

Efficient Network Administration for Smart Grid Data Center

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Abstract— Nowadays, the smart grid systems, which are intelligent electrical grid systems, are being installed in the real world. According to the statistics, about 79 million Advanced Metering Infrastructure is deployed in the United States and these devices generate terabytes to petabyte levels of electricity data. As IT technology developed, the energy provider can get beneficial information by processing the data in the way such as Machine Learning or Deep Learning. So smart grid administrator utilizes a data center to store the energy data and to process them. The amount of power data is increasing rapidly and the type of power data becoming more and more diverse. In addition, as computing power improves, a lot of advantageous applications such as blackout prediction is developed. In the smart grid, the importance of the data center becomes higher and higher. However, the traditional data center is designed in strict. Because the traditional data centers are designed by vendors, the operations of each component of centers are ineffective on the smart grid system. So in this paper, we applied the Software-Defined Data Center, which controls the data center in a virtualized and programmable manner, to operate the data in a more flexible and interoperable way.

Keywords— SDDC, SDN, Smart Grid, Network Slicing, Access Control

I. INTRODUCTION

Traditionally, electrical grids were composed of simple structures. Only a small number of power plants supply electric power to the consumers in a mono-directional way and only a few data packets are generated by the electric meters for the billing purpose. However, since the introduction of the smart grid system, the structure of electrical grids becomes more complex. The number of included electrical facilities grows rapidly and novel types of facilities are developed such as Advanced Metering Infrastructure (AMI) devices and IoT sensors. These smart components accelerated the increase of power data and many energy providers try to extract valuable information by processing and analyzing the collected data. For example, the energy providers can classify the consumer's features, predict demand forecast, even detect the anomaly behavior of electrical facilities [1].

However, handling lots of electricity data is a difficult issue. According to the statistic of U.S. Energy Information Administration, the number of AMI installation in the United

Frequency	1/day	1/hour	1/30min	1/15min
Records (billion)	0.37	8.75	17.52	35.04
Volume (Tb)	1.82	730	1460	2920

Table 1 Amount of data from 1 million AMI per year

Residential	Commercial	Industrial	Transportation
69,474,626	9,060,128	365,337	1,389
Total			
78,901,590			

Table 2 Number of AMI Installations by sector, 2017

States is about to 79 million [2], and 1 million AMI devices generate about 1.82 to 2920 terabytes per year [3]. Approximately, 143 terabytes to 230 petabytes of electricity data are generated in the United States. To extract valuable information from the mass amount of electrical data, a lot of computing power and storage are required. For this reason, the importance of the data center in the smart grid is emphasized.

To store and handle exponentially increasing data, the data center requires more storage and to process more powerful to get some advantageous information, the data center requires more computing power before. Nowadays, the data centers become more distributed for effective storage and computing power and this leads the data center to become more complex. However, the hardware components of the data center are already programmed without any consideration of the distributed system by the vendor. To solve this problem, the Software-Defined Data Center (SDDC) is introduced. SDDC is a novel system that leverages Software Defined Everything technologies such as Software Defined Computing (SDC) [6], Software-Defined Storage (SDS) [7] and Software-Defined Networking (SDN). All basic hardware composing the data center becomes bare-metal and the administrator of the data center can control the systems in a centralized way by virtualizing the components of the data center [4, 5].

In this paper, we introduce the SDDC system in the smart grid system to manage the data center more effective way and propose some management method that can control the data center optimized to the smart grid.

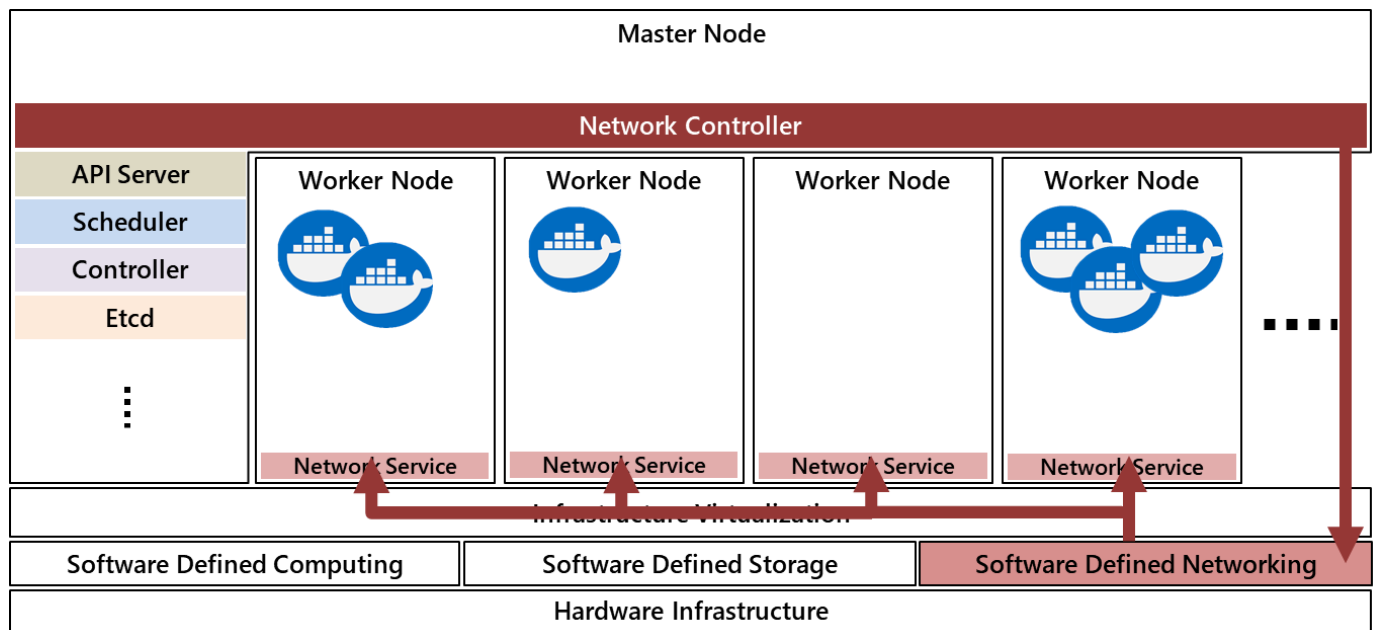


Figure 1 Structure of Software Defined Data Center

The paper is organized as follows. Section II suggests some advantages and problems of software-defined data centers. Section III proposes our method to solve the problems discussed in Section II. Section IV concludes the paper and suggest some future plans.

II. SDDC IN SMART GRID SYSTEM

A. Advantages

1) Flexible Computational Power: In the data center of a smart grid, collected electricity data is processed by the system to draw valuable information from it. Improvements in computing power enabled the smart grid to serve complex computation and plenty amount of data offers the possibilities of new intelligence. However, in a traditional data center, the computation power is inflexible. Computing power is decided by the hardware, the only way to improve computational power is by allocating more hardware manually to the process when it requires more computational power. However, in the SDDC system, the data center manages its computational power in a software manner called Software-Defined Computing (SDC). SDC virtualizes the computational power by using Virtual Machines or Container and put them into the resource pool [6]. This virtualized computing power is controlled by a centralized SDC controller and this can allocate computing power to the applications automatically. Thanks to the virtualization, data center users can utilize computational power without any need to care about the resource issue.

2) Scalable Storage: In the smart grid system, the amount of electricity data is dramatically increasing. As described in Section I, terabytes of data are generated in 2017. In addition, the number of AMI infrastructure installations still increases. This can occur sever storage issues in the future. SDDC adopted Software-Defined Storage (SDS) concepts on the

hardware structure. In the SDS system, the bare-metal storage devices are virtualized and the administrator manages the devices by defining actions in software manner [7]. Thanks to the virtualization, when the data center requires more storage, the administrator only needs to notify the storage controller. This makes the computing node can request data without any need to care about the storage issue.

B. Problems

1) Network Bottleneck: As described in Section I, various applications in the data center create a huge amount of data flow to extract valuable information from the data. For example, one application requires electricity leakage data to diagnose the anomaly behavior of electrical facilities [8]. Another application requests data about real-time electricity demands of consumers to prevent sudden blackouts [9]. Some applications can collect previous electricity usage statistics to extract and classify the consumer's features.

In the data center, each application has different priorities according to the importance of the final output of it. For example, process such as black prevention and anomaly detection is more important than the consumer feature extraction and classification. However, from the point of network switches, each packet should be handled in the same manner. So if a random application requests too many network resources, an urgent process such as anomaly detection can be slow down because of the network bottleneck.

2) Complex Access Control: To gather intelligence from the electricity data, the smart grid system runs various kinds of applications to process them. Each application can get energy data from the storage. However, because of the security or privacy issue, an application should get the minimum authority to access data. For example, blackout prevention applications can require only real-time electricity demand in specific areas to predict sudden blackout. This application

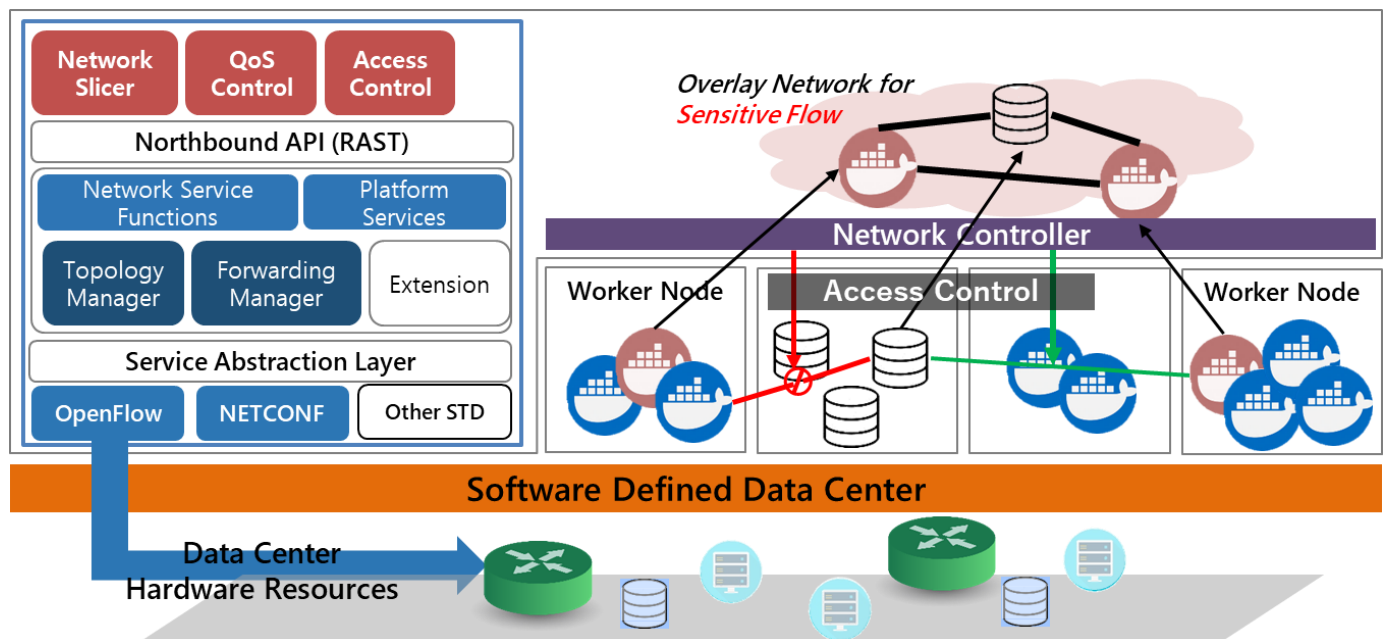


Figure 2. Network controller for Smart Grid's SDDC

doesn't need to access each consumer's private information. In contrast, extracting customer's features requires specific customer's power demand, however, information about electricity demand in the specific area should not be opened to the application, because of the security issue. In SDDC, the energy data is distributed in a number of network storages and the computing power is operated by a number of virtual machines and containers [6,7], it is complex to handle access control to each application.

III. OUR METHOD

A. Overlay Network & Differential QoS System

As described in Section II.B.1, in a smart grid system, there are a lot of applications that try to extract valuable information such as blackout prevention and customer feature extractions and the outputs of the applications have different importance. When the random application which has low priority occupies most of the network resources, an important application that

has high priority can be slow down because the data transmission speed is very slow.

To solve this problem, the system should offer a differential quality of service (QoS). A data flow generated by important applications should be handled before any other data flows generated by less-important applications. We implemented an Overlay generator and QoS Module on the network controller to differentiate network allocation.

Overlay generator creates overlay networks to accelerate sensitive data flows. A central SDN controller in SDDC has a global view of the entire data center network topology and can check real-time network resource consumption. If a sensitive flow is generated, the QoS controller retrieves the fastest path in the network and check current network status in the fastest path. If the resource in the path is already crowded, QoS retrieves an alternative path to flow. After retrieving the optimized flow path, the overlay generator request forwarding managers to create forwarding rules for the network switches. After the forwarding manager installs the flow rules with OpenFlow protocol, the sensitive flow can be transmitted without any interference.

B. Access Control System

As described in Section II.B.2, in a smart grid system, the system should be able to manage access control based on the goal of each application. However, in the large scale of a data center, it is difficult to control the authority. Because SDDC is designed to isolate the computing node and storage node separately, it is hard to manage access control on both sides. The storage node is isolated from the computing node, so the computing node's access control violates the design rule of SDDC. On the other hand, if the storage controller manages the authority, an overhead will occur because the storage controller should check the purpose of every computing resource generated.

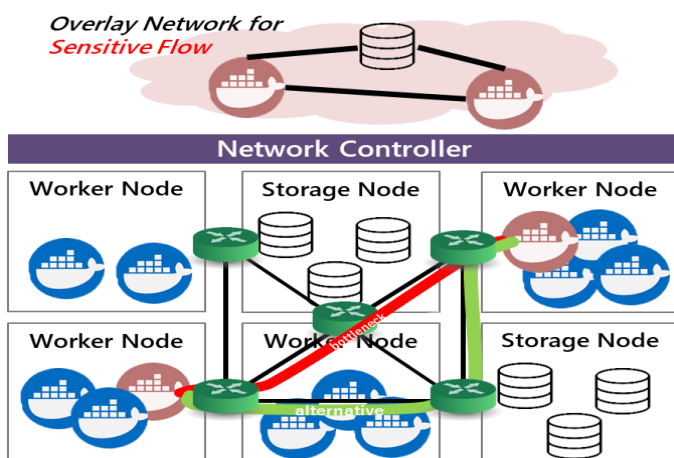


Figure 3 Differential QoS Module operation

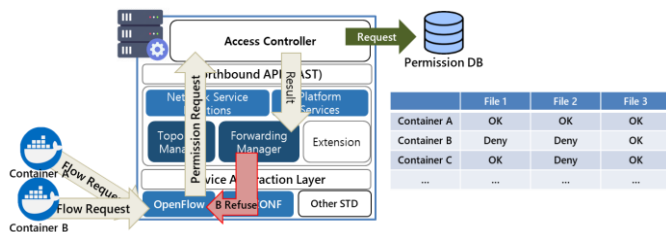


Figure 4 Access Control Module

We implemented an access control module in the network controller. When a computing node requests the data to a storage node, the computing node sends a request packet to the storage node via the network. If the storage node receives the request packet, the storage node starts to send the requested file back through the network. In shorts, the network is the only point that can observe the status of each node.

First, we implemented a central database that stores the information describes which application has permission to the data in the network controller. If an application requests a data flow, a network controller checks the application has the proper authority to the data. If the application does not have enough permissions to gather the data, the network controller refuses to generate the data packet flow.

IV. CONCLUSIONS & FUTURE WORKS

Since the scale and variety of the smart grid data become bigger and higher, the importance of data management becomes greater and greater. In this study, we applied SDDC concepts on the smart grid networks and implemented some management prototypes to accelerate and to secure data processing in terms of the network's perspective. As future work, we will optimize the QoS algorithm to make sensitive flow transmission faster and will implement a general permission-based Access Control Module which has a better convenience current one based on file-based permission.

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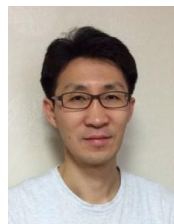
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