchanged to reduce communication loads. In addition, intermediate or final results of the calculations may need to be stored as valuable resources. Storing all of these data can be costly to store, but deleting the data may require recalculation as needed. In-depth research is needed to uncover tradeoff relationships between these heterogeneous resources to provide guidance on resource provisioning to efficiently handle big data.

Integrating Fog Computing. Implementing mobile fog computing can efficiently store and preprocess data collected from different sources. Due to the uneven distribution of data load in both space and time zones, collaborative fog computing is a useful solution for storing and processing large amounts of data in a cost-effective manner. While distributed storage systems can be co-configured by different cache, distributed fog computing can provide parallel computing capabilities for data processing.

Custom Networking for IoT Data. Network slicing has the potential to efficiently support various data services/use cases by establishing service-oriented networking in physical network infrastructure. End-to-end networking solutions can be customized in terms of virtual topology, resource provisioning, and built-in capabilities to meet service requirements such as delays. In addition, multiple slices should be well coordinated to efficiently utilize networking resources and meet their respective requirements. In addition, network slicing should adapt to the dynamics of network conditions and service requests.

Security and Personal Information. In smart factories, collection data can find information for efficient operation, but it also raises concerns about security and privacy. In order to obtain meaningful information from insights from data analysis, the data collected must be trusted and reliable. Prevent any deformation or deterioration of data that occurs during processing and analysis. In addition, only authorized entities can access data to protect data from unreliable entities. In addition, data mining for user data can violate user personal information such as location and habits information. Security and privacy issues must be addressed well for the proliferation of big data collection and analysis technologies at industrial sites.

5 Conclusion

This paper presented a smart factory IoT big data analysis platform using 5G wireless network, fog node and cloud computing. Leveraging various resources of 5G wireless network, it provides an optimized environment for collecting IoT

data such as size, speed and variety. Through fog nodes and cloud computing, it will address a variety of requirements needed for efficient big data analysis such as data collection, processing, analysis and management. In addition, a platform for processing data collected from fog nodes and cloud computing is presented, and the analyzed results can be utilized in a variety of ways. In addition, the proposed frame work was applied to provide examples and effects on the technology to detect defects through 5G network artificial intelligence machine vision technology in the manufacturing process. In the future, we will conduct various and ongoing research activities in this field to efficiently collect, process and analyze big data in smart factories.

Acknowledgements. This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education (NRF-2017R1A6A3A11035613).

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