I2NSF
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Framework for Interface to Network Security Functions
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Abstract

This document describes the framework for the Interface to Network Security Functions (I2NSF), and defines a reference model (including major functional components) for I2NSF. Network security functions (NSFs) are packet-processing engines that inspect and optionally modify packets traversing networks, either directly or in the context of sessions in which the packet is associated.

Status of this Memo

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1. Introduction

This document describes the framework for the Interface to Network Security Functions (I2NSF), and defines a reference model (including major functional components) for I2NSF. This includes an analysis of the threats implied by the deployment of NSFs that are externally provided. It also describes how I2NSF facilitates Software-Defined Networking (SDN) and Network Function Virtualization (NFV) control, while avoiding potential constraints that could limit the internal functionality and capabilities of NSFs.

The I2NSF use cases [I-D.ietf-i2nsf-problem-and-use-cases] call for standard interfaces for users of an I2NSF system (e.g., applications, overlay or cloud network management system, or enterprise network administrator or management system), to inform the I2NSF system which I2NSF functions should be applied to which traffic (or traffic patterns). The I2NSF system realizes this as a set of security rules for monitoring and controlling the behavior of different traffic. It also provides standard interfaces for users to monitor flow-based security functions hosted and managed by different administrative domains.

[I-D.ietf-i2nsf-problem-and-use-cases] also describes the motivation and the problem space for an Interface to Network Security Functions system.

2. Conventions used in this document

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 [RFC2119].

In this document, these words will appear with that interpretation only when in ALL CAPS. Lower case uses of these words are not to be interpreted as carrying RFC-2119 significance.

2.1. Acronyms

The following acronyms are used in this document:

BSS	Business Support System
CDN	Content Delivery Networks

ICN	Information-Centric Networks
IDS	Intrusion Detection System
IoT	Internet of Things
IPS	Intrusion Protection System
NSF	Network Security Function
OSS	Operation Support System

2.2. Definitions

The following terms, which are used in this document, are defined in the I2NSF terminology document [I-D.ietf-i2nsf-terminology]:

Capability

Consumer

Controller

Firewall

Interface

Interface Group

Intrusion Detection System

Intrusion Protection System

Network Security Function

Role

3. I2NSF Reference Model

Figure 1 shows a reference model (including major functional components and interfaces) for an I2NSF system. This figure is drawn from the point-of-view of the security controller; hence, this view does not assume any particular management architecture for either the NSFs or for how NSFs are managed (on the function developer's side). In particular, the security controller does not participate in NSF data plane activities.

```
       +-----------------------------------------------------------+
       |  I2NSF User (e.g., Overlay Network Mgnt, Enterprise   |
       |  network Mgnt, another network domain's mgnt, etc.)   |
       +---------------------+---------------------------------+
                             |
                             |  Consumer-Facing Interface
                             |
               +------------+---------+ Registration  +-------------+
               | Network Operator Mgmt|  Interface    | Developer's |
               | Security Controller  | < --------- > | Mgnt System |
               +----------------+-----+               +-------------+
                                 |
                                 | NSF-Facing Interface
                                 |
           +---------------+----+------------+--------------+
           |               |                 |              |
       +---+---+       +---+---+        +---+---+      +---+---+
       | NSF-1 |  ...  | NSF-m |        | NSF-1 |  ... | NSF-m |  ...
       +-------+       +-------+        +-------+      +-------+

      Developer Mgnt System A             Developer Mgnt System B
```

Figure 1: I2NSF Reference Model

When defining controller interfaces, this framework adheres to the following principles:

o Agnostic of network topology and NSF location in the network

o Agnostic of provider of the NSF (i.e., independent of the way that the provider makes an NSF available, as well as how the provider allows the NSF to be managed)

o Agnostic of any vendor-specific operational, administrative, and management implementation, hosting environment, and form-factor (physical or virtual)

o Agnostic to NSF control plane implementation (e.g., signaling capabilities)

o Agnostic to NSF data plane implementation (e.g., encapsulation capabilities)

3.1. Consumer-Facing Interface

The Consumer-Facing Interface is used to enable different users of a given I2NSF system to define, manage, and monitor security policies for specific flows within an administrative domain. In today's world, where everything is connected, preventing unwanted traffic has become a key challenge. More and more networks are implemented as a form of overlay network, with their paths or links among nodes being provided by other networks (a.k.a. underlay networks).

The overlay network's own security solutions cannot prevent various attacks from saturating the access links to the overlay network nodes, which may cause various components of one or more overlay nodes (e.g., CPU or link bandwidth) to become overloaded, and unable to handle their own legitimate traffic. An I2NSF system can be used by overlay networks to request certain flow-based security rules to be enforced by underlay networks. This operates in a similar manner to how traditional networks use firewalls or IPS devices to enforce traffic rules. The I2NSF system can reduce, or even eliminate, unwanted traffic, which prevents unwanted traffic from consuming critical node resources. The same approach can be used by enterprise networks to request their specific flow security policies to be enforced by the provider network that interconnects their users. The location and implementation of I2NSF policies are irrelevant to the consumer of I2NSF policies.

Some examples of I2NSF Consumers include:

o A videoconference network manager that needs to dynamically inform the underlay network to allow, rate-limit, or deny flows (some of which are encrypted) based on specific fields in the packets for a certain time span

o Enterprise network administrators and management systems that need to request their provider network to enforce specific I2NSF policies for particular flows

o An IoT management system sending requests to the underlay network to block flows that match a set of specific conditions.

3.2. NSF-Facing Interface

The NSF-Facing Interface is used to specify and monitor flow-based security policies enforced by one or more NSFs. Note that the controller does not need to use all features of a given NSF, nor does it need to use all available NSFs. Hence, this abstraction enables the different features from the set of NSFs that make up able given I2NSF system to be treated as building blocks, so that developers are

free to use the security functions needed independent of vendor and technology.

Flow-based NSFs [I-D.ietf-i2nsf-problem-and-use-cases] inspect packets in the order that they are received. The Interface to flow-based NSFs can be grouped into the following types of Interface Groups:

1. NSF Operational and Administrative Interface: an Interface Group used by a controller to program the operational state of the NSF; this also includes administrative control functions. Since applications and controllers need to dynamically control the behavior of traffic that they send and receive, much of the I2NSF effort is focused on this Interface Group.

2. Monitoring Interface: an Interface Group used by a controller to obtain monitoring information from one or more selected NSFs. Each interface in this Interface Group could be a query- or a report-based interface (as dedcribed above). This Interface Group includes logging and query functions between the NSF and external systems. The functionality of this Interface Group may also be defined by other protocols, such as SYSLOG and DOTS.

3. Notification Interface: an Interface Group used by a controller to receive notification events (e.g., alarms) from NSFs. This requires the NSF to be registered. The controller may take an action based on the event; this SHOULD be specified by an I2NSF policy. This Interface Group does NOT change the operational state of the NSF.

This draft proposes that the flow-based paradigm is used to develop the NSF-Facing Interface. A common trait of flow-based NSFs is in the processing of packets based on the content (e.g., header/payload) and/or context (e.g., session state, authentication state) of the received packets.

3.3. **Registration Interface**

NSFs provided by different vendors may have different capabilities. In order to automate the process of utilizing multiple types of security functions provided by different vendors, it is necessary to have an interface for vendors to define the capabilities of their NSFs. This Interface Group is called the Registration Interface Group.

An NSF's capabilities can either be pre-configured or retrieved dynamically through the Registration Interface Group. If a new function that is exposed to the consumer is added to an NSF, then

those capabilities SHOULD be notified to security controllers via the Registration Interface Group.

4. Threats Associated with Externally Provided NSFs

While associated with a much higher flexibility, and in many cases a necessary approach given the deployment conditions, the usage of externally provided NSFs implies several additional concerns in security. The most relevant threats associated with a security platform of this nature are:

- An unknown/unauthorized user can try to impersonate another user that can legitimately access external NSF services. This attack may lead to accessing the policies and applications of the attacked user or to generate network traffic outside the security functions with a falsified identity.

- An authorized user may misuse assigned privileges to alter the network traffic processing of other users in the NSF underlay or platform. This can become especially serious when such a user has higher (or even administration) privileges granted by the provider (the direct NSF provider, the ISP or the underlay network operator).

- A usermay try to install malformed elements (policy or configuration), trying to directly take the control of a NSF or the whole provider platform, for example by exploiting a vulnerability on one of the functions, or may try to intercept or modify the traffic of other users in the same provider platform.

- A malicious provider can modify the software providing the functions (the operating system or the specific NSF implementations) to alter the behavior of the latter. This event has a high impact on all users accessing NSFs as the provider has the highest level of privilege on the software in execution.

- A user that has physical access to the provider platform can modify the behavior of the hardware/software components, or the components themselves. Furthermore, it can access a serial console (most devices offer this interface for maintenance reasons) to access the NSF software with the same level of privilege of the provider.

The authentication between the user and the NSF environment and, what is more important, the attestation of the elements in the NSF environment by users could address these threats to an acceptable level of risk. Periodical attestation enables users to detect

alterations in the NSFs and their supporting infrastructure, and raises the degree of physical control necessary to perform an untraceable malicious modification of the environment.

5. Avoiding NSF Ossification

An important concept underlying this framework is the fact that attackers do not have standards as to how to attack networks, so it is equally important not to constrain NSF developers to offering a limited set of security functions. In other words, the introduction of I2NSF standards should not make it easier for attackers to compromise the network. Therefore, in constructing standards for rules provisioning interfaces to NSFs, it is equally important to allow support for specific functions, as this enables the introduction of NSFs that evolve to meet new threats. Proposed standards for rules provisioning interfaces to NSFs SHOULD NOT:

o Narrowly define NSF categories, or their roles when implemented within a network

o Attempt to impose functional requirements or constraints, either directly or indirectly, upon NSF developers

o Be a limited lowest common denominator approach, where interfaces can only support a limited set of standardized functions, without allowing for developer-specific functions

o Be seen as endorsing a best common practice for the implementation of NSFs

To prevent constraints on NSF developers' creativity and innovation, this document recommends the Flow-based NSF interfaces to be designed from the paradigm of processing packets in the network. Flow-based NSFs ultimately are packet-processing engines that inspect packets traversing networks, either directly or in the context of sessions in which the packet is associated. The goal is to create a workable interface to NSFs that aids in their integration within legacy, SDN, and/or NFV environments, while avoiding potential constraints which could limit their functional capabilities.

6. The Network Connecting I2NSF Components

6.1. Network Connecting I2NSF Users and I2NSF Controller

[TBD: should we add the Remote Attestation to this section?]

As a general principle, in the I2NSF environment users directly interact with the controller. Given the role of the Security Controller, a mutual authentication of users and the Security Controller maybe required. I2NSF does not mandate a specific authentication scheme; it is up to the users to choose available authentication scheme based on their needs.

Upon successful authentication, a trusted connection between the user and the Security Controller (or an endpoint designated by it) SHALL be established. All traffic to and from the NSF environment will flow through this connection. The connection is intended not only to be secure, but trusted in the sense that it SHOULD be bound to the mutual authentication between user and Security Controller, as described in [I-D.pastor-i2nsf-nsf-remote-attestation], with the only possible exception of the application of the lowest levels of assurance, in which case the user MUST be made aware of this circumstance.

6.2. Network Connecting the Security Controller and NSFs

Most likely the NSFs are not directly attached to the I2NSF Controller; for example, NSFs can be distributed across the network. The network that connects the I2NSF Controller with the NSFs can be the same network that carries the data traffic, or can be a dedicated network for management purposes only. In either case, packet loss could happen due to failure, congestion, or other reasons.

Therefore, the transport mechanism used to carry the control messages and monitoring information should provide reliable message delivery. Transport redundancy mechanisms such as Multipath TCP (MPTCP) and the Stream Control Transmission Protocol (SCTP) will need to be evaluated for applicability. Latency requirements for control message delivery must also be evaluated.

The network connection between the Security Controller and NSFs can rely either on:

o Closed environments, where there is only one administrative domain. Less restrictive access control and simpler validation can be used inside the domain because of the protected environment.

o Open environments, where some NSFs can be hosted in external administrative domains or reached via secure external network domains. This requires more restrictive security control to be placed over the I2NSF interface. The information over the I2NSF interfaces SHALL be exchanged used trusted channels as described in the previous section.

When running in an open environment, I2NSF needs to rely on interfaces to properly verify peer identities e.g. through an AAA framework. The implementation of identity management functions is out of scope for I2NSF.

6.3. Interface to vNSFs

Even though there is no difference between virtual network security functions (vNSF) and physical NSFs from the policy provisioning perspective, there are some unique characteristics in interfacing to the vNSFs:

- There could be multiple instantiations of one single NSF that has been distributed across a network. When different instantiations are visible to the Security Controller, different policies may be applied to different instantiations of an individual NSF (e.g., to reflect the different roles that each vNSF is designated for).

- When multiple instantiations of one single NSF appear as one single entity to the Security Controller, the policy provisioning has to be sent to the NSF Manager, which in turn disseminates the polices to the corresponding instantiations of the NSF, as shown in Figure 2 below.

- Policies to one vNSF may need to be retrieved and moved to another vNSF of the same type when user flows are moved from one vNSF to another.

- Multiple vNSFs may share the same physical platform.

- There may be scenarios where multiple vNSFs collectively perform the security policies needed.

```
                          +------------------------+
                          | Security Controller    |
                          +------------------------+
                                   ^        ^
                                   |        |
                       +-----------+        +------------+
                       |                                 |
                       v                                 v
    + - - - - - - - - - - - - - - - +  + - - - - - - - - - - - - - - - +
    |  NSF-A  +--------------+      |  |  NSF-B  +--------------+      |
    |         |NSF Manager   |      |  |         |NSF Manager   |      |
    |         +--------------+      |  |         +--------------+      |
    | + - - - - - - - - - - - - - + |  | + - - - - - - - - - - - - - + |
    | |+---------+     +---------+| |  | |+---------+     +---------+| |
    | || NSF-A#1 | ... |  NSF-A#n|| |  | ||  NSF-B#1| ... |  NSF-B#m|| |
    | |+---------+     +---------+| |  | |+---------+     +---------+| |
    | |         NSF-A cluster     | |  | |          NSF-B cluster    | |
    | + - - - - - - - - - - - - - + |  | + - - - - - - - - - - - - - + |
    + - - - - - - - - - - - - - - - +  + - - - - - - - - - - - - - - - +
```

Figure 2: Cluster of NSF Instantiations Management

7. I2NSF Flow Security Policy Structure

Even though security functions come in a variety of form factors and have different features, provisioning to flow-based NSFs can be standardized by using Event - Condition - Action (ECA) policy rulesets.

Event is used to determine whether the condition clause of the Policy Rule can be evaluated or not.

A Condition, when used in the context of policy rules for flow-based NSFs, is used to determine whether or not the set of Actions in that Policy Rule can be executed or not. A condition can be based on various combinations of the content (header/payload) and/or the context (session state, authentication state, etc) of the received packets.

Action can be simple permit/deny/rate-limiting, applying specify profile, or establishing specific secure tunnels, etc.

7.1. Customer-Facing Flow Security Policy Structure

This layer is for user's network management system to express and monitor the needed flow security policies for their specific flows.

Some customers may not have security skills. As such, they are not able to express requirements or security policies that are precise enough. These customers may instead express expectations or intent of the functionality desired by their security policies. Customers may also express guidelines such as which certain types of destinations are not allowed for certain groups. As a result, there could be different depths or layers of Service Layer policies. Here are some examples of more abstract security Policies that can be developed based on the I2NSF defined customer-facing interfaces:

Pass for Subscriber "xxx"

Enable basic parental control

Enable "school protection control"

Allow Internet traffic from 8:30 to 20:00

Scan email for malware detection protect traffic to corporate network with integrity and confidentiality

Remove tracking data from Facebook [website = *.facebook.com]

My son is allowed to access Facebook from 18:30 to 20:00

One flow policy over Customer-Facing Interface may need multiple network functions at various locations to achieve the enforcement. Some flow security policies from users may not be granted because of resource constraints.

I2NSF will first focus on simple user policies that can be modeled as closely as possible to the flow security policies to individual NSFs. The I2NSF simple user flow policies should have similar structure as the policies to NSFs, but with more of a user-oriented expression for the packet content, context, and other parts of an ECA policy rule. This enables the user to construct an ECA policy rule without having to know actual tags or addresses in the packets.

For example, when used in the context of policy rules over the Customer-Facing Interface:

An Event can be "traffic of type X detected"

A Condition can be a "user identifier is Z" and/or "traffic from domain-A to domain-B"

An Action can be "establish an IPSec tunnel"

7.2. NSF-Facing Flow Security Policy Structure

The NSF-Facing Interface is to pass explicit rules to individual NSFs to treat packets, as well as methods to monitor the execution status of those functions.

Here are some examples of events over the NSF facing interface:

time == 08:00

NSF state change from standby to active

Here are some examples of conditions over the NSF facing interface

- o Packet content values are based on one or more packet headers, data from the packet payload, bits in the packet, or something derived from the packet

- o Context values are based on measured and inferred knowledge that define the state and environment in which a managed entity exists or has existed. In addition to state data, this includes data from sessions, direction of the traffic, time, and geo-location information. State refers to the behavior of a managed entity at a particular point in time. Hence, it may refer to situations in which multiple pieces of information that are not available at the same time must be analyzed. For example, tracking established TCP connections (connections that have gone through the initial three-way handshake).

Actions to individual flow-based NSFs include:

- o Action ingress processing, such as pass, drop, rate limiting, mirroring, etc.

- o Action egress processing, such as invoke signaling, tunnel encapsulation, packet forwarding and/or transformation.

- o Applying a specific functional profile or signature - e.g., an IPS Profile, a signature file, an anti-virus file, or a URL filtering file. Many flow-based NSFs utilize profile and/or signature files to achieve more effective threat detection and prevention. It is not uncommon for a NSF to apply different profiles and/or signatures for different flows. Some profiles/signatures do not require any knowledge of past or future activities, while others are stateful, and may need to maintain state for a specific length of time.

The functional profile or signature file is one of the key properties

that determine the effectiveness of the NSF, and is mostly NSF-specific today. The rulesets and software interfaces of I2NSF aim to specify the format to pass profile and signature files while supporting specific functionalities of each.

Policy consistency among multiple security function instances is very critical because security policies are no longer maintained by one central security device, but instead are enforced by multiple security functions instantiated at various locations.

7.3. Differences from ACL Data Models

[I-D.ietf-netmod-acl-model] has defined rules for the Access Control List supported by most routers/switches that forward packets based on packets' L2, L3, or sometimes L4 headers. The actions for Access Control Lists include Pass, Drop, or Redirect.

The functional profiles (or signatures) for NSFs are not present in [I-D.ietf-netmod-acl-model] because the functional profiles are unique to specific NSFs. For example, most IPS/IDS implementations have their proprietary functions/profiles. One of the goals of I2NSF is to define a common envelop format for exchanging or sharing profiles among different organizations to achieve more effective protection against threats.

The "packet content matching" of the I2NSF policies should not only include the matching criteria specified by [I-D.ietf-netmod-acl-model] but also the L4-L7 fields depending on the NSFs selected.

Some Flow-based NSFs need matching criteria that include the context associated with the packets.

The I2NSF "actions" should extend the actions specified by [I-D.ietf-netmod-acl-model] to include applying statistics functions, threat profiles, or signature files that clients provide.

8. Capability Negotiation

It is very possible that the underlay network does not have the capability or resource to enforce the flow security policies requested by the overlay network. Therefore, it is very important to have capability discovery or inquiry mechanisms over the I2NSF Customer-Facing Interface for the clients to discover if the needed flow polices can be supported or not.

When an NSF cannot perform the desired provisioning (e.g., due to

resource constraints), it MUST inform the controller.

The protocol needed for this security function/capability negotiation may be somewhat correlated to the dynamic service parameter negotiation procedure described in [RFC7297]. The Connectivity Provisioning Profile (CPP) template, even though currently covering only Connectivity requirements (but includes security clauses such as isolation requirements, non-via nodes, etc.), could be extended as a basis for the negotiation procedure. Likewise, the companion Connectivity Provisioning Negotiation Protocol (CPNP) could be a candidate to proceed with the negotiation procedure.

The "security as a service" would be a typical example of the kind of (CPP-based) negotiation procedures that could take place between a corporate customer and a service provider. However, more security specific parameters have to be considered.

9. Registration Considerations

9.1. Flow-Based NSF Capability Characterization

There are many types of flow-based NSFs, although the differences among them are definitely blurring, due to technological capacity increases, integration of platforms, and new threats. Flow-based NSFs differ in the depth of packet header or payload they can inspect, the various session/context states they can maintain, and the specific profiles and the actions they can apply. Among the most common flow-based NSFs we can consider:

o A firewall analyzes packet headers attributes and enforces policy based on them.

o An IDS (Intrusion Detection System) analyzes packets, both header and payload, looking for known events, and generate an event (report, warning...) about them.

o And IPS (Intrusion Prevention System) analyzes packets, both header and payload, looking for known events, and enforces policies associated with them.

o A security gateway acts as one of the endpoints of an IPsec connection, establishing it with other security gateways and negotiating IPsec parameters.

Typically, additional functions, such as logging and notification of a system administrator, could optionally be enforced as well.

9.2. Categories Applicable to the Registration Interface

Developers can register their NSFs using Packet Content Match categories. The IDR Flow Specification [RFC5575] has specified 12 different packet header matching types. More packet content matching types have been proposed in the IDR WG. I2NSF should re-use the packet matching types being specified as much as possible. More matching types might be added for Flow-based NSFS. Tables 1-4 below list the applicable packet content categories that can be potentially used as packet matching types by Flow-based NSFs:

Packet Content Matching Capability Index	
Layer 2	Layer 2 header fields:
Header	Source/Destination/s-VID/c-VID/EtherType/.
Layer 3	Layer header fields:
	protocol
IPv4 Header	dest port
	src port
	src address
	dest address
	dscp
	length
	flags
	ttl
IPv6 Header	
	addr
	protocol/nh
	src port
	dest port
	src address
	dest address
	length
	traffic class
	hop limit
	flow label
	dscp
TCP	Port
SCTP	syn
DCCP	ack
	fin
	rst
	? psh

		? urg
		? window
		sockstress
	Note: bitmap could be used to represent all the fields	
UDP		
		flood abuse
		fragment abuse
		Port
HTTP layer		
		hash collision
		http - get flood
		http - post flood
		http - random/invalid url
		http - slowloris
		http - slow read
		http - r-u-dead-yet (rudy)
		http - malformed request
		http - xss
		https - ssl session exhaustion
IETF PCP	Configurable Ports	
IETF TRAM	profile	

Table 1: Subject Capability Index

context matching Capability Index	
Session	Session state, bidirectional state
Time	time span time occurrence
Events	Event URL, variables
Location	Text string, GPS coords, URL
Connection Type	Internet (unsecured), Internet (secured by VPN, etc.), Intranet, ...
Direction	Inbound, Outbound
State	Authentication State Authorization State Accounting State Session State

Table 2: Object Capability Index

Action Capability Index	
Ingress port	SFC header termination, VxLAN header termination
Actions	Pass Deny Mirror Simple Statistics: Count (X min; Day;..) Client specified Functions: URL
Egress	Encap SFC, VxLAN, or other header

Table 3: Action Capability Index

Functional profile Index	
Profile types Signature	Name, type, or Flexible Profile/signature URL Command for Controller to enable/disable

Table 4: Function Capability Index

10. Manageability Considerations

Management of NSFs usually includes:

- o Lifecycle management and resource management of NSFs
- o Configuration of devices, such as address configuration, device internal attributes configuration, etc.
- o Signaling
- o Policy rules provisioning

I2NSF only focuses on the policy rule provisioning part, i.e. the last bullet listed above.

11. Security Considerations

Having a secure access to control and monitor NSFs is crucial for hosted security services. Therefore, proper secure communication channels have to be carefully specified for carrying the controlling and monitoring information between the NSFs and their management entity or entities.

12. IANA Considerations

This document requires no IANA actions. RFC Editor: Please remove this section before publication.

13. Acknowledgements

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