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Towards a Management Plane of Software-Defined Networking

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Abstract

As for Software-Defined Networking (SDN), an additional management plane may possibly be of great significance besides the control plane and the data plane. However, the implementation of this management plane is not yet mature. Thus in this case, study on the management plane is of great importance for management issues of SDN. This paper then aims to promote the implementation of the management plane for SDN, by studying the SDN management roles, proposing the framework of the management plane for SDN, discussing the SDN management operations, and utilizing the queuing theory for SDN management. Simulation results validate that, the proposed queuing model for the management plane of SDN prospects a feasible way to understand the queuing principles between management applications and the SDN manager.

Keywords: *Software-Defined Networking, management plane, SDN manager, management operations, queuing theory*

1. Introduction

As for Software-Defined Networking (SDN), an additional management plane may possibly be of great significance besides the control plane and the data plane, although the implementation of this management plane is not yet mature [1]. As an organization to promote SDN standardizations, Open Networking Foundation (ONF) proposes the OpenFlow management and configuration protocol (OF-CONFIG, the newest version is 1.2 up to now) [2] for SDN management.

OF-CONFIG adopts NETCONF [3] as its transport protocol, and the current version 1.2 of OF-CONFIG uses the module companioning with YANG [4] to realize its data model. However, OF-CONFIG is still under development, and it is currently not powerful enough to realize the management plane of SDN. Furthermore, the relationship of this management plane and the existing control plane is also not clear.

This paper then tries to discuss the management plane for SDN from several viewpoints, including the SDN management roles, the framework of the management plane and the SDN management operations, and then apply the queuing theory to SDN management, in order to promote its implementation.

The remainder of this paper is organized as follows. Section 2 discusses the SDN management roles focusing on the SDN manager, and proposes a framework for SDN management. Section 3 then studies both active management operations and passive event notifications for the management plane of SDN. And Section 4 proposes a queuing model for SDN management, and applies the queuing theory to the management plane of SDN. Section 5 provides some simulation results to validate the feasibility of proposed queuing model. Section 6 concludes this paper.

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2. A Framework for SDN Management

Since an additional management plane for SDN seems to be of great importance besides the control plane and the data plane, this section first discusses the SDN management roles, and then proposes a framework for SDN management.

2.1. SDN Management Roles

As for the management plane of SDN, it has three implementation styles [1], with an overview shown in Table 1.

Table 1. Three Implementation Styles for the Management Plane of SDN

Implementation Style	Explanation	Advantages	Disadvantages
Integration of control and management for SDN	To add some network management functions to SDN controller	Low cost, high-level integration and rapid application	The management function of current OpenFlow protocol is limited
Separation of the SDN management function with the SDN control function	To apply SDN management as a management approach for SDN	Reuse of existing management platforms, ensuring external monitoring and management of the SDN controller	The specifications for communication manner and function of SDN management plane and control plane are in lack
Separation of the SDN management platform with the SDN control platform	To realize distributed management	High-reliability of management plane, rapid reaction of events, and low-complexity of key management platform	This implementation requires not only communication of management messages between the controller on the control plane and the devices on the data plane, but also communication of management messages between devices such as the OpenFlow switches

As is stated in Table 1, these three implementation styles for the management plane of SDN have both advantages and disadvantages. It seems that, the traditional manager-agent network management model is also feasible for SDN management. Thus in this case, two main roles for SDN management are the SDN manager and the SDN agent. Since the SDN controller is responsible to perform SDN operations, it can act as a SDN agent, and then a SDN manager is still in lack.

2.2. Proposed Framework

When the manager-agent model is applied to SDN management, the SDN controller on the control plane acts as the SDN agent, and the management plane is then responsible for realizing the SDN manager. Figure 1 proposes a framework for SDN management.

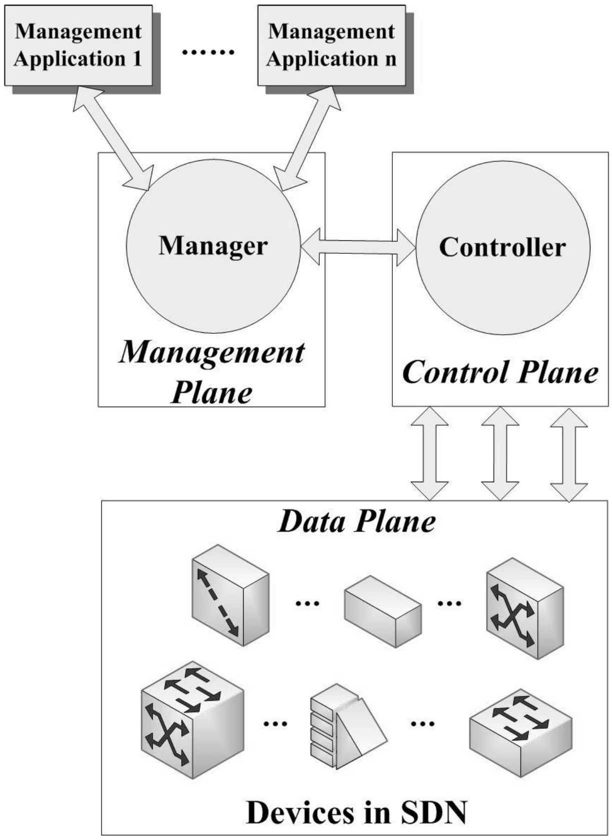

Figure 1. Proposed Framework for SDN Management

As is indicated in Figure 1, a management plane is added to SDN, when the control plane, the data plane and their communication manner remain unchanged. And in this proposed framework for SDN management, the management application communicates with the SDN manager on the management plane, and the relationship between the management plane and the control plane can adopt one of these three implementation styles shown in Table 1. After the SDN manager communicates with the SDN controller, the actual management task can be performed by the communication between the control plane and the data plane.

3. SDN Management Operations

As for the proposed framework shown in Figure 1, the SDN management operations should be provided by the management plane, mainly including two kinds of functions that are active management operations and passive event notifications.

3.1. Active Management Operations

Figure 2 demonstrates the flow of active management operations for SDN.

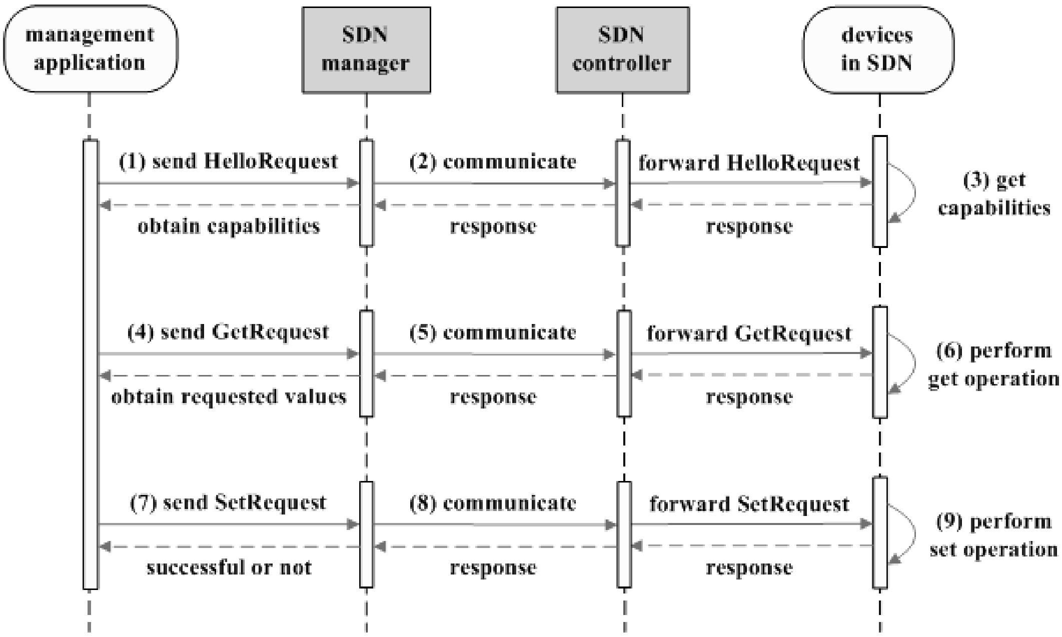

Figure 2. The Flow of Active Management Operations for SDN

As is shown in Figure 2, active management operations for SDN include following steps.

(1) The management application first sends a HelloRequest message to the SDN manager on the management plane, in order to obtain the capabilities of a specified device in SDN.

(2) When receiving the HelloRequest message, the SDN manager communicates with the SDN controller on the control plane, and the SDN controller forwards the HelloRequest message to the specified device in SDN.

(3) According to the HelloRequest message from the management application, the specified device in SDN gets the requested capabilities encapsulated in the response message, so that the management application can obtain these capabilities for future communication.

(4) After obtaining the capabilities of the specified device in SDN, the management application then sends a GetRequest message to the SDN manager on the management plane, in order to get requested values of the specified device in SDN.

(5) When receiving the GetRequest message, the SDN manager communicates with the SDN controller on the control plane, and the SDN controller forwards the GetRequest message to the specified device in SDN.

(6) According to the GetRequest message from the management application, the specified device in SDN performs the get operation and encapsulates requested values in the response message.

(7) When the management application tries to modify some values of the specified device in SDN, it sends a SetRequest message to the SDN manager on the management plane.

(8) When receiving the SetRequest message, the SDN manager communicates with the SDN controller on the control plane, and the SDN controller forwards the SetRequest message to the specified device in SDN.

(9) According to the SetRequest message from the management application, the specified device in SDN performs the set operation and encapsulates the result that is successful or not in the response message.

3.2. Passive Event Notifications

Figure 3 explains the flow of passive event notifications for SDN.

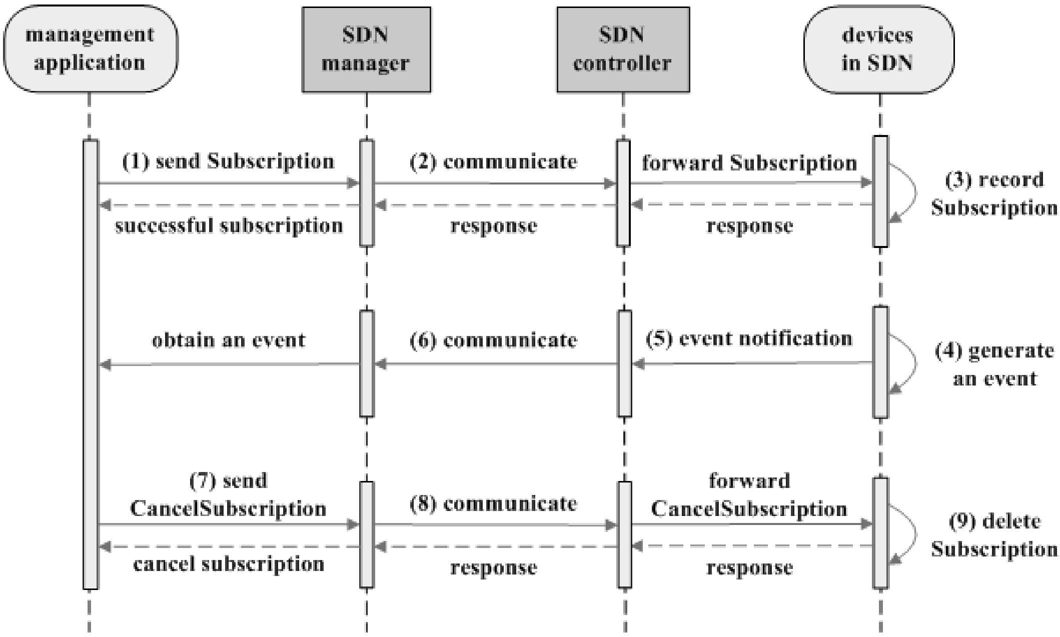

Figure 3. The Flow of Passive Event Notifications for SDN

As is shown in Figure 3, passives event notifications for SDN include the steps as follows.

(1) The management application first sends a Subscription message to the SDN manager on the management plane, in order to implement a particular subscription of a specified device in SDN.

(2) When receiving the Subscription message, the SDN manager communicates with the SDN controller on the control plane, and forwards the Subscription message to the specified device in SDN.

(3) According to the Subscription message from the management application, the specified device in SDN records subscription and it encapsulates the result of successful subscription in the response message.

(4) When an event in the recorded subscription happens, the specified device in SDN generates this event.

(5) After generating the event, the specified device in SDN performs event notification to the SDN controller on the control plane.

(6) The SDN controller on the control plane then communicates with the SDN manager on the management plane, and the SDN manager forwards the obtained event message to the management application.

(7) When the management application tries to cancel the recorded subscription of the specified device in SDN, it sends a CancelSubscription message to the SDN manager on the management plane.

(8) When receiving the CancelSubscription message, the SDN manager communicates with the SDN controller on the control plane, and forwards the CancelSubscription message to the specified device in SDN.

(9) According to the CancelSubscription message from the management application, the specified device in SDN deletes the recorded subscription and encapsulates the result of canceling subscription in the response message.

4. Proposed Queuing Model for the Management Plane of SDN

As is indicated in Figure 1, the SDN manager on the management plane is in favor of dealing with the management applications that randomly arrive. And in this case, the management applications and the SDN manager form a queuing system, and the queuing theory [5-6] can be utilized to study the queuing principles for SDN management. This section then proposes a queuing model for SDN management, and applies the queuing theory to the management plane of SDN.

4.1. Proposed M/M/1/K-FCFS Queuing Model

When the management plane assigns the SDN manager for requests from management applications, assume that, a) both the requests and the service time of the SDN manager are negative exponential distribution with parameter α and β respectively, b) there are K spaces on the management plane to deal with the requests, and c) the SDN manager adopts the service principle of First-Come-First-Serve (FCFS) for management applications.

In this case, an M/M/1/K-FCFS queuing model is then proposed for SDN management, in which M means the exponential distribution, and 1 means that only one SDN manager is assigned for requests from management applications. In this queuing model, $p_x = P\{X = x\}(x = 0,1,2,...)$ is introduced to define the possibility distribution for the number of management applications. Since the space for waiting requests is K-1, then

$$\alpha_x = \begin{cases} \alpha, x = 0,1,2,..., K-1 \\ 0, x \geq K \end{cases} \tag{1}$$

$$\beta_x = \beta, x = 1,2,..., K \tag{2}$$

4.2. Application of the Queuing Theory for the Management Plane of SDN

Suppose that $\lambda = \frac{\alpha}{\beta}$, and performance information of the proposed queuing model for the management plane of SDN can then be studied according to the queuing theory as follows.

a) The possibility of idle state for the SDN manager is

$$p_0 = \begin{cases} \frac{1-\lambda}{1-\lambda^{K+1}}, \lambda \neq 1 \\ \frac{1}{K+1}, \lambda = 1 \end{cases} \tag{3}$$

b) Based on Formula (3), the possibility distribution for the number of management applications is

$$p_x = \lambda^x p_0, x = 1,2,..., K \tag{4}$$

c) The average length for this queuing model is

$$L_m = \begin{cases} \frac{\lambda}{1-\lambda} - \frac{(K+1)\lambda^{K+1}}{1-\lambda^{K+1}}, \lambda \neq 1 \\ \frac{K}{2}, \lambda = 1 \end{cases} \tag{5}$$

d) Based on Formula (3) and (5), the average queue length for this queuing model is

$$L_q = L_m - (1 - p_0) \tag{6}$$

e) According to Little Formula in the queuing theory, the average staying time is

$$T_s = \frac{L_m}{\alpha(1 - p_K)} \tag{7}$$

f) According to Little Formula in the queuing theory, the average waiting time is

$$T_w = \frac{L_q}{\alpha(1 - p_K)} \tag{8}$$

g) In this proposed M/M/1/K-FCFS queuing model for SDN management, there is

$$T_s = T_w + \frac{1}{\beta} \tag{9}$$

5. Simulation Results

In order to validate the proposed M/M/1/K-FCFS queuing model for SDN management, α is set to 1 and K is fixed to 4. Thus in this case, Figure 4-7 respectively show the change of the average length, the average queue length, the average staying time and the average waiting time for this model when β is set from 0.1 to 1.

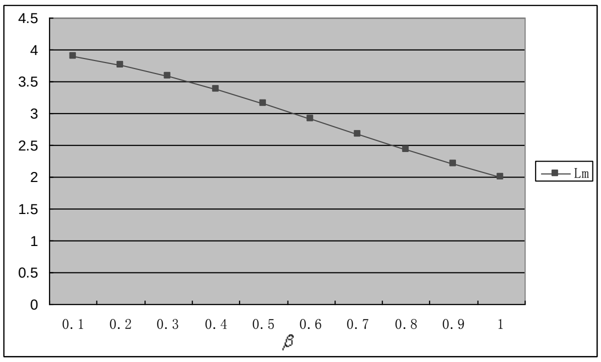

Figure 4. The Change of the Average Length for the Proposed M/M/1/K-FCFS Queuing Model when β is set from 0.1 to 1

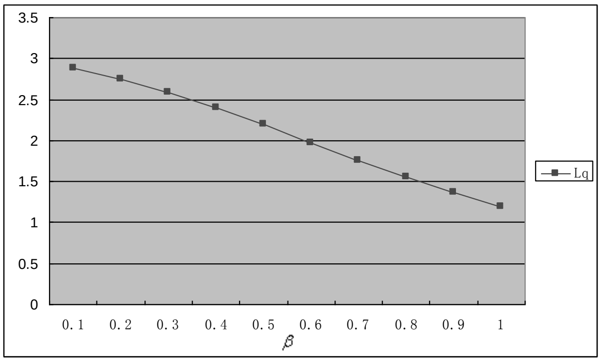

Figure 5. The Change of the Average Queue Length for the Proposed M/M/1/K-FCFS Queuing Model when β is Set from 0.1 to 1

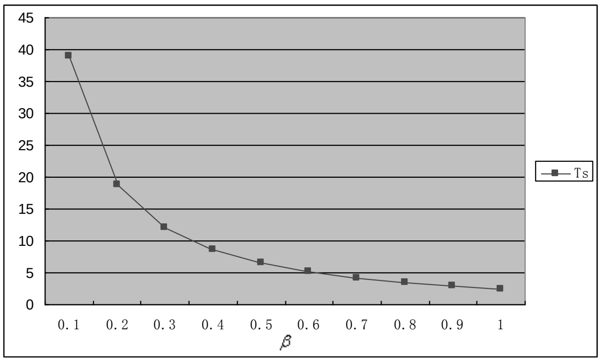

Figure 6. The Change of the Average Staying Time for the Proposed M/M/1/K-FCFS Queuing Model when β is Set from 0.1 to 1

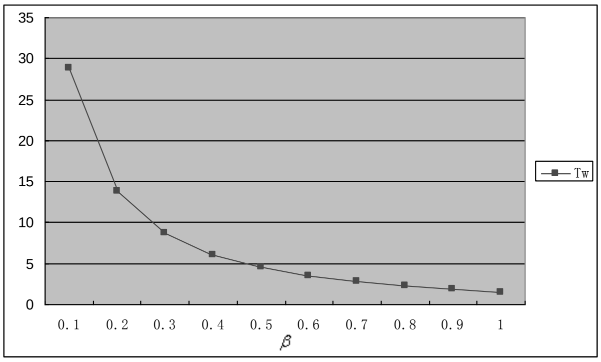

Figure 7. The Change of the Average Waiting Time for the Proposed M/M/1/K-FCFS Queuing Model when β is Set from 0.1 to 1

As is indicated in Figure 4-7, when β is set from 0.1 to 1, the average length, the average queue length, the average staying time and the average waiting time for the proposed M/M/1/K-FCFS queuing model in view of SDN management all reduce, and especially, both the average staying time and the average waiting time reduce with a significant change at the beginning and a relatively smooth speed then.

In summary, simulation results indicate that, the proposed queuing model for the management plane of SDN prospects a feasible way to understand the queuing principles between management applications and the SDN manager.

6. Conclusions

The main contribution of this paper is to study the SDN management roles, propose the framework of the management plane for SDN, discuss the SDN management operations, and utilize the queuing theory for SDN management, so as to promote the implementation of the management plane for SDN. Simulation results validate the feasibility of the proposed queuing model for the management plane of SDN based on the queuing theory, in order to understand the queuing principles between management applications and the SDN manager.

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