International Journal of Advanced Smart Convergence Vol.11 No.1 42-47 (2022)
http://dx.doi.org/10.7236/IJASC.2022.11.1.42

IJASC 22-1-6

The implementation of Network Layer in Smart Factory

Chun Kwan Park*, Jeong-Jin Kang **

**Professor, Div. of Navigation and Information Systems, Mokpo National Maritime University, Korea*
*** Professor, Department of Information and Communication, Dong Seoul University, Korea*
**ckpark@mmu.ac.kr, **jjkang@du.ac.kr*

Abstract

As smart factory is the factory which produces the products according to the customer's diverse demand and the changing conditions in it, it can be characterized by flexible production, dynamic reconstruction, and optimized production environment. To implement these characteristics, many kind of configuration elements in the smart factory should be connected to and communicated with each other. So the network is responsible for playing this role in the smart factory. As SDN (Software Defined Network) is the technology that can dynamically cope with the explosive increasing data amount and the hourly changing network condition, it is one of network technologies that can be applied to the smart factory. In this paper, we address SDN function and operation, SDN model suitable for the smart factory, and then performs the simulation for measuring this model.

Keywords: *Smart Factory, SDN, Reconstruction, Network Layer, IoT, Bigdata, Production,.*

1. Introduction

These days 4th industry revolution has been appeared based on ICT (Information and Communication Technology) such as Bigdata, AI (Artificial Intelligence), IoT (Internet of Things), and Clouding Computing technology. It allows the innovative changes to emerge as a result of convergence in all societies including industry area [1, 2].

In manufacturing area, Smart Factory has been emerged through the convergence of ICT technology and manufacturing. It can improve flexibility, efficiency, and productivity through the mutual harmony and interworking of many kind of components in Smart Factory [1, 3]. Smart factory gathers, stores, and uses in real time data from the underlying equipment using ICT such as IoT. By analyzing the stored data and then making the decision-making information through AI, this information can be used to control and adjust the systems according to the changing diverse conditions in smart factory. Therefore, it can make the accurate and reasonable decision and then generate new additional value [4, 5].

As smart factory is the factory that produces the products according to the customer's diverse demand, it can be characterized by flexible production, dynamic reconstruction, and optimized production environment.

To implement these characteristics, many kind of configuration elements in the smart factory should be

Manuscript Received: January. 23, 2022 / Revised: January. 27, 2022 / Accepted: February. 3, 2022
Corresponding Author: jjkang@du.ac.kr
Tel:***－****－****, Fax: +82-2-407-7716
**Professor, Department of Information and Communication, Dong Seoul University, Korea

connected to communicate with each other. Therefore, network is responsible for playing this important role in the smart factory. As SDN is the technology that can dynamically cope with the explosive increasing data amount and the hourly changing network condition, it is one of network technologies that can be applied to the smart factory [6]. In this paper, we address SDN function and operation, SDN model suitable for the smart factory, and then performs the simulation for measuring the performance of this model.

2. Architecture of Smart Factory

In the past, almost companies focused on productivity increase and convenience through the factory automation. But these days smart factory has been required to integrate all processes that consists of demand forecasting, product planning, design, production, sales, and promotion through ICT, and then produce customer-specific products in a timely manner [3]. As these days the essential of manufacturing is on small quantity batch production, Smart Factory has to have the architecture to deal with the dynamically changing production conditions according to the customer's demand flexibly. In order to have this architecture, it is necessary to has to pursue the flexible response to consumer demands and the maximization of production efficiency. These two elements are not separated from each other but have mutually dependent form [3, 4].

Smart Factory consists of the data-related function such as gathering, storing, treating, and analyzing data, and the network function to integrate many diverse elements and communicate with each other, and application function such as management, operation, and controllability based on above data-related and network function. Figure 1 shows smart factory architecture concept [1, 5]. This architecture consists of data management plane and product/business management plane.

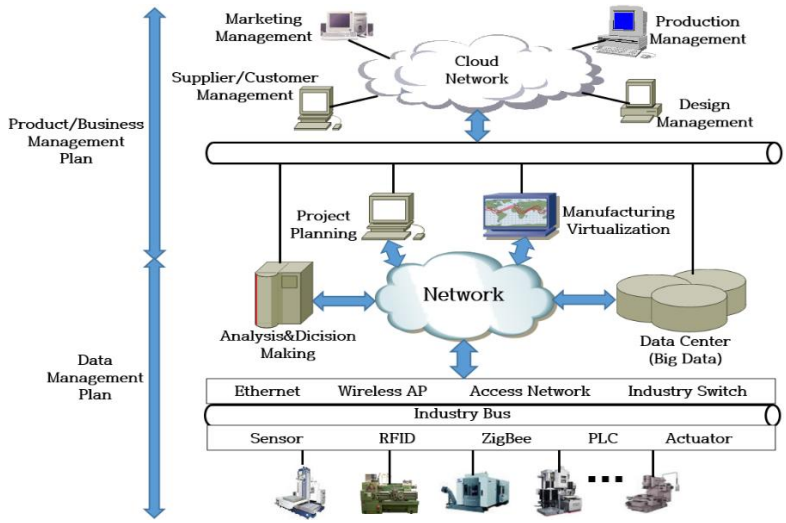

Figure 1. Smart factory architecture concept

Data management are based on IoT, and gathers, stores, and analyses data from the underlying hardware resources. Therefore, it establishes Bigdata through the gathered data. The server having analysis skills makes the decision-making and then provides it with the right place timely. In the middle of this architecture, Network connects all elements and then allows them to communicate with each other to adapt those to the changes of customer purchase form and product to produce. The product/business management plane are responsible for managing production, marketing, product design, and customers and suppliers. Therefore, the manufacturing company can improve production and marketing, and enhance controllability about all production processes

with minimizing the intervention of people in the workplace [2, 4].

3. Implementation of Network Layer in Smart Factory

Smart Factory consists of application layer, network layer, and physical resource layer. Network layer plays the very important role in Smart Factory because it connects all kind of elements and then allows data from underlying resource utilities to be gathered in Bigdata and then generate the useful information which many elements of Smart Factory can use.

Figure 2 shows the network architecture using SND in Smart Factory. It is necessary to introduce the network having the structure that can dynamically cope with the explosive increasing data amount and the hourly changing network condition. SDN is a technology developed to build the type of flexible network. Therefore, SDN can be applied to the smart factory [5, 7].

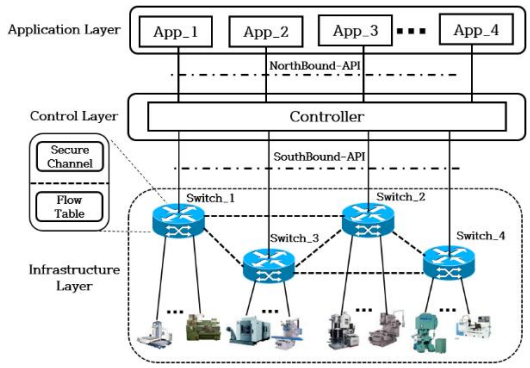

Figure 2. SDN architecture in smart factory

SDN architecture consists of 3 layers: Infrastructure Layer, Controller, and Application one. Infrastructure Layer includes switches which can connect the diverse underlying resource utilities. Controller layer provides the switch with the routing and control information based on the management functions for topology, path, link discovery, and flow. Application layer provides networks with information to make them intelligent through using the management functions of controller layer. Network controller is connected to individual switch via the secure channel to communicate with each other through OpenFlow. So the diverse information and flow table for processing the packet can be exchanged via the secure channel [8, 9].

4. SDN model and Performance in Smart Factory

Figure 3_(a) shows communication the architecture when Host_S has packets to send to Host_D. When the controller doesn't know Host_D and Host_S has no information about host_D, if switch receives the packet from host_A and has not the flow table, the switch sends Packet in Message including this packet to the controller. As the controller doesn't know host_D, it sends Packet Out message including ARP request and Output action to the switch. The flow table is made through this procedure. When a packet arrives at the existing network, this network performs the routing setting and control function for the header information of packet, and then can transfer the packet to the next hop or destination. Because it performs this procedure for all entered packets, this procedure can delay the packet transfer, and even cause the serious bottlenecks. The existing network is basically divided according to the physical location of the hardware resource.

To solve this phenomenon, the routing setting and control function is separated from data transfer function. Network is responsible for only transmitting the packet. The routing setting and control function is done in the

controller. This flexible network architecture is SDN [6, 7].

Figure 3_(b) shows the queuing model of network layer using SDN in smart factory. This model consists of control part and switching one. The switching part is responsible for packet forwarding function. Controller is responsible for the control on path and traffic. Output link of controller is separated from one of switch to verify the performance of controller.

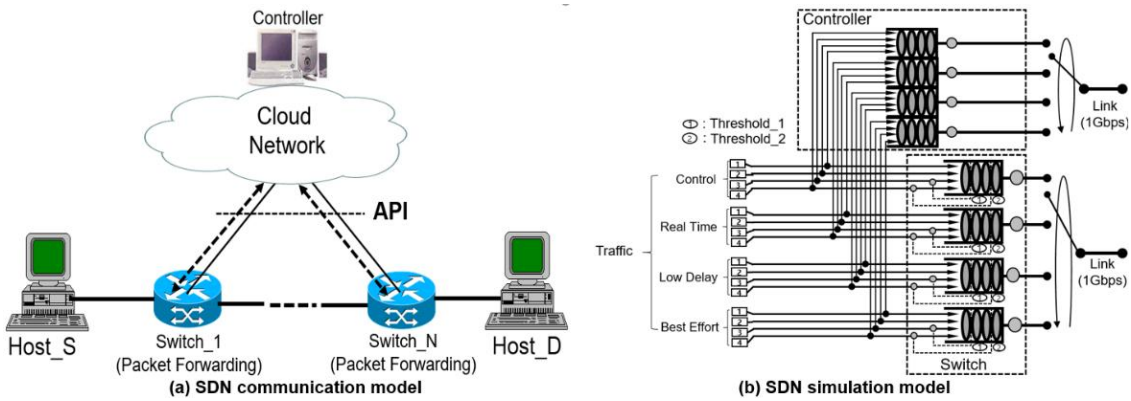

Figure 3. SND model in smart factory

Table 1. Traffic characteristics

Priority Num.	Traffic Type	Example Data
0	Control Data	Network Control
1	Real-Time Data	Telephony, Conferencing
2	Low Delay Data	Messenger, Chatting, Web App.
3	Best Effort	AS&M, Others

In table 1, This model has 4 traffic types such as control, real time, low delay, and best effort which lower value has higher priority. Packet length is from 64 bytes to 1,500 bytes. Packet arrive distribution has Poisson's distribution. When a packet is entered into a switch, if there is no flow table, the switch sends it to the controller. At this time, the packet distribution sent to the controller is considered 6%, 7%, 8%, 9% and 10% for simulation. Table 2 describes the attributes and their values for the entity which includes packet creation time, traffic type, packet length, link upload time, and delay time for switch and controller.

Table 2. Entity attributes

Attribute Name	Description
aCreationTime	Packet Generation Time; aCreationTime=TNOW(Initial value=TNOW)
aTrafficType	Service Type Information: 0: Control,1: Real-Time, 2: Low-Delay 3: Best Effort
aPacketLength	Packet Length (Unit: byte); UNIF(vPacketLengthProb(aServiceType)
aLinkUploadTime	(Packet Processing Time in Switch) (Unit: μs); aPacketLength/vLinkCapacity
aConrollerLinkUploadTime	(Processing Time of Controller) (Unit: μs), aPacketLength/vControllerLinkCapacity
aDeLay	Network Stay Time (Unit: μs); TNOW-aCreationTime

Figure 4 shows data input and initialization module for simulation model. This module generates a packet as entity, set the input values, and set the attribute values for the entity. In this module, we configure this simulation model which can be used also for UDP and TCP packet distribution. However, we consider only traffic type, UDP such as control, real time, low delay, and bets effort for the differential service.

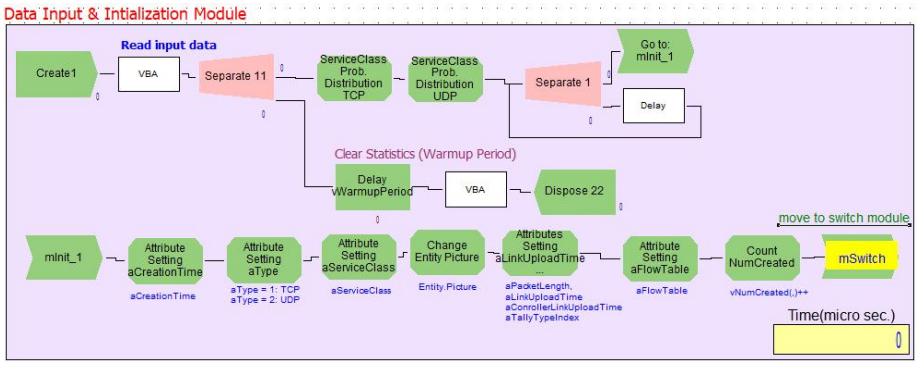

Figure 4. Data input and initialization module

To perform the simulation, we consider 1Gbps for link in both controller and switch, and 120%, 100%, 80% for overall input load ratio. Figure 5 shows the performance of packet sent to controller. Figure 5(a) shows the number of packet processed in controller according to input load ratio. In 80% input load ratio, the number of packet for 4 traffic types are small. Figure 5(b) shows the delay time of packet processed in controller according to input load ratio. In 120% input load ratio, the delay time of best effort packet is increased abruptly at 6% sharply. Figure 5(c) shows the utilization of controller according to input load ratio. In 80% input load ratio, it shows that the utilization of 4 traffic types are very low.

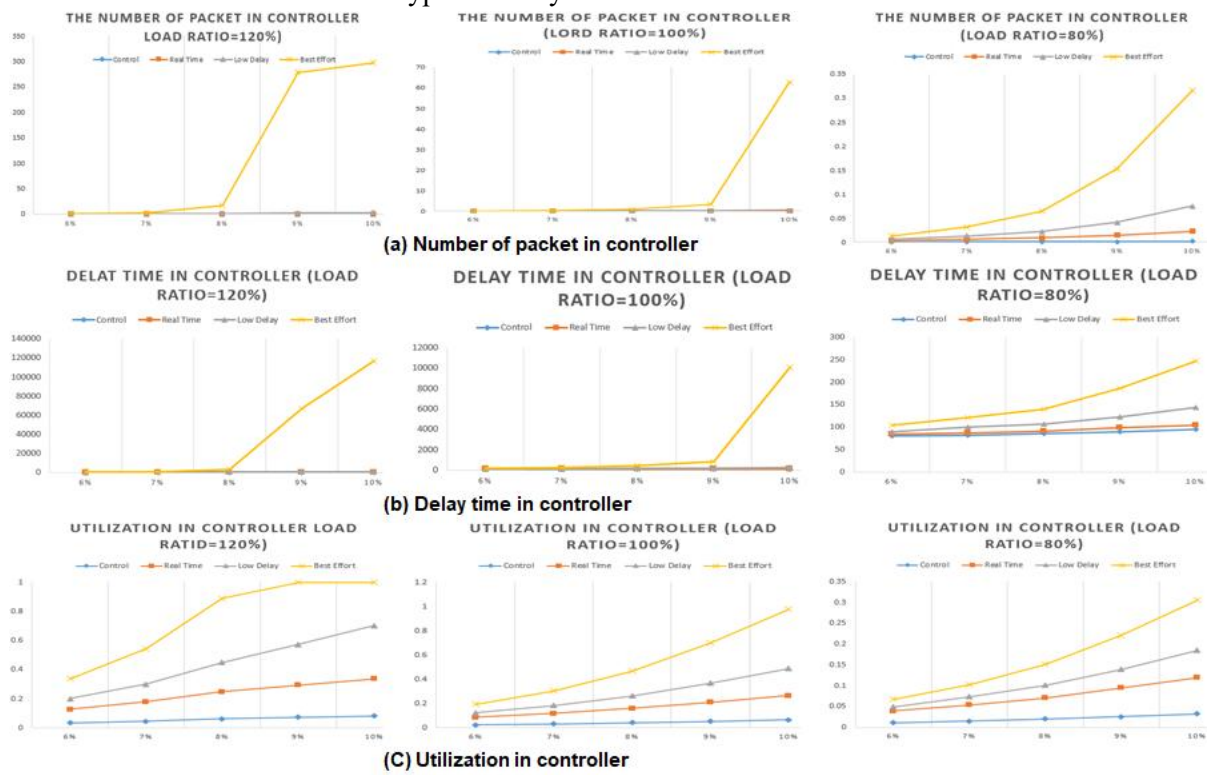

Figure 5. Performance of controller in SDN model

5. Conclusion

Smart Factory is to integrate all processes such as product planning, design, production, and distribution based on ICT, and then make its own smart. Network technology is to connect all equipment that need to communicate and then allow those to communication with each other's. So it is very important to transfer their own information to the right place at the right time. SDN is the technology that can dynamically cope with the explosive increasing data amount and the hourly changing network condition. So we applied SDN model to Smart Factory which are one of many technologies for it. The simulation is performed for performance in the controller using Arena tool. We consider 120%, 100%, 80% for overall input load ratio and 6%, 7%, 8%, 9% and 10% for packet distribution sent to the controller. For packets sent to the controller, the number of packet, delay time, and utilization are measured. In near future, we will consider UDP and TCP packet distribution in the smart factory.

References

[1] B. Chen, J. Wan, L. Shu, P. Li, M. Mukherjee, and B. Yin, "Smart Factory of Industry 4.0: Key Technologies, Application Case, and Challenges," in IEEE Access, vol. 6, pp. 6505~6519, 2018.

[2] Elvis Hozdić, "Smart Factory for Industry 4.0 : A review", International Journal of Modern Manufacturing Technologies," Vol. VII, No. 1, PP28~35, 2015.

[3] P. A. Okeme, A. D. Skakun, and A. R. Muzalevskii, "Transformation of Factory to Smart Factory," 2021 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (ElConRus), pp. 1499~1503, 2021.

[4] D. Sinha and R. Roy, "Reviewing Cyber-Physical System as a Part of Smart Factory in Industry 4.0," in IEEE Engineering Management Review, vol. 48, no. 2, pp. 103~117, 2020.

[5] Halenar Igor, Juhasva Bohuslava, Juhas Martin, "Proposal of Communication standardization of Industrial Network in Industry 4.0," IEEE International Conference on Intelligence Engineering Systems. 2016.

[6] Fei Hu, Qi Hao, and Ke Bao, "A Survey on Software-Defined Network and OpenFlow: From Concept to Implementation," IEEE Communications Surveys & Tutorials, , VOL. 16, NO. 4, PP2181~2206, 2014.

[7] Lane Thames, Dirk Schaefer, "Software-Defined Cloud Manufacturing for Industry 4.0," Peer-review under responsibility of the scientific committee of the Changeable, Agile, Reconfigurable & Virtual Production Conference 2016, pp 12~17, 2016.

[8] T. Kobzan, S. Heymann, S. Schriegel, and J. Jasperneite, "Utilizing SDN Infrastructure to provide Smart Services from the Factory to the Cloud," 2019 15th IEEE International Workshop on Factory Communication Systems (WFCS), pp. 1~4, 2019.

[9] S. Stepanov and M. Stepanov, "Modeling of OpenFlow-Based SDN Node with Taking into Account the Differences of Serving TCP and UDP Traffic Streams," 2019 24th Conference of Open Innovations Association (FRUCT), 2019, pp. 415-421.