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**Software-Defined Networking Based Security Services using Interface to
Network Security Functions
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Abstract

This document describes a framework, use cases, and requirements for security services based on Software-Defined Networking (SDN) using a common interface to Network Security Functions (NSF). It specifies objectives and requirements in SDN-based security services using an interface to NSF (I2NSF). Also, it proposes two use cases, such as centralized firewall system and centralized DDoS-attack mitigation system.

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1. Introduction

Software-Defined Networking (SDN) is a set of techniques that enables users to directly program, orchestrate, control and manage network resources through software (e.g., SDN applications). It relocates the control of network resources to a dedicated network element, namely SDN controller. The SDN controller uses interfaces to arbitrate the control of network resources in a logically centralized manner. It also manages and configures the distributed network resources, and provides the abstracted view of the network resources to the SDN applications. The SDN applications can customize and automate the operations (including management) of the abstracted network resources in a programmable manner via the interfaces [[RFC7149](#)][ITU-T.Y.3300][[ONF-SDN-Architecture](#)][ONF-OpenFlow].

Due to the increase of sophisticated network attacks, the legacy security services become difficult to cope with such network attacks in an autonomous manner. SDN has been introduced to make networks more controllable and manageable, and this SDN technology will be promising to autonomously deal with such network attacks in a prompt manner.

This document describes a framework, objectives and requirements to support the protection of network resources through SDN-based security services using a common interface to Network Security Functions (NSF) [[i2nsf-framework](#)]. It uses an interface to NSF (I2NSF) for such SDN-based security services that are performed in virtual machines through network functions virtualization [[ETSI-NFV](#)].

This document addresses the challenges of the existing systems for security services. As feasible solutions to handle these challenges, this document proposes two use cases of the security services, such as centralized firewall system and centralized DDoS-attack mitigation system.

For the centralized firewall system, this document raises limitations in legacy firewalls in terms of flexibility and administration costs. Since in many cases, access control management for firewall is manually performed, it is difficult to add the access control policy rules corresponding to new network attacks in a prompt and autonomous manner. Thus, this situation requires expensive administration costs. This document introduces a use case of SDN-based firewall system to overcome these limitations.

For the centralized DDoS-attack mitigation system, this document raises limitations in legacy DDoS-attack mitigation techniques in terms of flexibility and administration costs. Since in many cases, network configuration for the mitigation is manually performed, it is

difficult to dynamically configure network devices to limit and control suspicious network traffic for DDoS attacks. This document introduces a use case of SDN-based DDoS-attack mitigation system to provide an autonomous and prompt configuration for suspicious network traffic.

2. Requirements Language

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC 2119](#) [[RFC2119](#)].

3. Terminology

This document uses the terminology described in [[RFC7149](#)], [[ITU-T.Y.3300](#)], [[ONF-SDN-Architecture](#)], [[ONF-OpenFlow](#)], [[ITU-T.X.1252](#)], and [[ITU-T.X.800](#)]. In addition, the following terms are defined below:

- o Software-Defined Networking: A set of techniques that enables to directly program, orchestrate, control, and manage network resources, which facilitates the design, delivery and operation of network services in a dynamic and scalable manner [[ITU-T.Y.3300](#)].
- o Access Control: A procedure used to determine if an entity should be granted access to resources, facilities, services, or information based on pre-established rules and specific rights or authority associated with the requesting party [[ITU-T.X.1252](#)].
- o Access Control Policy: The set of rules that define the conditions under which access may take place [[ITU-T.X.800](#)].
- o Access Control Policy Rules: Security policy rules concerning the provision of the access control service [[ITU-T.X.800](#)].
- o Network Resources: Network devices that can perform packet forwarding in a network system. The network resources include network switch, router, gateway, WiFi access points, and similar devices.
- o Firewall: A firewall that is a device or service at the junction of two network segments that inspects every packet that attempts to cross the boundary. It also rejects any packet that does not satisfy certain criteria for disallowed port numbers or IP addresses.
- o Centralized Firewall System: A centralized firewall that can establish and distribute access control policy rules into network

resources for efficient firewall management. These rules can be managed dynamically by a centralized server for firewall. SDN can work as a network-based firewall system through a standard interface between firewall applications and network resources.

- o Centralized DDoS-attack Mitigation System: A centralized mitigator that can establish and distribute access control policy rules into network resources for efficient DDoS-attack mitigation. These rules can be managed dynamically by a centralized server for DDoS-attack mitigation. SDN can work as a network-based mitigation system through a standard interface between DDoS-attack mitigation applications and network resources.

4. Overview

This section describes the referenced architecture to support SDN-based security services, such as centralized firewall system and centralized DDoS-attack mitigation system. Also, it describes a framework for SDN-based security services using I2NSF.

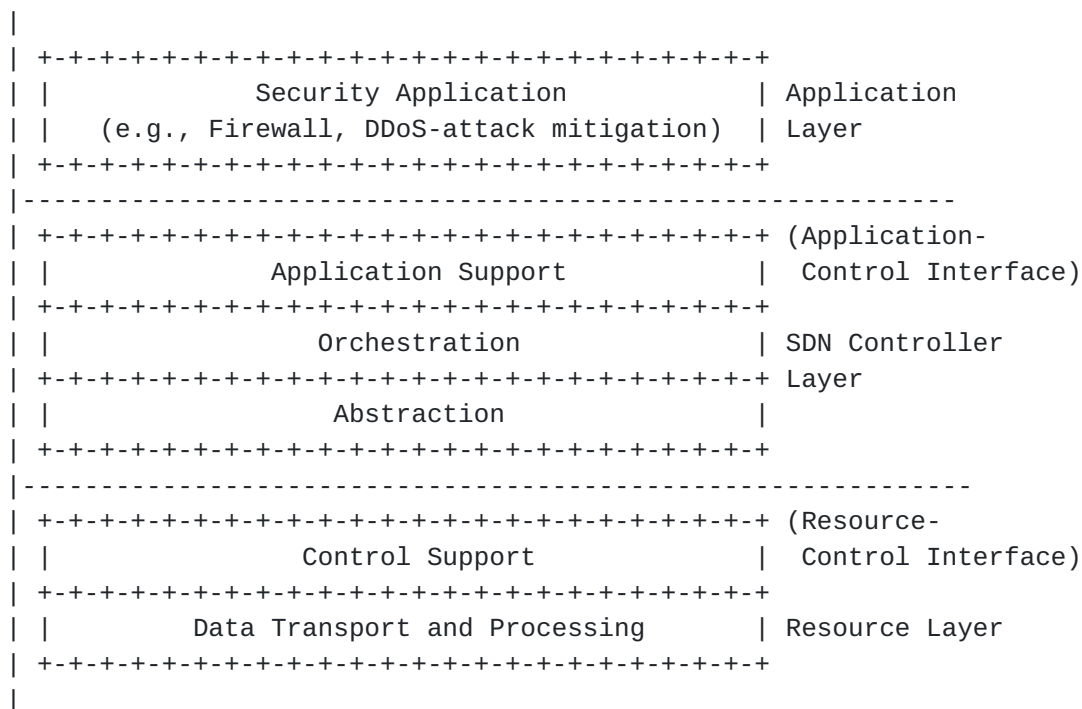


Figure 1: High-level Architecture for SDN-based Security Services

As shown in Figure 1, applications for security services (e.g., firewall and DDoS-attack mitigation) run on the top of SDN controller [ITU-T.Y.3300][ONF-SDN-Architecture]. When an administrator enforces security policies for the security services through an application interface, SDN controller generates the corresponding access control

policy rules to meet such security policies in an autonomous and prompt manner. According to the generated access control policy rules, the network resources such as switches take an action to mitigate network attacks, for example, dropping packets with suspicious patterns.

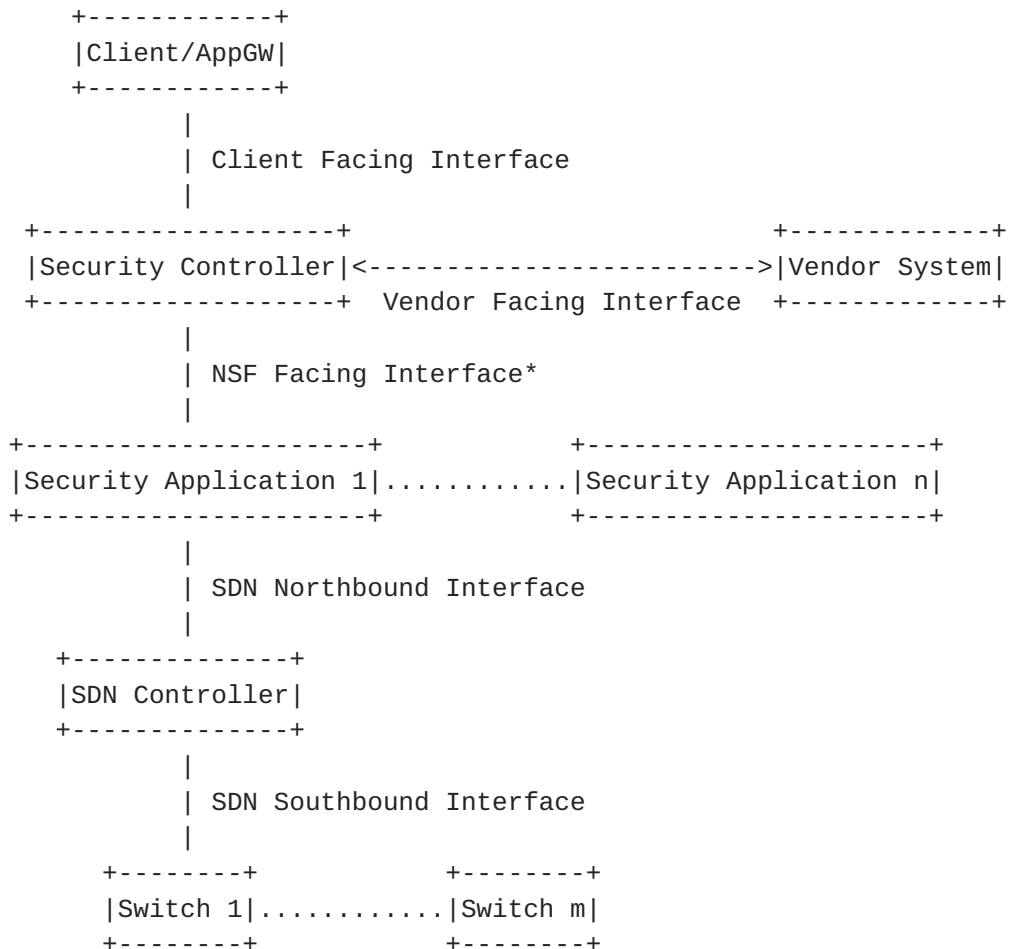


Figure 2: A Framework for SDN-based Security Services using I2NSF

Figure 2 shows a framework to support SDN-based security services using I2NSF [[i2nsf-framework](#)]. As shown in Figure 2, client and application gateway (AppGW) can use security services with their high-level security policies through security controller. Security controller calls function-level security services via NSF facing interface, which are performed by security applications, running on top of virtual machines through NFV [[ETSI-NFV](#)]. Security application asks SDN controller to perform its required security functions on switches under the supervision of SDN controller.

NSF facing interface between security controller and security applications can be implemented by Network Configuration Protocol

(NETCONF) [[RFC6241](#)] with a data modeling language called YANG [[RFC6020](#)] that describes function-level security services.

5. Objectives

- o Prompt reaction to new network attacks: SDN-based security services allow private networks to defend themselves against new sophisticated network attacks.
- o Automatic defense from network attacks: SDN-based security services identify the category of network attack (e.g., malware and DDoS attacks) and take counteraction for the defense without the intervention of network administrators.
- o Network-load-aware resource allocation: SDN-based security services measure the overhead of resources for security services and dynamically select resources considering load balance for the maximum network performance.

6. Requirements

SDN-based security services provide dynamic and flexible network resource management to mitigate network attacks, such as malware and DDoS attacks. In order to support this capability, the requirements for SDN-based security services are described as follows:

- o SDN-based security services are required to support the programmability of network resources to mitigate network attacks.
- o SDN-based security services are required to support the orchestration of network resources and SDN applications to mitigate network attacks.
- o SDN-based security services are required to provide an application interface allowing the management of access control policies in an autonomous and prompt manner.
- o SDN-based security services are required to provide a resource-control interface for the control of network resources to mitigate network attacks.
- o SDN-based security services are required to provide the logically centralized control of network resources to mitigate network attacks.

7. Use Cases

This section introduces two use cases for security services based on SDN: (i) centralized firewall system and (ii) centralized DDoS-attack mitigation system.

7.1. Centralized Firewall System

For the centralized firewall system, a centralized network firewall can manage each network resource and firewall rules can be managed flexibly by a centralized server for firewall (called Firewall). The centralized network firewall controls each switch for the network resource management and the firewall rules can be added or deleted dynamically.

The procedure of firewall operations in the centralized firewall system is as follows:

1. Switch forwards an unknown flow's packet to SDN Controller.
2. SDN Controller forwards the unknown flow's packet to an appropriate security service application, such as Firewall.
3. Firewall analyzes the headers and contents of the packet.
4. If Firewall regards the packet as a malware's packet with a suspicious pattern, it reports the malware's packet to SDN Controller.
5. SDN Controller installs new rules (e.g., drop packets with the suspicious pattern) into switches.
6. The malware's packets are dropped by switches.

For the above centralized firewall system, the existing SDN protocols can be used through standard interfaces between the firewall application and switches [[RFC7149](#)][ITU-T.Y.3300][[ONF-SDN-Architecture](#)][ONF-OpenFlow].

Legacy firewalls have some challenges such as the expensive cost, performance, management of access control, establishment of policy, and packet-based access mechanism. The proposed framework can resolve these challenges through the above centralized firewall system based on SDN as follows.

- o Cost: The cost of adding firewalls to network resources such as routers, gateways, and switches is substantial due to the reason that we need to add firewall on each network resource. To solve

this, each network resource can be managed centrally such that a single firewall is manipulated by a centralized server.

- o Performance: The performance of firewalls is often slower than the link speed of network interfaces. Every network resource for firewall needs to check firewall rules according to network conditions. Firewalls can be adaptively deployed among network switches, depending on network conditions in the framework.
- o The management of access control: Since there may be hundreds of network resources in an administered network, the dynamic management of access control for security services like firewall is a challenge. In the framework, firewall rules can be dynamically added for new malware.
- o The establishment of policy: Policy should be established for each network resource. However, it is difficult to describe what flows are permitted or denied for firewall within a specific organization network under management. Thus, a centralized view is helpful to determine security policies for such a network.
- o Packet-based access mechanism: Packet-based access mechanism is not enough for firewall in practice since the basic unit of access control is usually users or applications. Therefore, application level rules can be defined and added to the firewall system through the centralized server.

7.2. Centralized DDoS-attack Mitigation System

For the centralized DDoS-attack mitigation system, a centralized DDoS-attack mitigation can manage each network resource and manipulate rules to each switch through a centralized server for DDoS-attack mitigation (called DDoS-attack Mitigator). The centralized DDoS-attack mitigation system defends servers against DDoS attacks outside private network, that is, from public network.

Servers are categorized into stateless servers (e.g., DNS servers) and stateful servers (e.g., web servers). For DDoS-attack mitigation, traffic flows in switches are dynamically configured by traffic flow forwarding path management according to the category of servers [[AVANT-GUARD](#)]. Such a management should consider the load balance among the switches for the defense against DDoS attacks.

The procedure of DDoS-attack mitigation operations in the centralized DDoS-attack mitigation system is as follows:

1. Switch periodically reports an inter-arrival pattern of a flow's packets to SDN Controller.

2. SDN Controller forwards the flow's inter-arrival pattern to an appropriate security service application, such as DDoS-attack Mitigator.
3. DDoS-attack Mitigator analyzes the reported pattern for the flow.
4. If DDoS-attack Mitigator regards the pattern as a DDoS attack, it computes a packet dropping probability corresponding to suspiciousness level and reports this DDoS-attack flow to SDN Controller.
5. SDN Controller installs new rules into switches (e.g., forward packets with the suspicious inter-arrival pattern with a dropping probability).
6. The suspicious flow's packets are randomly dropped by switches with the dropping probability.

For the above centralized DDoS-attack mitigation system, the existing SDN protocols can be used through standard interfaces between the DDoS-attack mitigator application and switches [[RFC7149](#)] [[ITU-T.Y.3300](#)] [ONF-SDN-Architecture] [[ONF-OpenFlow](#)].

The centralized DDoS-attack mitigation system has challenges similar to the centralized firewall system. The proposed framework can resolve these challenges through the above centralized DDoS-attack mitigation system based on SDN as follows.

- o Cost: The cost of adding DDoS-attack mitigators to network resources such as routers, gateways, and switches is substantial due to the reason that we need to add DDoS-attack mitigator on each network resource. To solve this, each network resource can be managed centrally such that a single DDoS-attack mitigator is manipulated by a centralized server.
- o Performance: The performance of DDoS-attack mitigators is often slower than the link speed of network interfaces. The checking of DDoS attacks may reduce the performance of the network interfaces. DDoS-attack mitigators can be adaptively deployed among network switches, depending on network conditions in the framework.
- o The management of network resources: Since there may be hundreds of network resources in an administered network, the dynamic management of network resources for performance (e.g., load balancing) is a challenge for DDoS-attack mitigation. In the framework, as dynamic network resource management, traffic flow forwarding path management can handle the load balancing of network switches [[AVANT-GUARD](#)]. With this management, the current

and near-future workload can be spread among the network switches for DDoS-attack mitigation. In addition, DDoS-attack mitigation rules can be dynamically added for new DDoS attacks.

- o The establishment of policy: Policy should be established for each network resource. However, it is difficult to describe what flows are permitted or denied for new DDoS-attacks (e.g., DNS reflection attack) within a specific organization network under management. Thus, a centralized view is helpful to determine security policies for such a network.

8. Security Considerations

This document shares all the security issues of SDN that are specified in the "Security Considerations" section of [[ITU-T.Y.3300](#)].

9. Acknowledgements

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