Workgroup: I2NSF Working Group
Internet-Draft:
draft-ietf-i2nsf-registration-interface-dm-14
Published: 28 January 2022
Intended Status: Standards Track
Expires: 1 August 2022
Authors: S. Hyun, Ed.
Myongji University
J. Jeong, Ed.
Sungkyunkwan University
T. Roh
Sungkyunkwan University
S. Wi
Sungkyunkwan University
J. Park
ETRI

I2NSF Registration Interface YANG Data Model

Abstract

This document defines an information model and a YANG data model for Registration Interface between Security Controller and Developer's Management System (DMS) in the Interface to Network Security Functions (I2NSF) framework to register Network Security Functions (NSF) of the DMS with the Security Controller. The objective of these information and data models is to support NSF capability registration and query via I2NSF Registration Interface.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-Drafts is at https://datatracker.ietf.org/drafts/current/.

Internet-Drafts are draft documents valid for a maximum of six months and may be updated, replaced, or obsoleted by other documents at any time. It is inappropriate to use Internet-Drafts as reference material or to cite them other than as "work in progress."

This Internet-Draft will expire on 1 August 2022.

Copyright Notice

Copyright (c) 2022 IETF Trust and the persons identified as the document authors. All rights reserved.

This document is subject to BCP 78 and the IETF Trust's Legal Provisions Relating to IETF Documents (https://trustee.ietf.org/license-info) in effect on the date of

publication of this document. Please review these documents carefully, as they describe your rights and restrictions with respect to this document. Code Components extracted from this document must include Revised BSD License text as described in Section 4.e of the Trust Legal Provisions and are provided without warranty as described in the Revised BSD License.

Table of Contents

1. Introduction
2. Terminology
3. Objectives
4. Information Model
  4.1. NSF Capability Registration
    4.1.1. NSF Capability Information
    4.1.2. NSF Access Information
  4.2. NSF Capability Query
5. Data Model
  5.1. YANG Tree Diagram
    5.1.1. Definition of Symbols in Tree Diagrams
    5.1.2. I2NSF Registration Interface
    5.1.3. NSF Capability Information
    5.1.4. NSF Access Information
  5.2. YANG Data Modules
6. IANA Considerations
7. Security Considerations
8. References
  8.1. Normative References
  8.2. Informative References
Appendix A. XML Examples of I2NSF Registration Interface Data Model
  A.1. Example 1: Registration for the Capabilities of a General Firewall
  A.2. Example 2: Registration for the Capabilities of a Time-based Firewall
  A.3. Example 3: Registration for the Capabilities of a Web Filter
  A.4. Example 4: Registration for the Capabilities of a VoIP/VoLTE Filter
  A.5. Example 5: Registration for the Capabilities of a DDoS Mitigator
  A.6. Example 6: Query for the Capabilities of a Time-based Firewall
Appendix B. NSF Lifecycle Management in NFV Environments
Appendix C. Acknowledgments
Appendix D. Contributors
Appendix E. Changes from draft-ietf-i2nsf-registration-interface-dm-13
Authors' Addresses

1. Introduction

A number of Network Security Functions (NSF) may exist in the Interface to Network Security Functions (I2NSF) framework [RFC8329]. Since each of these NSFs likely has different security capabilities from each other, it is important to register the security capabilities of the NSF with the security controller. In addition, it is required to search NSFs of some required security capabilities on demand. As an example, if additional security capabilities are required to serve some security service request(s) from an I2NSF user, the security controller SHOULD be able to request the DMS for NSFs that have the required security capabilities.

This document describes an information model (see Section 4) and a YANG [RFC7950] data model (see Section 5) for the I2NSF Registration Interface [RFC8329] between the security controller and the developer's management system (DMS) to support NSF capability registration and query via the registration interface. It also describes the operations which SHOULD be performed by the security controller and the DMS via the Registration Interface using the defined model.

2. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

This document uses the following terms defined in [RFC8329] and [I-D.ietf-i2nsf-capability-data-model].

* Network Security Function (NSF): A function that is responsible for a specific treatment of received packets. A Network Security Function can act at various layers of a protocol stack (e.g., at the network layer or other OSI layers). Sample Network Security Service Functions are as follows: Firewall, Intrusion Prevention/ Detection System (IPS/IDS), Deep Packet Inspection (DPI), Application Visibility and Control (AVC), network virus and malware scanning, sandbox, Data Loss Prevention (DLP), Distributed Denial of Service (DDoS) mitigation and TLS proxy.

* Data Model: A data model is a representation of concepts of interest to an environment in a form that is dependent on data repository, data definition language, query language, implementation language, and protocol.

* Information Model: An information model is a representation of concepts of interest to an environment in a form that is

independent of data repository, data definition language, query language, implementation language, and protocol.

*YANG: This document follows the guidelines of [RFC8407], uses the common YANG types defined in [RFC6991], and adopts the Network Management Datastore Architecture (NMDA) [RFC8342]. The meaning of the symbols in tree diagrams is defined in [RFC8340].

3. Objectives

*Registering NSFs to I2NSF framework: Developer's Management System (DMS) in I2NSF framework is typically run by an NSF vendor, and uses Registration Interface to provide NSFs developed by the NSF vendor to Security Controller. DMS registers NSFs and their capabilities to I2NSF framework through Registration Interface. For the registered NSFs, Security Controller maintains a catalog of the capabilities of those NSFs.

*Updating the capabilities of registered NSFs: After an NSF is registered into Security Controller, some modifications on the capability of the NSF MAY be required later. In this case, DMS uses Registration Interface to update the capability of the NSF, and this update SHOULD be reflected in the catalog of NSFs.

*Asking DMS about some required capabilities: In cases that some security capabilities are required to serve the security service request from an I2NSF user, Security Controller searches through the registered NSFs to find ones that can provide the required capabilities. But Security Controller might fail to find any NSFs having the required capabilities among the registered NSFs. In this case, Security Controller needs to request DMS for additional NSF(s) that can provide the required security capabilities via Registration Interface.

4. Information Model

The I2NSF registration interface is used by Security Controller and Developer's Management System (DMS) in I2NSF framework. The following summarizes the operations done through the registration interface:

1) DMS registers NSFs and their capabilities to Security Controller via the registration interface. DMS also uses the registration interface to update the capabilities of the NSFs registered previously.

2) In case that Security Controller fails to find some required capabilities from any registered NSF that can provide , Security Controller queries DMS about NSF(s) having the required capabilities via the registration interface.

Figure 1 shows the information model of the I2NSF registration interface, which consists of two submodels: NSF capability registration and NSF capability query. Each submodel is used for the operations listed above. The remainder of this section will provide in-depth explanations of each submodel.

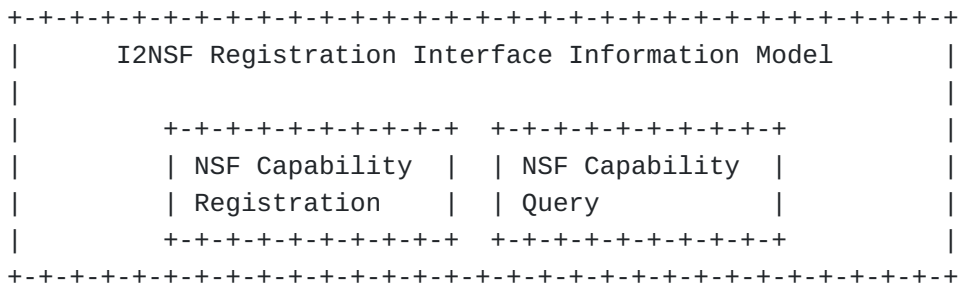


Figure 1: I2NSF Registration Interface Information Model

4.1. NSF Capability Registration

This submodel is used by DMS to register an NSF with Security Controller. Figure 2 shows how this submodel is constructed. The most important part in Figure 2 is the NSF capability, and this specifies the set of capabilities that the NSF to be registered can offer. The NSF Name contains a unique name of this NSF with the specified set of capabilities. When registering the NSF, DMS additionally includes the network access information of the NSF which is required to enable network communications with the NSF.

The following will further explain the NSF capability information and the NSF access information in more detail.

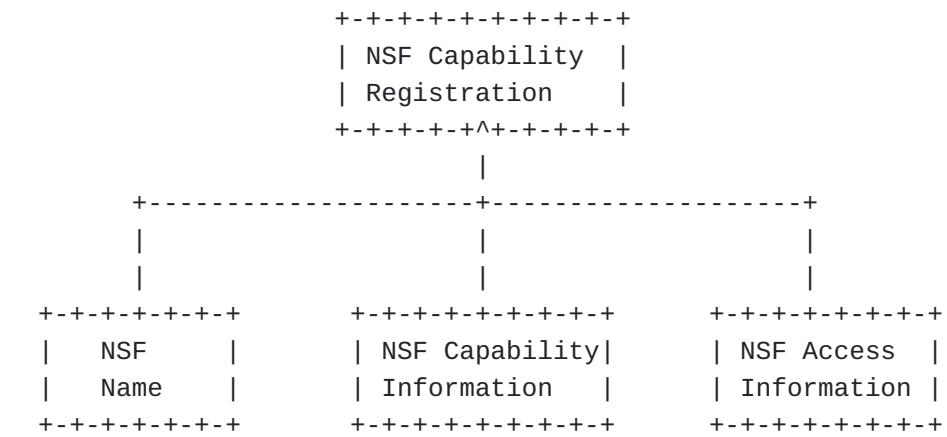


Figure 2: NSF Capability Registration Sub-Model

4.1.1. NSF Capability Information

NSF Capability Information basically describes the security capabilities of an NSF. In Figure 3, we show capability objects of an NSF. Following the information model of NSF capabilities defined in [I-D.ietf-i2nsf-capability-data-model], we share the same I2NSF security capabilities: Time Capabilities, Event Capabilities, Condition Capabilities, Action Capabilities, Resolution Strategy Capabilities, Default Action Capabilities, and IPsec Method [RFC9061]. Also, NSF Capability Information additionally contains the performance capabilities of an NSF as shown in Figure 3.

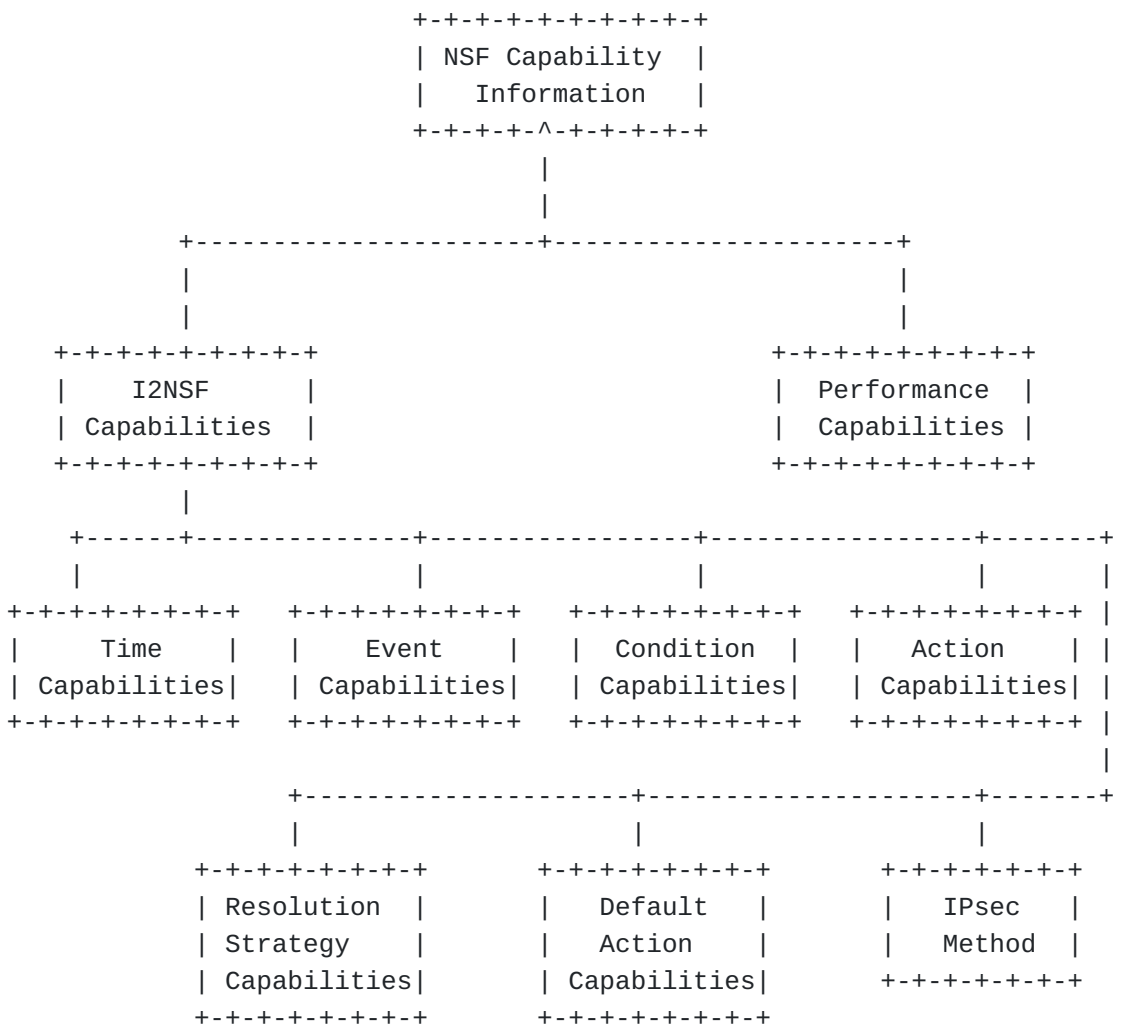


Figure 3: NSF Capability Information

4.1.1.1. Performance Capabilities

This information represents the processing capability of an NSF. Assuming that the current workload status of each NSF is being collected through NSF monitoring [I-D.ietf-i2nsf-nsf-monitoring-

data-model], this capability information of the NSF can be used to determine whether the NSF is in congestion by comparing it with the current workload of the NSF. Moreover, this information can specify an available amount of each type of resource, such as processing power which are available on the NSF. (The registration interface can control the usages and limitations of the created instance and make the appropriate request according to the status.) As illustrated in Figure 4, this information consists of two items: Processing and Bandwidth. Processing information describes the NSF's available processing power. Bandwidth describes the information about available network amount in two cases, outbound, inbound. These two information can be used for the NSF's instance request.

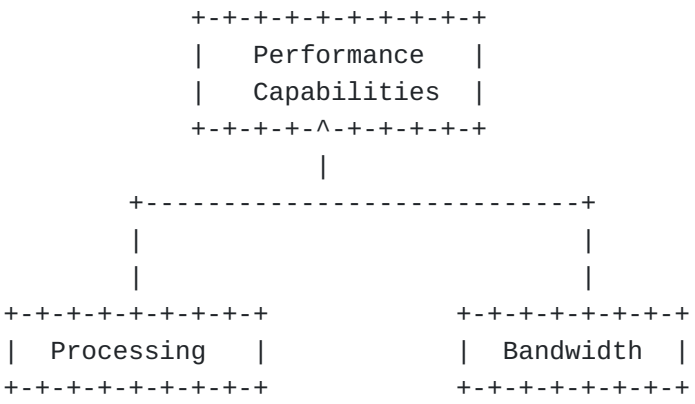


Figure 4: Performance Capability Overview

4.1.2. NSF Access Information

NSF Access Information contains the followings that are required to communicate with an NSF: IPv4 address, IPv6 address, port number, and supported transport protocol(s) (e.g., Virtual Extensible LAN (VXLAN) [RFC7348], Generic Protocol Extension for VXLAN (VXLAN-GPE) [I-D.ietf-nvo3-vxlan-gpe], Generic Route Encapsulation (GRE), Ethernet etc.). In this document, NSF Access Information is used to identify a specific NSF instance (i.e. NSF Access Information is the signature(unique identifier) of an NSF instance in the overall system).

4.2. NSF Capability Query

Security Controller MAY require some additional capabilities to serve the security service request from an I2NSF user, but none of the registered NSFs has the required capabilities. In this case, Security Controller makes a description of the required capabilities by using the NSF capability information sub-model in Section 4.1.1, and sends DMS a query about which NSF(s) can provide these capabilities.

5. Data Model

5.1. YANG Tree Diagram

This section provides the YANG Tree diagram of the I2NSF registration interface.

5.1.1. Definition of Symbols in Tree Diagrams

A simplified graphical representation of the data model is used in this section. The meaning of the symbols used in the following diagrams [RFC8431] is as follows:

Brackets "[" and "]" enclose list keys.

Abbreviations before data node names: "rw" means configuration (read-write) and "ro" state data (read-only).

Symbols after data node names: "?" means an optional node and "*" denotes a "list" and "leaf-list".

Parentheses enclose choice and case nodes, and case nodes are also marked with a colon (":").

Ellipsis ("...") stands for contents of subtrees that are not shown.

5.1.2. I2NSF Registration Interface

```
module : ietf-i2nsf-reg-interface
      +--rw nsf-capability-registration
      |  uses nsf-registrations

rpcs :
      +---x i2nsf-capability-query
      |  uses nsf-capability-query
```

Figure 5: YANG Tree of I2NSF Registration Interface

The I2NSF registration interface is used for the following purposes. Developer's Management System (DMS) registers NSFs and their capabilities into Security Controller via the registration interface. In case that Security Controller fails to find any NSF among the registered NSFs which can provide some required capabilities, Security Controller uses the registration interface to query DMS about NSF(s) having the required capabilities. The following sections describe the YANG data models to support these operations.

5.1.2.1. NSF Capability Registration

This section expands the i2nsf-nsf-registrations in Figure 5.

```
NSF Capability Registration
 +--rw nsf-registrations
     +--rw nsf-information*  [nsf-name]
        +--rw nsf-name       string
        +--rw nsf-capability-info
        |  uses nsf-capability-info
              +--rw security-capability
              |  uses ietf-i2nsf-capability
              +--rw performance-capability
              |  uses performance-capability
        +--rw nsf-access-info
           +--rw ip
           +--rw port
```

Figure 6: YANG Tree of NSF Capability Registration Module

When registering an NSF to Security Controller, DMS uses this module to describe what capabilities the NSF can offer. DMS includes the network access information of the NSF which is required to make a network connection with the NSF as well as the capability description of the NSF.

5.1.2.2. NSF Capability Query

This section expands the nsf-capability-query in Figure 5.

```
I2NSF Capability Query
  +---x nsf-capability-query
      +---w input
      |  +---w query-nsf-capability
      |  |   uses ietf-i2nsf-capability
      +--ro output
          +--ro nsf-access-info
              +--rw nsf-name
              +--rw ip
              +--rw port
```

Figure 7: YANG Tree of NSF Capability Query Module

Security Controller MAY require some additional capabilities to provide the security service requested by an I2NSF user, but none of the registered NSFs has the required capabilities. In this case, Security Controller makes a description of the required capabilities using this module and then queries DMS about which NSF(s) can

provide these capabilities. Use NETCONF RPCs to send a NSF capability query. Input data is query-i2nsf-capability-info and output data is nsf-access-info. In Figure 7, the ietf-i2nsf-capability refers to the module defined in [I-D.ietf-i2nsf-capability-data-model].

5.1.3. NSF Capability Information

This section expands the nsf-capability-info in Figure 6 and Figure 7.

```
NSF Capability Information
  +--rw nsf-capability-info
    +--rw security-capability
    |  uses ietf-i2nsf-capability
    +--rw performance-capability
    |  uses nsf-performance-capability
```

Figure 8: YANG Tree of I2NSF NSF Capability Information

In Figure 8, the ietf-i2nsf-capability refers to the module defined in [I-D.ietf-i2nsf-capability-data-model]. The performance-capability is used to specify the performance capability of an NSF.

5.1.3.1. NSF Performance Capability

This section expands the nsf-performance-capability in Figure 8.

```
NSF Performance Capability
  +--rw nsf-performance-capability
   +--rw processing
   |   +--rw processing-average  uint16
   |   +--rw processing-peak     uint16
   +--rw bandwidth
   |   +--rw outbound
   |   |  +--rw outbound-average  uint16
   |   |  +--rw outbound-peak     uint16
   |   +--rw inbound
   |   |  +--rw inbound-average   uint16
   |   |  +--rw inbound-peak      uint16
```

Figure 9: YANG Tree of I2NSF NSF Performance Capability

This module is used to specify the performance capabilities of an NSF when registering or initiating the NSF.

5.1.4. NSF Access Information

This section expands the nsf-access-info in Figure 6.

```
NSF Access Information
  +--rw nsf-access-info
    +--rw ip      inet:ip-address-no-zone
    +--rw port    inet:port-number
```

Figure 10: YANG Tree of I2NSF NSF Access Informantion

This module contains the network access information of an NSF that is required to enable network communications with the NSF. The field of ip can have either an IPv4 address or an IPv6 address.

5.2. YANG Data Modules

This section provides a YANG module of the data model for the registration interface between Security Controller and Developer's Management System, as defined in Section 4.

This YANG module imports from [RFC6991], and makes a reference to [I-D.ietf-i2nsf-capability-data-model].

```
<CODE BEGINS> file "ietf-i2nsf-reg-interface@2022-01-28.yang"

module ietf-i2nsf-reg-interface {
  yang-version 1.1;

  namespace "urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface";

  prefix nsfreg;

  //RFC Ed.: replace occurences of XXXX with actual RFC number and
  //remove this note

  import ietf-inet-types {
    prefix inet;
    reference "RFC 6991";
  }
  import ietf-i2nsf-capability {
    prefix nsfcap;
  // RFC Ed.: replace YYYY with actual RFC number of
  // draft-ietf-i2nsf-capability-data-model and remove this note.
    reference "RFC YYYY: I2NSF Capability YANG Data Model";
  }

  organization
   "IETF I2NSF (Interface to Network Security Functions)
    Working Group";

  contact
    "WG Web: <https://datatracker.ietf.org/wg/i2nsf>
     WG List: <mailto:i2nsf@ietf.org>

     Editor: Sangwon Hyun
     <mailto:shyun@mju.ac.kr>

     Editor: Jaehoon Paul Jeong
     <mailto:pauljeong@skku.edu>";

  description
    "This module defines a YANG data model for I2NSF
     Registration Interface.

     The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL',
     'SHALL NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED',
     'NOT RECOMMENDED', 'MAY', and 'OPTIONAL' in this
     document are to be interpreted as described in BCP 14
     (RFC 2119) (RFC 8174) when, and only when, they appear
     in all capitals, as shown here.

     Copyright (c) 2022 IETF Trust and the persons
     identified as authors of the code. All rights reserved.
```

```
   Redistribution and use in source and binary forms, with or
   without modification, is permitted pursuant to, and subject
   to the license terms contained in, the Simplified BSD License
   set forth in Section 4.c of the IETF Trust's Legal Provisions
   Relating to IETF Documents
   (https://trustee.ietf.org/license-info).

   This version of this YANG module is part of RFC XXXX; see
   the RFC itself for full legal notices.";

revision "2022-01-28" {
  description "Initial revision";
  reference
    "RFC XXXX: I2NSF Registration Interface YANG Data Model";
  // RFC Ed.: replace XXXX with actual RFC number and remove
  // this note
}

grouping nsf-performance-capability {
  description
    "Description of the performance capabilities of an NSF";

  container processing {
    description
      "Processing power of an NSF in the unit of GHz (gigahertz)";

    leaf processing-average {
      type uint16;
      units "GHz";
      description
        "Average processing power";
    }
    leaf processing-peak {
      type uint16;
      units "GHz";
      description
        "Peak processing power";
    }
  }

  container bandwidth {
    description
      "Network bandwidth available on an NSF
       in the unit of Mbps (megabits per second)";

    container outbound {
      description
        "Outbound network bandwidth";
      leaf outbound-average {
```

```
        type uint32;
        units "Mbps";
        description
          "Average outbound bandwidth";
      }
      leaf outbound-peak {
        type uint32;
        units "Mbps";
        description
          "Peak outbound bandwidth";
      }
    }

    container inbound {
      description
        "Inbound network bandwidth";
      leaf inbound-average {
        type uint32;
        units "Mbps";
        description
          "Average inbound bandwidth";
      }
      leaf inbound-peak {
        type uint32;
        units "Mbps";
        description
          "Peak inbound bandwidth";
      }
    }
  }
}

grouping nsf-capability-info {
  description
    "Capability description of an NSF";
  container security-capability {
    description
      "Description of the security capabilities of an NSF";
    uses nsfcap:nsf-capabilities;
    reference "RFC YYYY: I2NSF Capability YANG Data Model";
    // RFC Ed.: replace YYYY with actual RFC number of
    // draft-ietf-i2nsf-capability-data-model and remove this note.
  }
  container performance-capability {
    description
      "Description of the performance capabilities of an NSF";
    uses nsf-performance-capability;
  }
}
```

```
grouping nsf-access-info {
  description
    "Information required to access an NSF";
  leaf ip {
    type inet:ip-address-no-zone;
    description
      "Either an IPv4 address or an IPv6 address of this NSF";
  }
  leaf port {
    type inet:port-number;
    description
      "Port available on this NSF";
  }
}

container nsf-registrations {
  description
    "Information of an NSF that DMS registers
     to Security Controller";
  list nsf-information {
    key "nsf-name";
    description
      "Required information for registration";
    leaf nsf-name {
      type string;
      description
      "The name of this registered NSF. The NSF name MUST be unique
       to identify the NSF with the capability. The name can be an
       arbitrary string including FQDN (Fully Qualified Domain
       Name).";
    }
    container nsf-capability-info {
      description
        "Capability description of this NSF";
      uses nsf-capability-info;
    }
    container nsf-access-info {
      description
        "Network access information of this NSF";
      uses nsf-access-info;
    }
  }
}

rpc nsf-capability-query {
  description
    "Description of the capabilities that the
     Security Controller requests to the DMS";
```

```
    input {
      container query-nsf-capability {
        description
          "Description of the capabilities to request";
        uses nsfcap:nsf-capabilities;
        reference "RFC YYYY: I2NSF Capability YANG Data Model";
      //RFC Ed.: replace YYYY with actual RFC number of
      //draft-ietf-i2nsf-capability-data-model and remove this note.
      }
    }
    output {
      container nsf-access-info {
        description
          "Network access information of an NSF
           with the requested capabilities";
        leaf nsf-name {
          type string;
          description
          "The name of this registered NSF. The NSF name MUST be
           unique to identify the NSF with the capability. The name
           can be an arbitrary string including FQDN (Fully Qualified
           Domain Name).";
        }
        uses nsf-access-info;
      }
    }
  }
}

<CODE ENDS>
```

Figure 11: Registration Interface YANG Data Model

6. IANA Considerations

This document requests IANA to register the following URI in the "IETF XML Registry" [RFC3688]:

```
URI: urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface
Registrant Contact: The IESG.
XML: N/A; the requested URI is an XML namespace.
```

This document requests IANA to register the following YANG module in the "YANG Module Names" registry [RFC7950][RFC8525]:

```
Name: ietf-i2nsf-reg-interface
Namespace: urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface
Prefix: nsfreg
Reference: RFC XXXX

// RFC Ed.: replace XXXX with actual RFC number and remove
// this note
```

7. Security Considerations

The YANG module specified in this document defines a data schema designed to be accessed through network management protocols such as NETCONF [RFC6241] or RESTCONF [RFC8040]. The lowest NETCONF layer is the secure transport layer, and the required secure transport is Secure Shell (SSH) [RFC6242]. The lowest RESTCONF layer is HTTPS, and the required secure transport is TLS [RFC8446].

The NETCONF access control model [RFC8341] provides a means of restricting access to specific NETCONF or RESTCONF users to a preconfigured subset of all available NETCONF or RESTCONF protocol operations and content.

There are a number of data nodes defined in this YANG module that are writable/creatable/deletable (i.e., config true, which is the default). These data nodes MAY be considered sensitive or vulnerable in some network environments. Write operations (e.g., edit-config) to these data nodes without proper protection can have a negative effect on network operations. These are the subtrees and data nodes and their sensitivity/vulnerability:

- nsf-registrations: The attacker MAY exploit this to register a compromised or malicious NSF instead of a legitimate NSF with the Security Controller.

- nsf-performance-capability: The attacker MAY provide incorrect information of the performance capability of any target NSF by illegally modifying this.

- nsf-capability-info: The attacker MAY provide incorrect information of the security capability of any target NSF by illegally modifying this.

- nsf-access-info: The attacker MAY provide incorrect network access information of any target NSF by illegally modifying this.

Some of the readable data nodes in this YANG module MAY be considered sensitive or vulnerable in some network environments. It is thus important to control read access (e.g., via get, get-config,

or notification) to these data nodes. These are the subtrees and data nodes and their sensitivity/vulnerability:

- *nsf-registrations: The attacker MAY try to gather some sensitive information of a registered NSF by sniffing this.

- *nsf-performance-capability: The attacker MAY gather the performance capability information of any target NSF and misuse the information for subsequent attacks.

- *nsf-capability-info: The attacker MAY gather the security capability information of any target NSF and misuse the information for subsequent attacks.

- *nsf-access-info: The attacker MAY gather the network access information of any target NSF and misuse the information for subsequent attacks.

The RPC operation in this YANG module MAY be considered sensitive or vulnerable in some network environments. It is thus important to control access to this operation. The following is the operation and its sensitivity/vulnerability:

- *nsf-capability-query: The attacker MAY exploit this RPC operation to deteriorate the availability of the DMS and/or gather the information of some interested NSFs from the DMS.

8. References

8.1. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/info/rfc2119>.

[RFC3688] Mealling, M., "The IETF XML Registry", BCP 81, RFC 3688, DOI 10.17487/RFC3688, January 2004, <https://www.rfc-editor.org/info/rfc3688>.

[RFC6241] Enns, R., Ed., Bjorklund, M., Ed., Schoenwaelder, J., Ed., and A. Bierman, Ed., "Network Configuration Protocol

(NETCONF)", RFC 6241, DOI 10.17487/RFC6241, June 2011, <https://www.rfc-editor.org/info/rfc6241>.

[RFC6242] Wasserman, M., "Using the NETCONF Protocol over Secure Shell (SSH)", RFC 6242, DOI 10.17487/RFC6242, June 2011, <https://www.rfc-editor.org/info/rfc6242>.

[RFC6991] Schoenwaelder, J., Ed., "Common YANG Data Types", RFC 6991, DOI 10.17487/RFC6991, July 2013, <https://www.rfc-editor.org/info/rfc6991>.

[RFC7950] Bjorklund, M., Ed., "The YANG 1.1 Data Modeling Language", RFC 7950, DOI 10.17487/RFC7950, August 2016, <https://www.rfc-editor.org/info/rfc7950>.

[RFC8040] Bierman, A., Bjorklund, M., and K. Watsen, "RESTCONF Protocol", RFC 8040, DOI 10.17487/RFC8040, January 2017, <https://www.rfc-editor.org/info/rfc8040>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

[RFC8329] Lopez, D., Lopez, E., Dunbar, L., Strassner, J., and R. Kumar, "Framework for Interface to Network Security Functions", RFC 8329, DOI 10.17487/RFC8329, February 2018, <https://www.rfc-editor.org/info/rfc8329>.

[RFC8340] Bjorklund, M. and L. Berger, Ed., "YANG Tree Diagrams", BCP 215, RFC 8340, DOI 10.17487/RFC8340, March 2018, <https://www.rfc-editor.org/info/rfc8340>.

[RFC8341] Bierman, A. and M. Bjorklund, "Network Configuration Access Control Model", STD 91, RFC 8341, DOI 10.17487/RFC8341, March 2018, <https://www.rfc-editor.org/info/rfc8341>.

[RFC8342] Bjorklund, M., Schoenwaelder, J., Shafer, P., Watsen, K., and R. Wilton, "Network Management Datastore Architecture (NMDA)", RFC 8342, DOI 10.17487/RFC8342, March 2018, <https://www.rfc-editor.org/info/rfc8342>.

[RFC8407] Bierman, A., "Guidelines for Authors and Reviewers of Documents Containing YANG Data Models", BCP 216, RFC 8407, DOI 10.17487/RFC8407, October 2018, <https://www.rfc-editor.org/info/rfc8407>.

[RFC8431] Wang, L., Chen, M., Dass, A., Ananthakrishnan, H., Kini, S., and N. Bahadur, "A YANG Data Model for the Routing Information Base (RIB)", RFC 8431, DOI 10.17487/RFC8431,

September 2018, <https://www.rfc-editor.org/info/rfc8431>.

[RFC8446] Rescorla, E., "The Transport Layer Security (TLS) Protocol Version 1.3", RFC 8446, DOI 10.17487/RFC8446, August 2018, <https://www.rfc-editor.org/info/rfc8446>.

[RFC8525] Bierman, A., Bjorklund, M., Schoenwaelder, J., Watsen, K., and R. Wilton, "YANG Library", RFC 8525, DOI 10.17487/RFC8525, March 2019, <https://www.rfc-editor.org/info/rfc8525>.

[I-D.ietf-i2nsf-capability-data-model]
Hares, S., Jeong, J. (., Kim, J. (., Moskowitz, R., and Q. Lin, "I2NSF Capability YANG Data Model", Work in Progress, Internet-Draft, draft-ietf-i2nsf-capability-data-model-22, 22 January 2022, <https://www.ietf.org/archive/id/draft-ietf-i2nsf-capability-data-model-22.txt>.

8.2. Informative References

[RFC3849] Huston, G., Lord, A., and P. Smith, "IPv6 Address Prefix Reserved for Documentation", RFC 3849, DOI 10.17487/RFC3849, July 2004, <https://www.rfc-editor.org/info/rfc3849>.

[RFC5737] Arkko, J., Cotton, M., and L. Vegoda, "IPv4 Address Blocks Reserved for Documentation", RFC 5737, DOI 10.17487/RFC5737, January 2010, <https://www.rfc-editor.org/info/rfc5737>.

[RFC7348]
Mahalingam, M., Dutt, D., Duda, K., Agarwal, P., Kreeger, L., Sridhar, T., Bursell, M., and C. Wright, "Virtual eXtensible Local Area Network (VXLAN): A Framework for Overlaying Virtualized Layer 2 Networks over Layer 3 Networks", RFC 7348, DOI 10.17487/RFC7348, August 2014, <https://www.rfc-editor.org/info/rfc7348>.

[RFC9061] Marin-Lopez, R., Lopez-Millan, G., and F. Pereniguez-Garcia, "A YANG Data Model for IPsec Flow Protection Based on Software-Defined Networking (SDN)", RFC 9061, DOI 10.17487/RFC9061, July 2021, <https://www.rfc-editor.org/info/rfc9061>.

[I-D.ietf-i2nsf-nsf-monitoring-data-model]
Jeong, J. (., Lingga, P., Hares, S., Xia, L. (., and H. Birkholz, "I2NSF NSF Monitoring Interface YANG Data Model", Work in Progress, Internet-Draft, draft-ietf-

i2nsf-nsf-monitoring-data-model-12, 17 November 2021, <https://www.ietf.org/archive/id/draft-ietf-i2nsf-nsf-monitoring-data-model-12.txt>.

[I-D.ietf-nvo3-vxlan-gpe] (Editor), F. M., (editor), L. K., and U. E. (editor), "Generic Protocol Extension for VXLAN (VXLAN-GPE)", Work in Progress, Internet-Draft, draft-ietf-nvo3-vxlan-gpe-12, 22 September 2021, <https://www.ietf.org/archive/id/draft-ietf-nvo3-vxlan-gpe-12.txt>.

[nfv-framework] "Network Functions Virtualisation (NFV); Architectureal Framework", ETSI GS NFV 002 ETSI GS NFV 002 V1.1.1, October 2013.

Appendix A. XML Examples of I2NSF Registration Interface Data Model

This section describes XML examples of the I2NSF Registration Interface data model under the assumption of registering several types of NSFs and querying NSF capability.

A.1. Example 1: Registration for the Capabilities of a General Firewall

This section shows an XML example for registering the capabilities of a general firewall in either IPv4 networks [RFC5737] or IPv6 networks [RFC3849].

```
<nsf-registrations
 xmlns="urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface"
 xmlns:nsfcap="urn:ietf:params:xml:ns:yang:ietf-i2nsf-capability">
 <nsf-information>
  <nsf-name>general_firewall</nsf-name>
  <nsf-capability-info>
   <security-capability>
    <condition-capabilities>
     <generic-nsf-capabilities>
      <ipv4-capability>nsfcap:next-header</ipv4-capability>
      <ipv4-capability>nsfcap:source-address</ipv4-capability>
      <ipv4-capability>nsfcap:destination-address</ipv4-capability>
      <tcp-capability>nsfcap:source-port-number</tcp-capability>
      <tcp-capability>nsfcap:destination-port-number</tcp-capability>
     </generic-nsf-capabilities>
    </condition-capabilities>
    <action-capabilities>
     <ingress-action-capability>
      nsfcap:pass
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:drop
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:mirror
     </ingress-action-capability>
     <egress-action-capability>
      nsfcap:pass
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:drop
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:mirror
     </egress-action-capability>
    </action-capabilities>
   </security-capability>
   <performance-capability>
    <processing>
     <processing-average>1000</processing-average>
     <processing-peak>5000</processing-peak>
    </processing>
    <bandwidth>
     <outbound>
      <outbound-average>1000</outbound-average>
      <outbound-peak>5000</outbound-peak>
     </outbound>
     <inbound>
      <inbound-average>1000</inbound-average>
```

```
      <inbound-peak>5000</inbound-peak>
     </inbound>
    </bandwidth>
   </performance-capability>
  </nsf-capability-info>
  <nsf-access-info>
   <ip>192.0.2.11</ip>
   <port>49152</port>
  </nsf-access-info>
 </nsf-information>
</nsf-registrations>
```

Figure 12: Configuration XML for Registration of a General Firewall in an IPv4 Network

Figure 12 shows the configuration XML for registering a general firewall in an IPv4 network [RFC5737] and its capabilities as follows.

1. The instance name of the NSF is general_firewall.

2. The NSF can inspect IPv4 protocol header field, source address(es), and destination address(es)

3. The NSF can inspect the port number(s) for the transport layer protocol, i.e., TCP.

4. The NSF can determine whether the packets are allowed to pass, drop, or mirror.

5. The NSF can support IPsec not through IKEv2, but through a Security Controller [RFC9061].

6. The NSF can have processing power and bandwidth.

7. The IPv4 address of the NSF is 192.0.2.11.

8. The port of the NSF is 49152.

```
<nsf-registrations
 xmlns="urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface"
 xmlns:nsfcap="urn:ietf:params:xml:ns:yang:ietf-i2nsf-capability">
 <nsf-information>
  <nsf-name>general_firewall</nsf-name>
  <nsf-capability-info>
   <security-capability>
    <condition-capabilities>
     <generic-nsf-capabilities>
      <ipv6-capability>nsfcap:next-header</ipv6-capability>
      <ipv6-capability>nsfcap:source-address</ipv6-capability>
      <ipv6-capability>nsfcap:destination-address</ipv6-capability>
      <tcp-capability>nsfcap:source-port-number</tcp-capability>
      <tcp-capability>nsfcap:destination-port-number</tcp-capability>
     </generic-nsf-capabilities>
    </condition-capabilities>
    <action-capabilities>
     <ingress-action-capability>
      nsfcap:pass
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:drop
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:mirror
     </ingress-action-capability>
     <egress-action-capability>
      nsfcap:pass
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:drop
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:mirror
     </egress-action-capability>
    </action-capabilities>
   </security-capability>
   <performance-capability>
    <processing>
     <processing-average>1000</processing-average>
     <processing-peak>5000</processing-peak>
    </processing>
    <bandwidth>
     <outbound>
      <outbound-average>1000</outbound-average>
      <outbound-peak>5000</outbound-peak>
     </outbound>
     <inbound>
      <inbound-average>1000</inbound-average>
```

```
      <inbound-peak>5000</inbound-peak>
     </inbound>
    </bandwidth>
   </performance-capability>
  </nsf-capability-info>
  <nsf-access-info>
   <ip>2001:db8:0:1::11</ip>
   <port>49152</port>
  </nsf-access-info>
 </nsf-information>
</nsf-registrations>
```

Figure 13: Configuration XML for Registration of a General Firewall in an IPv6 Network

In addition, Figure 13 shows the configuration XML for registering a general firewall in an IPv6 network [RFC3849] and its capabilities as follows.

1. The instance name of the NSF is general_firewall.

2. The NSF can inspect IPv6 next header, flow direction, source address(es), and destination address(es)

3. The NSF can inspect the port number(s) and flow direction for the transport layer protocol, i.e., TCP and UDP.

4. The NSF can determine whether the packets are allowed to pass, drop, or mirror.

5. The NSF can have processing power and bandwidth.

6. The IPv6 address of the NSF is 2001:db8:0:1::11.

7. The port of the NSF is 49152.

A.2. Example 2: Registration for the Capabilities of a Time-based Firewall

This section shows an XML example for registering the capabilities of a time-based firewall in either IPv4 networks [RFC5737] or IPv6 networks [RFC3849].

```
<nsf-registrations
 xmlns="urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface"
 xmlns:nsfcap="urn:ietf:params:xml:ns:yang:ietf-i2nsf-capability">
 <nsf-information>
  <nsf-name>time_based_firewall</nsf-name>
  <nsf-capability-info>
   <security-capability>
    <event-capabilities>
     <time-capabilities>nsfcap:absolute-time</time-capabilities>
     <time-capabilities>nsfcap:periodic-time</time-capabilities>
    </event-capabilities>
    <condition-capabilities>
     <generic-nsf-capabilities>
      <ipv4-capability>nsfcap:next-header</ipv4-capability>
      <ipv4-capability>nsfcap:source-address</ipv4-capability>
      <ipv4-capability>nsfcap:destination-address</ipv4-capability>
      <tcp-capability>nsfcap:source-port-number</tcp-capability>
      <tcp-capability>nsfcap:destination-port-number</tcp-capability>
     </generic-nsf-capabilities>
    </condition-capabilities>
    <action-capabilities>
     <ingress-action-capability>
      nsfcap:pass
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:drop
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:mirror
     </ingress-action-capability>
     <egress-action-capability>
      nsfcap:pass
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:drop
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:mirror
     </egress-action-capability>
    </action-capabilities>
   </security-capability>
   <performance-capability>
    <processing>
     <processing-average>1000</processing-average>
     <processing-peak>5000</processing-peak>
    </processing>
    <bandwidth>
     <outbound>
      <outbound-average>1000</outbound-average>
```

```
      <outbound-peak>5000</outbound-peak>
     </outbound>
     <inbound>
      <inbound-average>1000</inbound-average>
      <inbound-peak>5000</inbound-peak>
     </inbound>
    </bandwidth>
   </performance-capability>
  </nsf-capability-info>
  <nsf-access-info>
   <ip>192.0.2.11</ip>
   <port>49152</port>
  </nsf-access-info>
 </nsf-information>
</nsf-registrations>
```

Figure 14: Configuration XML for Registration of a Time-based Firewall in an IPv4 Network

Figure 14 shows the configuration XML for registering a time-based firewall in an IPv4 network [RFC5737] and its capabilities as follows.

1. The instance name of the NSF is time_based_firewall.

2. The NSF can enforce the security policy rule according to absolute time and periodic time.

3. The NSF can inspect the IPv4 protocol header field, IPv4 source address(es), IPv4 destination address(es), TCP source port number(s), and TCP destination port number(s).

4. The NSF can determine whether the packets are allowed to pass, drop, or mirror.

5. The NSF can have processing power and bandwidth.

6. The IPv4 address of the NSF is 192.0.2.11.

7. The port of the NSF is 49152.

```
<nsf-registrations
 xmlns="urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface"
 xmlns:nsfcap="urn:ietf:params:xml:ns:yang:ietf-i2nsf-capability">
 <nsf-information>
  <nsf-name>time_based_firewall</nsf-name>
  <nsf-capability-info>
   <security-capability>
    <event-capabilities>
     <time-capabilities>nsfcap:absolute-time</time-capabilities>
     <time-capabilities>nsfcap:periodic-time</time-capabilities>
    </event-capabilities>
    <condition-capabilities>
     <generic-nsf-capabilities>
      <ipv6-capability>nsfcap:next-header</ipv6-capability>
      <ipv6-capability>nsfcap:source-address</ipv6-capability>
      <ipv6-capability>nsfcap:destination-address</ipv6-capability>
      <tcp-capability>nsfcap:source-port-number</tcp-capability>
      <tcp-capability>nsfcap:destination-port-number</tcp-capability>
     </generic-nsf-capabilities>
    </condition-capabilities>
    <action-capabilities>
     <ingress-action-capability>
      nsfcap:pass
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:drop
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:mirror
     </ingress-action-capability>
     <egress-action-capability>
      nsfcap:pass
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:drop
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:mirror
     </egress-action-capability>
    </action-capabilities>
   </security-capability>
   <performance-capability>
    <processing>
     <processing-average>1000</processing-average>
     <processing-peak>5000</processing-peak>
    </processing>
    <bandwidth>
     <outbound>
      <outbound-average>1000</outbound-average>
```

```
      <outbound-peak>5000</outbound-peak>
     </outbound>
     <inbound>
      <inbound-average>1000</inbound-average>
      <inbound-peak>5000</inbound-peak>
     </inbound>
    </bandwidth>
   </performance-capability>
  </nsf-capability-info>
  <nsf-access-info>
   <ip>2001:db8:0:1::11</ip>
   <port>49152</port>
  </nsf-access-info>
 </nsf-information>
</nsf-registrations>
```

Figure 15: Configuration XML for Registration of a Time-based Firewall in an IPv6 Network

In addition, Figure 15 shows the configuration XML for registering a time-based firewall in an IPv6 network [RFC3849] and its capabilities as follows.

1. The instance name of the NSF is time_based_firewall.

2. The NSF can enforce the security policy rule according to absolute time and periodic time.

3. The NSF can inspect the IPv6 next header field, IPv6 source address(es), IPv6 destination address(es), TCP source port number(s), and TCP destination port number(s).

4. The NSF can determine whether the packets are allowed to pass, drop, or mirror.

5. The NSF can have processing power and bandwidth.

6. The IPv6 address of the NSF is 2001:db8:0:1::11.

7. The port of the NSF is 49152.

A.3. Example 3: Registration for the Capabilities of a Web Filter

This section shows an XML example for registering the capabilities of a web filter in either IPv4 networks [RFC5737] or IPv6 networks [RFC3849].

```
<nsf-registrations
 xmlns="urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface"
 xmlns:nsfcap="urn:ietf:params:xml:ns:yang:ietf-i2nsf-capability">
 <nsf-information>
  <nsf-name>web_filter</nsf-name>
  <nsf-capability-info>
   <security-capability>
    <condition-capabilities>
     <advanced-nsf-capabilities>
      <url-filtering-capability>
        nsfcap:user-defined
      </url-filtering-capability>
     </advanced-nsf-capabilities>
    </condition-capabilities>
    <action-capabilities>
     <ingress-action-capability>
      nsfcap:pass
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:drop
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:mirror
     </ingress-action-capability>
     <egress-action-capability>
      nsfcap:pass
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:drop
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:mirror
     </egress-action-capability>
    </action-capabilities>
   </security-capability>
   <performance-capability>
    <processing>
     <processing-average>1000</processing-average>
     <processing-peak>5000</processing-peak>
    </processing>
    <bandwidth>
     <outbound>
      <outbound-average>1000</outbound-average>
      <outbound-peak>5000</outbound-peak>
     </outbound>
     <inbound>
      <inbound-average>1000</inbound-average>
      <inbound-peak>5000</inbound-peak>
     </inbound>
```

```
    </bandwidth>
   </performance-capability>
  </nsf-capability-info>
  <nsf-access-info>
   <ip>192.0.2.11</ip>
   <port>49152</port>
  </nsf-access-info>
 </nsf-information>
</nsf-registrations>
```

Figure 16: Configuration XML for Registration of a Web Filter in an IPv4 Network

Figure 16 shows the configuration XML for registering a web filter in an IPv4 network [RFC5737] and its capabilities are as follows.

1. The instance name of the NSF is web_filter.

2. The NSF can inspect URL from a pre-defined database or a added new URL by user (user-defined).

3. The NSF can determine whether the packets are allowed to pass, drop, or mirror.

4. The NSF can have processing power and bandwidth.

5. The IPv4 address of the NSF is 192.0.2.11.

6. The port of the NSF is 49152.

```
<nsf-registrations
 xmlns="urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface"
 xmlns:nsfcap="urn:ietf:params:xml:ns:yang:ietf-i2nsf-capability">
 <nsf-information>
  <nsf-name>web_filter</nsf-name>
  <nsf-capability-info>
   <security-capability>
    <condition-capabilities>
     <advanced-nsf-capabilities>
      <url-filtering-capability>
       nsfcap:user-defined
      </url-filtering-capability>
      <url-filtering-capability>
       nsfcap:pre-defined
      </url-filtering-capability>
     </advanced-nsf-capabilities>
    </condition-capabilities>
    <action-capabilities>
     <ingress-action-capability>
      nsfcap:pass
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:drop
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:mirror
     </ingress-action-capability>
     <egress-action-capability>
      nsfcap:pass
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:drop
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:mirror
     </egress-action-capability>
    </action-capabilities>
   </security-capability>
   <performance-capability>
    <processing>
     <processing-average>1000</processing-average>
     <processing-peak>5000</processing-peak>
    </processing>
    <bandwidth>
     <outbound>
      <outbound-average>1000</outbound-average>
      <outbound-peak>5000</outbound-peak>
     </outbound>
     <inbound>
```

```
      <inbound-average>1000</inbound-average>
      <inbound-peak>5000</inbound-peak>
     </inbound>
    </bandwidth>
   </performance-capability>
  </nsf-capability-info>
  <nsf-access-info>
   <ip>2001:db8:0:1::11</ip>
   <port>49152</port>
  </nsf-access-info>
 </nsf-information>
</nsf-registrations>
```

Figure 17: Configuration XML for Registration of a Web Filter in an IPv6 Network

In addition, Figure 17 shows the configuration XML for registering a web filter in an IPv6 network [RFC3849] and its capabilities are as follows.

1. The instance name of the NSF is web_filter.

2. The NSF can inspect URL from a pre-defined database or a added new URL by user (user-defined).

3. The NSF can determine whether the packets are allowed to pass, drop, or mirror.

4. The NSF can have processing power and bandwidth.

5. The IPv6 address of the NSF is 2001:db8:0:1::11.

6. The port of the NSF is 49152.

A.4. Example 4: Registration for the Capabilities of a VoIP/VoLTE Filter

This section shows an XML example for registering the capabilities of a VoIP/VoLTE filter in either IPv4 networks [RFC5737] or IPv6 networks [RFC3849].

```
<nsf-registrations
 xmlns="urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface"
 xmlns:nsfcap="urn:ietf:params:xml:ns:yang:ietf-i2nsf-capability">
 <nsf-information>
  <nsf-name>voip_volte_filter</nsf-name>
  <nsf-capability-info>
   <security-capability>
    <condition-capabilities>
     <advanced-nsf-capabilities>
      <voip-volte-filtering-capability>
        nsfcap:call-id
      </voip-volte-filtering-capability>
     </advanced-nsf-capabilities>
    </condition-capabilities>
    <action-capabilities>
     <ingress-action-capability>
      nsfcap:pass
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:drop
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:mirror
     </ingress-action-capability>
     <egress-action-capability>
      nsfcap:pass
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:drop
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:mirror
     </egress-action-capability>
    </action-capabilities>
   </security-capability>
   <performance-capability>
    <processing>
     <processing-average>1000</processing-average>
     <processing-peak>5000</processing-peak>
    </processing>
    <bandwidth>
     <outbound>
      <outbound-average>1000</outbound-average>
      <outbound-peak>5000</outbound-peak>
     </outbound>
     <inbound>
      <inbound-average>1000</inbound-average>
      <inbound-peak>5000</inbound-peak>
     </inbound>
```

```
    </bandwidth>
   </performance-capability>
  </nsf-capability-info>
  <nsf-access-info>
   <ip>192.0.2.11</ip>
   <port>49152</port>
  </nsf-access-info>
 </nsf-information>
</nsf-registrations>
```

Figure 18: Configuration XML for Registration of a VoIP/VoLTE Filter in an IPv4 Network

Figure 18 shows the configuration XML for registering a VoIP/VoLTE filter in an IPv4 network [RFC5737] and its capabilities are as follows.

1. The instance name of the NSF is voip_volte_filter.

2. The NSF can inspect a call id for VoIP/VoLTE packets.

3. The NSF can determine whether the packets are allowed to pass, drop, or mirror.

4. The NSF can have processing power and bandwidth.

5. The IPv4 address of the NSF is 192.0.2.11.

6. The port of the NSF is 49152.

```
<nsf-registrations
 xmlns="urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface"
 xmlns:nsfcap="urn:ietf:params:xml:ns:yang:ietf-i2nsf-capability">
 <nsf-information>
  <nsf-name>voip_volte_filter</nsf-name>
  <nsf-capability-info>
   <security-capability>
    <condition-capabilities>
     <advanced-nsf-capabilities>
      <voip-volte-filtering-capability>
       nsfcap:call-id
      </voip-volte-filtering-capability>
     </advanced-nsf-capabilities>
    </condition-capabilities>
    <action-capabilities>
     <ingress-action-capability>
      nsfcap:pass
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:drop
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:mirror
     </ingress-action-capability>
     <egress-action-capability>
      nsfcap:pass
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:drop
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:mirror
     </egress-action-capability>
    </action-capabilities>
   </security-capability>
   <performance-capability>
    <processing>
     <processing-average>1000</processing-average>
     <processing-peak>5000</processing-peak>
    </processing>
    <bandwidth>
     <outbound>
      <outbound-average>1000</outbound-average>
      <outbound-peak>5000</outbound-peak>
     </outbound>
     <inbound>
      <inbound-average>1000</inbound-average>
      <inbound-peak>5000</inbound-peak>
     </inbound>
```

```
    </bandwidth>
   </performance-capability>
  </nsf-capability-info>
  <nsf-access-info>
   <ip>2001:db8:0:1::11</ip>
   <port>49152</port>
  </nsf-access-info>
 </nsf-information>
</nsf-registrations>
```

Figure 19: Configuration XML for Registration of a VoIP/VoLTE Filter in an IPv6 Network

Figure 19 shows the configuration XML for registering a VoIP/VoLTE filter in an IPv6 network [RFC3849] and its capabilities are as follows.

1. The instance name of the NSF is voip_volte_filter.

2. The NSF can inspect a call id for VoIP/VoLTE packets.

3. The NSF can determine whether the packets are allowed to pass, drop, or mirror.

4. The NSF can have processing power and bandwidth.

5. The IPv6 address of the NSF is 2001:db8:0:1::11.

6. The port of the NSF is 49152.

A.5. Example 5: Registration for the Capabilities of a DDoS Mitigator

This section shows an XML example for registering the capabilities of a DDoS mitigator in either IPv4 networks [RFC5737] or IPv6 networks [RFC3849].

```
<nsf-registrations
 xmlns="urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface"
 xmlns:nsfcap="urn:ietf:params:xml:ns:yang:ietf-i2nsf-capability">
 <nsf-information>
  <nsf-name>anti_DDoS</nsf-name>
  <nsf-capability-info>
   <security-capability>
    <condition-capabilities>
     <advanced-nsf-capabilities>
      <anti-ddos-capability>
       nsfcap:packet-rate
      </anti-ddos-capability>
      <anti-ddos-capability>
       nsfcap:flow-rate
      </anti-ddos-capability>
      <anti-ddos-capability>
       nsfcap:byte-rate
      </anti-ddos-capability>
     </advanced-nsf-capabilities>
    </condition-capabilities>
    <action-capabilities>
     <ingress-action-capability>
      nsfcap:pass
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:drop
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:mirror
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:rate-limit
     </ingress-action-capability>
     <egress-action-capability>
      nsfcap:pass
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:drop
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:mirror
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:rate-limit
     </egress-action-capability>
    </action-capabilities>
   </security-capability>
   <performance-capability>
    <processing>
```

```
      <processing-average>1000</processing-average>
      <processing-peak>5000</processing-peak>
     </processing>
     <bandwidth>
      <outbound>
       <outbound-average>1000</outbound-average>
       <outbound-peak>5000</outbound-peak>
      </outbound>
      <inbound>
       <inbound-average>1000</inbound-average>
       <inbound-peak>5000</inbound-peak>
      </inbound>
     </bandwidth>
    </performance-capability>
   </nsf-capability-info>
   <nsf-access-info>
    <ip>192.0.2.11</ip>
    <port>49152</port>
   </nsf-access-info>
  </nsf-information>
</nsf-registrations>
```

Figure 20: Configuration XML for Registration of a DDoS Mitigator in an IPv4 Network

Figure 20 shows the configuration XML for registering a DDoS mitigator in an IPv4 network [RFC5737] and its capabilities are as follows.

1. The instance name of the NSF is anti_DDoS.

2. The NSF can detect the amount of packet, flow, and byte rate in the network for potential DDoS Attack.

3. The NSF can determine whether the packets are allowed to pass, drop, or mirror.

4. The NSF can have processing power and bandwidth.

5. The IPv4 address of the NSF is 192.0.2.11.

6. The port of the NSF is 49152.

```
<nsf-registrations
 xmlns="urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface"
 xmlns:nsfcap="urn:ietf:params:xml:ns:yang:ietf-i2nsf-capability">
 <nsf-information>
  <nsf-name>anti_DDoS</nsf-name>
  <nsf-capability-info>
   <security-capability>
    <condition-capabilities>
     <advanced-nsf-capabilities>
      <anti-ddos-capability>
       nsfcap:packet-rate
      </anti-ddos-capability>
      <anti-ddos-capability>
       nsfcap:flow-rate
      </anti-ddos-capability>
      <anti-ddos-capability>
       nsfcap:byte-rate
      </anti-ddos-capability>
     </advanced-nsf-capabilities>
    </condition-capabilities>
    <action-capabilities>
     <ingress-action-capability>
      nsfcap:pass
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:drop
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:mirror
     </ingress-action-capability>
     <ingress-action-capability>
      nsfcap:rate-limit
     </ingress-action-capability>
     <egress-action-capability>
      nsfcap:pass
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:drop
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:mirror
     </egress-action-capability>
     <egress-action-capability>
      nsfcap:rate-limit
     </egress-action-capability>
    </action-capabilities>
   </security-capability>
   <performance-capability>
    <processing>
```

```
      <processing-average>1000</processing-average>
      <processing-peak>5000</processing-peak>
     </processing>
     <bandwidth>
      <outbound>
       <outbound-average>1000</outbound-average>
       <outbound-peak>5000</outbound-peak>
      </outbound>
      <inbound>
       <inbound-average>1000</inbound-average>
       <inbound-peak>5000</inbound-peak>
      </inbound>
     </bandwidth>
    </performance-capability>
   </nsf-capability-info>
   <nsf-access-info>
    <ip>2001:db8:0:1::11</ip>
    <port>49152</port>
   </nsf-access-info>
  </nsf-information>
</nsf-registrations>
```

Figure 21: Configuration XML for Registration of a DDoS Mitigator in an IPv6 Network

In addition, Figure 21 shows the configuration XML for registering a DDoS mitigator in an IPv6 network [RFC3849] and its capabilities are as follows.

1. The instance name of the NSF is anti_DDoS.

2. The NSF can detect the amount of packet, flow, and byte rate in the network for potential DDoS Attack.

3. The NSF can determine whether the packets are allowed to pass, drop, mirror, or rate-limit.

4. The NSF can have processing power and bandwidth.

5. The IPv6 address of the NSF is 2001:db8:0:1::11.

6. The port of the NSF is 49152.

A.6. Example 6: Query for the Capabilities of a Time-based Firewall

This section shows an XML example for querying the capabilities of a time-based firewall in either IPv4 networks [RFC5737] or IPv6 networks [RFC3849].

```
<rpc message-id="101"
 xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
 <nsf-capability-query
  xmlns="urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface"
  xmlns:nsfcap="urn:ietf:params:xml:ns:yang:ietf-i2nsf-capability">
  <query-i2nsf-capability>
   <time-capabilities>absolute-time</time-capabilities>
   <time-capabilities>periodic-time</time-capabilities>
   <condition-capabilities>
    <generic-nsf-capabilities>
     <ipv4-capability>nsfcap:next-header</ipv4-capability>
     <ipv4-capability>nsfcap:source-address</ipv4-capability>
     <ipv4-capability>nsfcap:destination-address</ipv4-capability>
    </generic-nsf-capabilities>
   </condition-capabilities>
   <action-capabilities>
    <ingress-action-capability>
     nsfcap:pass
    </ingress-action-capability>
    <ingress-action-capability>
     nsfcap:drop
    </ingress-action-capability>
    <ingress-action-capability>
     nsfcap:mirror
    </ingress-action-capability>
    <egress-action-capability>
     nsfcap:pass
    </egress-action-capability>
    <egress-action-capability>
     nsfcap:drop
    </egress-action-capability>
    <egress-action-capability>
     nsfcap:mirror
    </egress-action-capability>
   </action-capabilities>
  </query-i2nsf-capability>
 </nsf-capability-query>
</rpc>

<rpc-reply message-id="101"
 xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
 <nsf-access-info
  xmlns="urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface">
  <nsf-name>time_based_firewall</nsf-name>
  <ip>192.0.2.11</ip>
  <port>49152</port>
 </nsf-access-info>
</rpc-reply>
```

Figure 22: Configuration XML for Query of a Time-based Firewall in an IPv4 Network

Figure 22 shows the XML configuration for querying the capabilities of a time-based firewall in an IPv4 network [RFC5737]. The access information of the announced time-based firewall has the IPv4 address of 192.0.2.11 and the port number of 49152.

```
<rpc message-id="101"
 xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
 <nsf-capability-query
  xmlns="urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface"
  xmlns:nsfcap="urn:ietf:params:xml:ns:yang:ietf-i2nsf-capability">
  <query-i2nsf-capability>
   <time-capabilities>absolute-time</time-capabilities>
   <time-capabilities>periodic-time</time-capabilities>
   <condition-capabilities>
    <generic-nsf-capabilities>
     <ipv6-capability>nsfcap:next-header</ipv6-capability>
     <ipv6-capability>nsfcap:source-address</ipv6-capability>
     <ipv6-capability>nsfcap:destination-address</ipv6-capability>
    </generic-nsf-capabilities>
   </condition-capabilities>
   <action-capabilities>
    <ingress-action-capability>
     nsfcap:pass
    </ingress-action-capability>
    <ingress-action-capability>
     nsfcap:drop
    </ingress-action-capability>
    <ingress-action-capability>
     nsfcap:mirror
    </ingress-action-capability>
    <egress-action-capability>
     nsfcap:pass
    </egress-action-capability>
    <egress-action-capability>
     nsfcap:drop
    </egress-action-capability>
    <egress-action-capability>
     nsfcap:mirror
    </egress-action-capability>
   </action-capabilities>
  </query-i2nsf-capability>
 </nsf-capability-query>
</rpc>

<rpc-reply message-id="101"
 xmlns="urn:ietf:params:xml:ns:netconf:base:1.0">
 <nsf-access-info
  xmlns="urn:ietf:params:xml:ns:yang:ietf-i2nsf-reg-interface">
  <nsf-name>time_based_firewall</nsf-name>
  <ip>2001:db8:0:1::11</ip>
  <port>49152</port>
 </nsf-access-info>
</rpc-reply>
```

Figure 23: Configuration XML for Query of a Time-based Firewall in an IPv6 Network

In addition, Figure 23 shows the XML configuration for querying the capabilities of a time-based firewall in an IPv6 network [RFC3849]. The access information of the announced time-based firewall has the IPv6 address of 2001:db8:0:1::11 and the port number of 49152.

Appendix B. NSF Lifecycle Management in NFV Environments

Network Functions Virtualization (NFV) can be used to implement I2NSF framework. In NFV environments, NSFs are deployed as virtual network functions (VNFs). Security Controller can be implemented as an Element Management (EM) of the NFV architecture, and is connected with the VNF Manager (VNFM) via the Ve-Vnfm interface [nfv-framework]. Security Controller can use this interface for the purpose of the lifecycle management of NSFs. If some NSFs need to be instantiated to enforce security policies in the I2NSF framework, Security Controller could request the VNFM to instantiate them through the Ve-Vnfm interface. Or if an NSF, running as a VNF, is not used by any traffic flows for a time period, Security Controller MAY request deinstantiating it through the interface for efficient resource utilization.

Appendix C. Acknowledgments

This document is a product by the I2NSF Working Group (WG) including WG Chairs (i.e., Linda Dunbar and Yoav Nir) and Diego Lopez. This document took advantage of the review and comments from the following people: Roman Danyliw, Reshad Rahman (YANG doctor), and Tom Petch. We authors sincerely appreciate their sincere efforts and kind help.

This work was supported by Institute of Information & Communications Technology Planning & Evaluation (IITP) grant funded by the Korea MSIT (Ministry of Science and ICT) (No. 2016-0-00078, Cloud Based Security Intelligence Technology Development for the Customized Security Service Provisioning). This work was supported in part by the IITP (2020-0-00395, Standard Development of Blockchain based Network Management Automation Technology).

Appendix D. Contributors

The following are co-authors of this document:

Patrick Lingga - Department of Electrical and Computer Engineering, Sungkyunkwan University, 2066 Seo-ro Jangan-gu, Suwon, Gyeonggi-do 16419, Republic of Korea, EMail: patricklink@skku.edu

Jinyong (Tim) Kim - Department of Electronic, Electrical and Computer Engineering, Sungkyunkwan University, 2066 Seo-ro Jangan-gu, Suwon, Gyeonggi-do 16419, Republic of Korea, EMail: timkim@skku.edu

Chaehong Chung - Department of Electronic, Electrical and Computer Engineering, Sungkyunkwan University, 2066 Seo-ro Jangan-gu, Suwon, Gyeonggi-do 16419, Republic of Korea, EMail: darkhong@skku.edu

Susan Hares - Huawei, 7453 Hickory Hill, Saline, MI 48176, USA, EMail: shares@ndzh.com

Diego R. Lopez - Telefonica I+D, Jose Manuel Lara, 9, Seville, 41013, Spain, EMail: diego.r.lopez@telefonica.com

Appendix E. Changes from draft-ietf-i2nsf-registration-interface-dm-13

The following changes are made from draft-ietf-i2nsf-registration-interface-dm-13:

- *This version has been updated to synchronize its contents with the contents in the other I2NSF YANG data model documents.

Authors' Addresses

Sangwon Hyun (editor)
Department of Computer Engineering
Myongji University
116 Myongji-ro, Cheoin-gu
Yongin
Gyeonggi-do
17058
Republic of Korea

Email: shyun@mju.ac.kr

Jaehoon (Paul) Jeong (editor)
Department of Computer Science and Engineering
Sungkyunkwan University
2066 Seobu-Ro, Jangan-Gu
Suwon
Gyeonggi-Do
16419
Republic of Korea

Phone: +82 31 299 4957
Email: pauljeong@skku.edu
URI: http://iotlab.skku.edu/people-jaehoon-jeong.php

Taekyun Roh

Department of Electronic, Electrical and Computer Engineering
Sungkyunkwan University
2066 Seobu-Ro, Jangan-Gu
Suwon
Gyeonggi-Do
16419
Republic of Korea

Phone: +82 31 290 7222
Email: tkroh0198@skku.edu

Sarang Wi
Department of Electronic, Electrical and Computer Engineering
Sungkyunkwan University
2066 Seobu-Ro, Jangan-Gu
Suwon
Gyeonggi-Do
16419
Republic of Korea

Phone: +82 31 290 7222
Email: dnl9795@skku.edu

Jung-Soo Park
Electronics and Telecommunications Research Institute
218 Gajeong-Ro, Yuseong-Gu
Daejeon
305-700
Republic of Korea

Phone: +82 42 860 6514
Email: pjs@etri.re.kr