

SDN-Enabled Network Virtualization for Industry 4.0 Based on IoTs and Cloud Computing

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Abstract— With the rapid development of digital and network technologies, Industry 4.0 is having a huge impact on commerce. In the manufacturing sector, enterprises that produce many customized products, and those that produce a few and different of products, have the opportunity to achieve the same production standards and costs as each other. In an intelligent factory, workers and operators are shifting from traditional machine operators to production process controllers, and staff who make adjustments to management and decisions, to optimize production processes. This work proposes a software-defined infrastructure, which is then deployed in an Industry 4.0 network environment. This infrastructure improves the overall operations of the network environment, the rate of data transmission and the quality of services provided.

Keywords—Software Defined Networking (SDN), Software Defined Infrastructure (SDI), Internet of Things (IoT), Network Function Virtualization, Industry 4.0

I. INTRODUCTION

The development of the concept of Industry 4.0 in Germany has set off a new wave of manufacturing innovation around the world. The main objective of Industry 4.0 is to integrate information technology into industry and to implement customization to improve productivity; to satisfy users' needs, and to improve industrial technology. Several countries have made plans to promote such developments, such as "Made in China 2025" and the US's "Advanced Manufacturing Partnership", which seek to use information technology to improve manufacturing competitiveness in the era of globalization [1].

Industry 4.0 integrates the Internet of Things (IoT), cloud computing, big data and artificial intelligence. To establish smart factories, various problems have to be solved. For example, when a company has various orders, it must implement the required, but the order in which the products need to undergo the processes and steps differs from different requirements [2, 3].

Smart industry of the future will need to process large amounts of complex information, and production processes will depend on real-time monitoring of equipment status. To perform huge amounts of data processing and complex

operations, enterprises must be able to perform many calculations, transmit data at high speed and easily manage for high performance and reliability [4-6].

II. BACKGROUND KNOWLEDGE

This work focuses on Software-defined Networking (SDN), network virtualization, network function virtualization, cognitive radio networking, multi-domain cooperation and information center networking.

A. Software-Defined Networking, SDN

In today's era of high-tech networking, the increasing demand for networking, diversification and complexity of function is causing traditional network architectures gradually to become unsuitable for today's enterprises, operators and end users, motivating an evolution from traditional networking to new network architectures. The new network architecture is divided into the control plane and the data plane. SDN has the advantages of programmability, automation, and network control, enabling operators to establish highly scalable and flexible networks while adapting to changes in the network environment [7-11].

B. Network Virtualization

A network environment must be adjusted frequently to meet changing needs. The incorrect setting up of a job can cause a complete network failure or error, adversely affecting the overall network environment. Traditional network managers cannot meet with frequent changes in networks. A new technology that supports more flexible network management and control is required. Network virtualization can be like virtual machine services, as it can be used to start network services conveniently and rapidly. Therefore, the traditional network operating time of a few days is reduced to a few hours, and a virtual network can be store, restore and delete. A virtual network is roughly the same as a physical network. The difference is that a virtual network operates in a software environment. An application uses a virtual network as if it were a physical network. Virtual network operation the physical network and the application. Network virtualization can be performed in a single or several data centers [12-16].

C. Network Function Virtualization (NFV)

NFV is the Open System Interconnection (OSI) reference model in four to seven layers that performs functional virtualization; it has network nodes, routers, firewalls, Intrusion Detection and Prevention System (IDPS), and load balancers. Virtualization technology is currently used in networks in support of packet delivery, routers, data transmission and other network functions, and is managed by general network hardware and control software. Administrators can establish the required virtual functions of the network on a virtual machine, such as by adding a firewall or IDPS to the network. Installation of the required networking capabilities in the network can reduce manpower cost and time [17-21].

D. Cognitive Radio Network (CRN)

A Cognitive Radio Network (CRN) is a novel wireless communication technology that defines a primary user (PU) with priority access to a particular band of resources in a wireless network and allows open secondary users (SUs) to use unlicensed resources; the wireless node be able to sense the surrounding radio spectrum while controlling use of the band. A CRN can observe the network environment and identify available idle frequency bands [22-26].

III. SOFTWARE DEFINED INFRASTRUCTURE INTEGRATED SYSTEM

The proposed architecture is composed of four parts Software-Defined Infrastructure layer, Virtualized Network layer, Control Plane Management layer and Network Function Virtualization layer. In this work, Software Defined Infrastructure (SDI) is utilized to construct a complete Industry 4.0 operating environment, to separate data operations from control operations, and to optimize service quality by virtualizing the functioning of the network and its capabilities, to improve industrial production efficiency. Figure 1 shows the integrated system architecture.

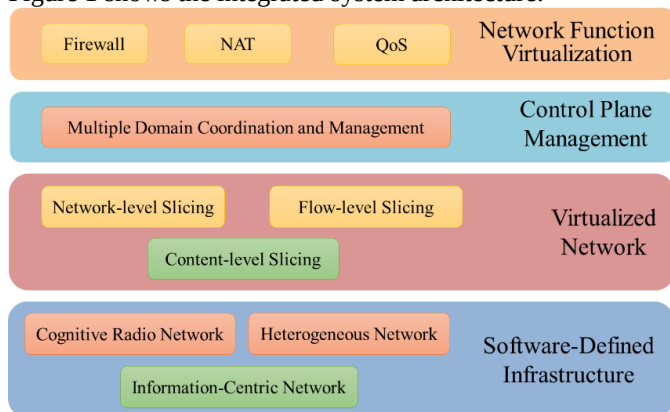


Figure 1. Software Defined Infrastructure Integrated System

To operate smoothly, a sensor network must be at least partially wireless. A wireless network is an important type of network in integrated system architecture. Improving the efficiency of wireless networks is an important issue. In this

work, wireless sensing technology is used to collect information about the current network environment, analyze its current status, to plan the network spectrum, and to make environmental adjustments to optimize the network.

3.1 Network Virtualization

Networks commonly must be used according to various categories. For example, in a corporate environment, each department may have its own independent network environment, or different projects may have to be able to use part of the network without external interference. This work proposes network-level slicing and flow-level slicing for network virtualization. Network-level slicing uses FlowVisor technology, and flow-level slicing uses Virtual Tenant Network (VTN) technology. FlowVisor technology cuts a network into slices, which are configured in separately managed units, each performing different operations. VTN technology is used to perform virtual rental network regulation and to adjust resources to enable managers more easily and improve its overall efficiency. Network virtualization slicing technology enables a physical network to be cut into multiple virtual networks for various slices, enabling the effective allocation of network resources to users. Optimize the use of network resources, while providing users with high-quality services.

This work proposes a mechanism for use with EnterpriseVisor to perform enterprise network virtualization. A network virtualized is to monitor network usage. When the network demand changes or the network resources are temporarily insufficient, the resource utilization rate of each slice is analyzed, and the supply or demand for the network resources of each slice are evaluated. This study concerns path allocation and resource scheduling in the SDN virtual tenant network. Using the virtual tenant network application that is provided by the SDN controller, various virtual tenant networks are constructed on a physical SDN network. The network can allocate paths so that each virtual tenant network can run on a fast and efficient path; and plan effective network resource scheduling. The mechanism that is proposed in this work uniformly allocates traffic of each virtual tenant network uniformly to all physical paths and monitors and analyzes the resource utilization on each path.

3.2 Network Function Virtualization

The smooth operation of a large network commonly depends on many network functions that assist in the operation of the traditional network function model. Different network functions require different network hardware equipment. Therefore, several network devices must be installed in the environment, so network construction and adjustment are not easy; network management are involved, and man-made errors occur. Network function virtualization technologies enable functional virtualization from four to seven in the OSI to virtualize the network functions that are required for the overall network functioning.

In this study, a Virtual Machine (VM) is constructed in a server cluster and network function virtualization is used. Services are provided as functional blocks to eliminate the need for specific hardware devices to impose a restrictions on the virtual network. Different network functions require different network units. The network administrator needs only configure the services to satisfy a different requirements using a control interface. Network management can monitor network usage at all times. All virtual tenant networks can run on a fast and efficient path; analyze the performance of each path and plan the effective network resource scheduling to ensure that the SLA demand are satisfied. Network enabled virtualization technology reduces the need for hardware network equipment and provides a simple network configuration to improve job efficiency.

3.3 Software-Defined Cognitive Radio Network

The use of a Software Defined Cognitive Radio Network (SDCRN) is proposed to construct CRN technology on an SDN backbone. Unlike the original CRN technology, in a SDCRN to reduce the computational burden on the underlying equipment and to separate SDN control and data transmission, the decision to use the frequency band is made by the SDN controller. The OpenFlow Access Point (OF-AP), which supports the OpenFlow transport protocol, is used to enable the administrator to control directly from the SDN controller. In the first, multiple OF-APs are deployed in the bottom layer to establish a wireless environment. Each OF-AP collects usage information about particular band resources and open band resources in each service area, and transmits this information to the SDN controller through the OpenFlow switch. Second, the CRP core is embedded in the control layer of the SDN controller. The information about the OF-AP backhaul is analyzed by the CRP core to determine whether the bands of each OF-AP area are presently busy or idle. Then, the Cognitive Radio Process (CRP) is adjusted and controlled using the individual OF-AP spectrum. The overall efficiency of the wireless network is thus increased.

3.5 Multi-domain Network collaboration and management

The two ways to construct a multiple controller are parallel construction and hierarchical construction. In this work, hierarchical construction is utilized. The effective controller mechanism can optimize the network traffic distribution and thereby greatly improve the network management and data processing performance. This work proposes a management mechanism that is based on a Meta-Controller. The mediator controller utilizes the multiple controller decentralized strategy to monitor the utilization of the zone controller and the network.

3.6 Information-Centric Networking (ICN)

The information center network is a network-based improvement on a host-based network environment to a message-based network environment. Along with the transmission of the central data, this concept can be used to network changes be solved. To eliminate the delay in the

transmission of a content message, a cache mechanism is used to store the content from the database on the cache sever. The delay is thus reduced and the speed of reading is increased, providing high-performance, scalable network characteristics.

3.7 Content-Level Slicing (CLS)

Content segmentation refers to a set of mechanisms that are used to support simultaneous access. A client commonly has non-unilateral access to avoid any delay in reading data, the content segmentation mechanism is used with the storage function of the node or intermediary storage point. The purpose is to divide the information or the overall data into multiple virtual information blocks, which are stored in different storage devices, giving the client access to the required information. By reducing access latency and providing multiple users with the same information, content segmentation considerably improves overall operating efficiency, and is useful for users and managers.

IV. CONCLUSIONS

This work proposed a software-defined infrastructure system that integrates the SDN environment with an industrial environment. The development of Industry 4.0 is expected to provide smarter digital technology that integrates digital sensors, IoTs, mass data and the Internet. Automated production and supply chain capabilities, and intelligent robots will find a wider range of applications than today. To make industrial production more convenient, a given enterprise may have different departments, which are responsible for different processes, so that different units do not interfere with each other. Such an approach facilitates management. Network virtualization involves dividing a network into many virtual networks. To solve the problem of the inefficient use of network devices, virtual network functions are used to reduce the complexity of network design, and dynamically to adjust the network. Network function virtualization technology reduces the configuration of network equipment and improves the efficiency of the network.

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