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A General SDN-Based IoT Framework with NVF Implementation

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Abstract

The emerging technologies of Internet of Things (IoT), software defined networking (SDN), and network function virtualization (NFV) have great potential for the information service innovation in the cloud and big data era. The architecture models of IoT, SDN with NFV implementation are studied in this paper. A general SDN-based IoT framework with NFV implantation is presented. This framework takes advantages of SDN and NFV and improves IoT architecture.

Keywords

Internet of Things; saftware defined networking; network function virtualization

1 Introduction

The Internet of Things (IoT) is a paradigm that is rapidly gaining ground in the scenario of modern wireless telecommunications. The basic idea of this concept is the pervasive presence around us of a variety of smart things or devices such as radio-frequency identification (RFID) tags, sensors, actuators and smart mobile phones through unique addressing schemes for interacting with each other and cooperating with their neighbors to reach common goals in an intelligent way [1]. Advancement in wireless networking has let these thousands of smart devices connect to the internet anywhere and anytime. With the development of IoT, the amount of data produced per day increases exponentially [1], [2].

In today's cloud computing and big data era, most of computing and communication resources are shared and provided to users. This era has the characteristics of diversity, dynamics, and big data explosion, and brings a big challenge for the design of IoT architecture.

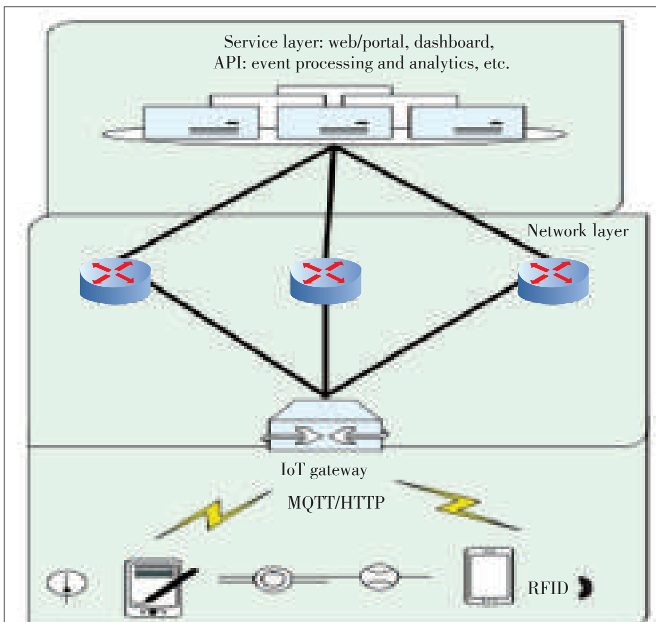
Current networks should be more intelligent, more powerful, more efficient, more secure, more reliable, and more scalable to meet the requirements of diversity and dynamics. The software defined networking (SDN) [3] and network functions virtualization (NFV) [4], [5] are two promising technologies for addressing the challenges and leveraging IoT architecture in the cloud era.

In this paper, we present a general SDN-based IoT framework with NFV implementation.

The rest of paper is organized as follows. Section 2 describes the conventional IoT architecture. Section 3 introduces the concepts of SDN and NFV and the design problems. Section 4 presents a general SDN-based IoT framework with NFV implementation. Section 5 concludes the paper.

2 IoT Architecture Models

Several IoT architecture models have been proposed [1], [6], [7]. These exiting IoT architecture models focus on different application aspects related to IoT. In this paper, we want to study the impacts of SDN and NFV on the IoT architecture. We divide the IoT architecture into the sensing layer, network layer, and service layer based on [6], [7] (**Fig. 1**).



API: application programming interface
IoT: Internet of Things
MQTT: Message Queue Telemetry Transport
RFID: radio-frequency identification

▲**Figure 1. IoT architecture.**

The sensing layer includes sensing devices such as sensors, actuators, and RFID. These devices are usually not expensive but smart enough for sensing. They sense and collect data from different physical, human, and natural worlds in an intelligent and collaborative way, and store the collected data in the devices with small amount of memory.

The collected data are then transmitted to the gateways for wireless transmission. The gateways usually use Message Queue Telemetry Transport (MQTT) protocol or Hypertext Transfer protocol (HTTP). Since the amount of sensed and collected data may be large, the data compression and aggregation methods are necessary for efficient data transmission. The network layer includes the gateways and the routes for data transmission from gateways to different application users.

The service layer provides information services according to requirements. This layer includes powerful data centers and different data servers for data mining, analysis, processing, storage, and applications.

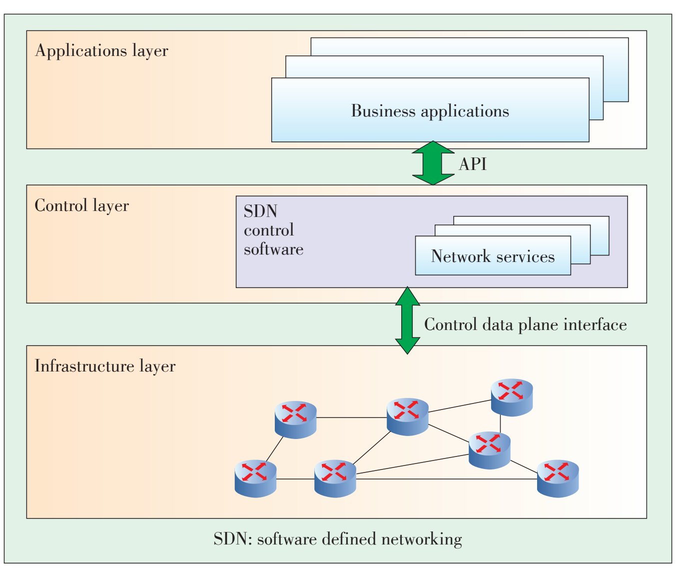
3 SDN and NVF Overview

SDN [8]–[10] is a novel networking paradigm. It separates the system and makes decisions where traffic is sent (the control plane) from the underlying system that forwards traffic to the selected destination (the data plane). In traditional routers and switches, the control and data planes are in one device. However, the separation of the control and data planes enables network more flexible, manageable, and adaptable, which meets the requirements of current applications for high-bandwidth, dynamic performance [3]. The Open Networking Foundation (ONF) [3] takes the leading role in SDN standardization, and has defined an SDN architecture model as depicted in **Fig. 2**. This model consists of the application layer, control layer, and infrastructure layer. End-user business applications are on the application layer and use SDN communications services. The control layer uses SDN controllers to provide the logically centralized control functionality that supervises the network forwarding behavior through an open interface. The infrastructure layer consists of the network elements (NE) and devices such as switches and routers which belong to the data plane. Packet switching and forwarding are implemented at this layer.

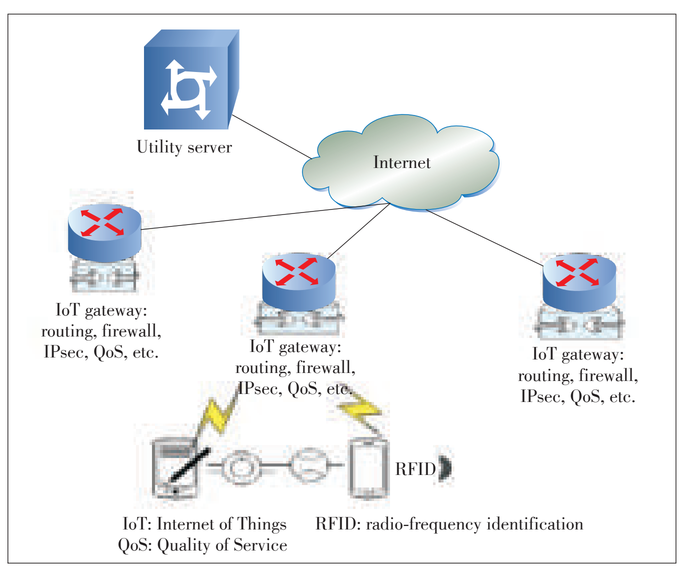
NFV [4], [5] is a network architecture concept that uses IT virtualization related technologies to virtualize entire network functions into building blocks. These blocks may be connected, or chained, to create communication services. An NFV system uses one or more virtual machines to run different software and processes on network servers, switches, storage, and even cloud computing infrastructure. In this way, the hardware does not need to be customized for each network function. Introduction of NFV and SDN to the IoT framework can leverage the network efficiency and implement the programmability and flexibility of networks [5], [11], [12]. For example, the OpenFlow-based SDN (SDN-OF) technologies, with NFV implementation, can achieve the IoT networking functions such as routing, access control in firewalls, secure tunneling between IoT gateway and utility server in IPSec protocol, and prioritizing critical and control traffic for QoS in a centralized programmable controller [12]. **Fig. 3** shows the network architecture with conventional IoT gateways. **Fig. 4** shows network architecture using SDN-OF and NFV technologies. The efficiency and network agility of IoT can be leveraged significantly by the network function virtualization of an SDN-based IoT framework.

4 A General SDN-Based IoT Framework with NFV Implementation

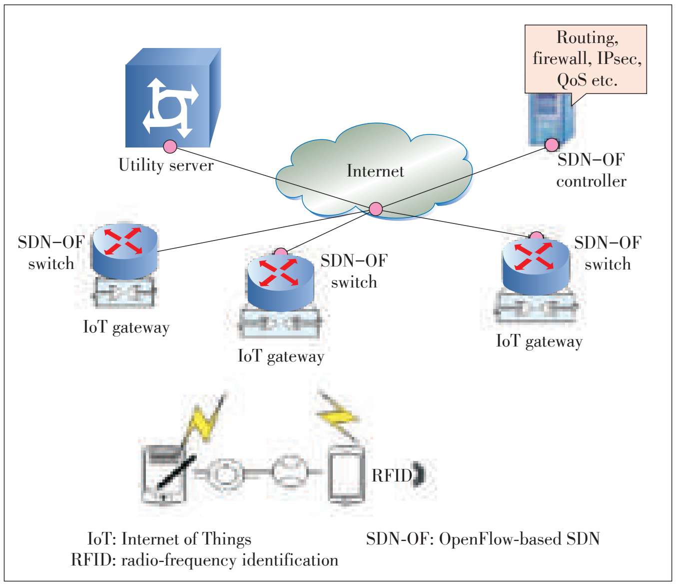
In SDN architecture, the controller is very important. It



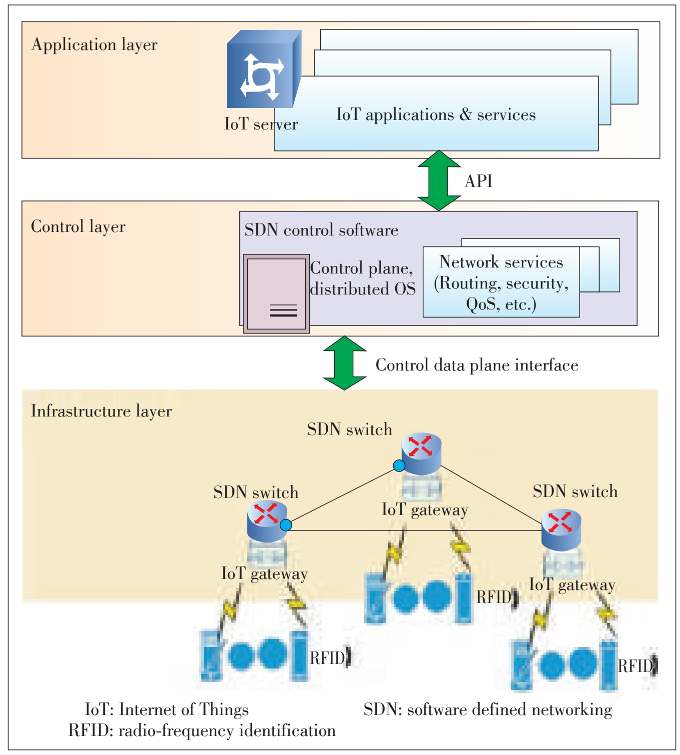
▲Figure 2. SDN architecture.



▲Figure 3. Network architecture with conventional IoT gateway.



▲**Figure 4. Network architecture using SDN-OF and NFV technologies.**



▲**Figure 5. A general SDN-based IoT framework with NFV implementation.**

deals with networking services such as routing, firewall, load balancing, QoS, and charging for the whole network. A centralized controller for a network overall controls the whole network. This is a desirable characteristic for system implementation and development. It is clear that a centralized controller cannot provide all the networking services when the size of a network becomes large [13], [14]. Hu *et al.* [13] provides a survey of controllers and proposed methods for enhancing controllers' performance. Xavier and Seol [14] mention that placement of controllers in a SDN network can be centralized, physically distributed, hierarchically distributed, and logically distributed briefly. Kang *et al.* [9] presents a rule-placement algorithm that distribute data forwarding policies while managing rule-space constraints across general SDN networks in a logically centralized way. Voellmy *et al.* [15] presents an efficient programming model to design algorithms for SDN control. An interesting idea about the SDN-based framework combing 4G cellular networks for machine-to-machine communications is presented in [8]. The proposed framework depends on a specific 4G cellular network architecture. An extended Multinetwork Information Architecture (MINA) with layered SDN controller is proposed for IoT [16]. However, the research works has not studied the general IoT architecture using SDN and NFV.

Based on the study of IoT architecture, SDN architecture, NFV technologies, we propose a general SDN-based IoT framework with NFV implementation (**Fig. 5**). In the framework, the application layer consists of IoT servers for different applications and services through APIs. The control layer consists of SDN controllers run by distributed operating system (OS). The distributed OS provides a logically centralized control and view of IoT in a physically distributed network environment for network data forwarding. The infrastructure layer consists of IoT gateways combined with SDN switches for access to different IoT devices such as RFIDs and sensors through the control data plane interface. It can be treated as an extension of the SDN architecture for IoT.

An efficient distributed OS for the SDN-based IoT plays an important role in the proposed general SDN-based IoT framework. The distributed OS in the control plane is the brain of SDN-based IoT with NFV implementation and provides a centralized control and visibility of different IoT services. Because of the diversity and dynamics of different users and infrastructures in IoT, designing and implementing an efficient distributed OS for this framework is a big challenge. Recently, many SDN associations such as OpenFlow and ONF are trying to make the standardization of the APIs in order to address the issue. NOSIX [17] has been proposed to achieve the portability and performance across different SDN switches. It provides a lightweight portability layer for the SDN OS. The Open Network Operating System (ONOS) project [18] aims at releasing a basic SDN-based distributed OS. The important issues of performance, scalability, and availability of the SDN control plane have been addressed in [19] and [20]. The design and implementation of an efficient distributed OS for the SDN-based IoT are ongoing.

5 Conclusion

The emerging technologies of IoT, SDN, and NFV have great potential for the information service innovation in the cloud and big data era. Decoupling the control plane from the data plane in SDN architecture achieves centralized system and control of IoT. However, the design of an efficient SDN-based IoT architecture with NFV is a big technical challenge. In this paper, we provide a brief up-to-date overview of IoT architecture model, SDN, and NFV. We study the characteristics of these emerging technologies. A general SDN-based IoT framework with NFV implantation is presented. As a future work, we will study the organization and components of each part in the SDN-based IoT framework.

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