

Service Function Chaining
Internet-Draft
Intended status: Standards Track
Expires: January 1, 2018

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June 30, 2017

Network Service Header
draft-ietf-sfc-nsh-13.txt

Abstract

This document describes a Network Service Header (NSH) inserted onto packets or frames to realize service function paths. NSH also provides a mechanism for metadata exchange along the instantiated service path. NSH is the SFC encapsulation required to support the Service Function Chaining (SFC) Architecture (defined in [RFC7665](#)).

1. Requirements Language

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

Status of this Memo

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2. Introduction

Service functions are widely deployed and essential in many networks. These service functions provide a range of features such as security, WAN acceleration, and server load balancing. Service functions may be instantiated at different points in the network infrastructure such as the wide area network, data center, campus, and so forth.

Prior to development of the SFC architecture [[RFC7665](#)] and the protocol specified in this document, current service function deployment models have been relatively static, and bound to topology for insertion and policy selection. Furthermore, they do not adapt well to elastic service environments enabled by virtualization.

New data center network and cloud architectures require more flexible service function deployment models. Additionally, the transition to virtual platforms requires an agile service insertion model that supports dynamic and elastic service delivery; the movement of service functions and application workloads in the network and the ability to easily bind service policy to granular information such as per-subscriber state and steer traffic to the requisite service function(s) are necessary.

NSH defines a new service plane protocol specifically for the creation of dynamic service chains and is composed of the following elements:

1. Service Function Path identification
2. Indication of location within a Service Function Path.
3. Optional, per packet metadata (fixed length or variable).

NSH is designed to be easy to implement across a range of devices, both physical and virtual, including hardware platforms.

An NSH-aware control plane is outside the scope of this document.

[RFC7665] provides an overview of a service chaining architecture that clearly defines the roles of the various elements and the scope of a service function chaining encapsulation. NSH is the SFC encapsulation referenced in [RFC7665](#).

2.1. Definition of Terms

Classification: Defined in [[RFC7665](#)].

Classifier: Defined in [[RFC7665](#)].

Metadata: Defined in [[RFC7665](#)].

Network Locator: dataplane address, typically IPv4 or IPv6, used to send and receive network traffic.

Network Node/Element: Device that forwards packets or frames based on outer header (i.e. transport) information.

Network Overlay: Logical network built on top of existing network (the underlay). Packets are encapsulated or tunneled to create the overlay network topology.

Service Classifier: Logical entity providing classification function. Since they are logical, classifiers may be co-resident with SFC elements such as SFs or SFFs. Service classifiers perform classification and impose NSH. The initial classifier imposes the initial NSH and sends the NSH packet to the first SFF in the path. Non-initial (i.e. subsequent) classification can occur as needed and can alter, or create a new service path.

Service Function (SF): Defined in [[RFC7665](#)].

Service Function Chain (SFC): Defined in [[RFC7665](#)].

Service Function Forwarder (SFF): Defined in [[RFC7665](#)].

Service Function Path (SFP): Defined in [[RFC7665](#)].

SFC Proxy: Defined in [[RFC7665](#)].

[2.2.](#) Problem Space

Network Service Header (NSH) addresses several limitations associated with service function deployments. [[RFC7498](#)] provides a comprehensive review of those issues.

[2.3.](#) NSH-based Service Chaining

NSH creates a dedicated service plane, more specifically, NSH enables:

1. Topological Independence: Service forwarding occurs within the service plane, the underlying network topology does not require modification. NSH provides an identifier used to select the

network overlay for network forwarding.

2. Service Chaining: NSH enables service chaining per [\[RFC7665\]](#). NSH contains path identification information needed to realize a service path. Furthermore, NSH provides the ability to monitor and troubleshoot a service chain, end-to-end via service-specific OAM messages. NSH fields can be used by administrators (via, for example, a traffic analyzer) to verify (account, ensure correct chaining, provide reports, etc.) the path specifics of packets being forwarded along a service path.
3. NSH provides a mechanism to carry shared metadata between participating entities and service functions. The semantics of the shared metadata is communicated via a control plane, which is outside the scope of this document, to participating nodes. [\[SFC-CP\]](#) provides an example of such in [section 3.3](#). Examples of metadata include classification information used for policy enforcement and network context for forwarding post service delivery. Sharing the metadata allows service functions to share initial and intermediate classification results with downstream service functions saving re-classification, where enough information was enclosed.
4. NSH offers a common and standards-based header for service chaining to all network and service nodes.
5. Transport Agnostic: NSH is transport independent. An appropriate (for a given deployment) network transport protocol can be used to transport NSH-encapsulated traffic. This transport may form an overlay network and if an existing overlay topology provides the required service path connectivity, that existing overlay may be used.

3. Network Service Header

A Network Service Header (NSH) contains service path information and optionally metadata that are added to a packet or frame and used to create a service plane. An outer transport header is imposed, on NSH and the original packet/frame, for network forwarding.

A Service Classifier adds NSH. NSH is removed by the last SFF in the service chain or by a SF that consumes the packet.

3.1. Network Service Header Format

NSH is composed of a 4-byte (all references to bytes in this document refer to 8-bit bytes, or octets) Base Header, a 4-byte Service Path Header and optional Context Headers, as shown in Figure 1 below.

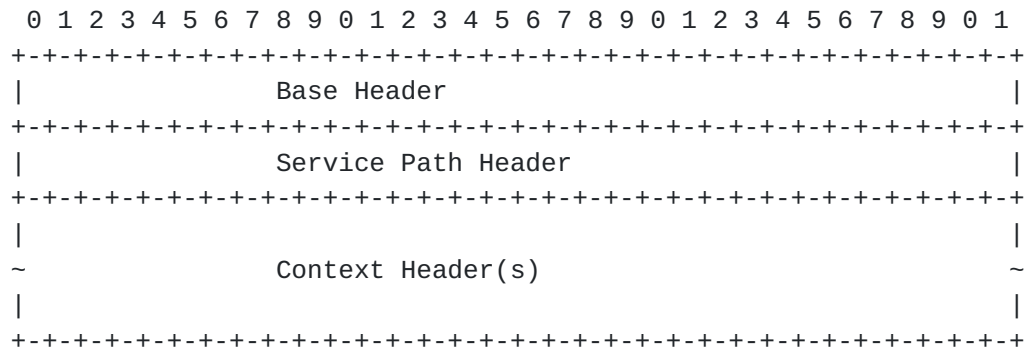


Figure 1: Network Service Header

Base header: provides information about the service header and the payload protocol.

Service Path Header: provide path identification and location within a service path.

Context header: carry metadata (i.e. context data) along a service path.

3.2. NSH Base Header

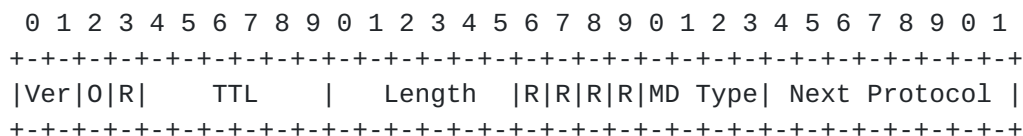


Figure 2: NSH Base Header

Base Header Field Descriptions:

Version: The version field is used to ensure backward compatibility going forward with future NSH updates. It MUST be set to 0x0 by the sender, in this first revision of NSH. Given the widespread implementation of existing hardware that uses the first nibble after an MPLS label stack for ECMP decision processing, this document reserves version 01 and this value MUST NOT be used in future versions of the protocol. Please see [[RFC7325](#)] for further discussion of MPLS-related forwarding requirements.

O bit: Setting this bit indicates an Operations, Administration, and Maintenance (OAM) packet. The actual packet format and processing of SFC OAM messages is outside the scope of this specification (see [[oam-frame](#)]).

SF/SFF/SFC Proxy/Classifier implementations that do not support SFC OAM procedures SHOULD discard packets with O-bit set, but MAY support a configurable parameter to enable forwarding received SFC OAM packets unmodified to the next element in the chain. Forwarding OAM packets unmodified by SFC elements that do not support SFC OAM procedures may be acceptable for a subset of OAM functions, but can result in unexpected outcomes for others, thus it is recommended to analyze the impact of forwarding an OAM packet for all OAM functions prior to enabling this behavior. The configurable parameter MUST be disabled by default.

The O-bit MUST be set for OAM packets and MUST NOT be set for non-OAM packets. The O-bit MUST NOT be modified along the SFP.

TTL: Indicates the maximum SFF hops for an SFP. The initial TTL value SHOULD be configurable via the control plane; the configured initial value can be specific to one or more SFPs. If no initial value is explicitly provided, the default initial TTL value 63 MUST be used. Each SFF involved in forwarding an NSH packet MUST decrement the TTL value by 1 prior to NSH forwarding lookup. Decrementing by 1 from an incoming value of 0 shall result in a TTL value of 63. The packet MUST NOT be forwarded if TTL is, after decrement, 0.

All other flag fields are reserved for future use. Reserved bits MUST be set to zero upon origination and MUST be preserved unmodified by other NSH supporting elements. Elements which do not understand the meaning of any of these bits MUST not modify their actions based on those unknown bits.

Length: The total length, in 4-byte words, of the NSH including the Base Header, the Service Path Header, the Fixed Length Context Header or Variable Length Context Header(s). The length **MUST** be of value 0x6 for MD Type equal to 0x1, and **MUST** be of value 0x2 or greater for MD Type equal to 0x2. The length of the NSH header **MUST** be an integer multiple of 4 bytes, thus variable length metadata is always padded out to a multiple of 4 bytes.

MD Type: indicates the format of NSH beyond the mandatory Base Header and the Service Path Header. MD Type defines the format of the metadata being carried. Please see IANA Considerations section below.

This document defines two MD Type values:

0x1 - which indicates that the format of the header includes a fixed length Context Header (see Figure 4 below).

0x2 - which does not mandate any headers beyond the Base Header and Service Path Header, but may contain optional variable length Context Header(s). The semantics of the variable length Context Header(s) are not defined in this document

The format of the Base Header and the Service Path Header is invariant, and not affected by MD Type.

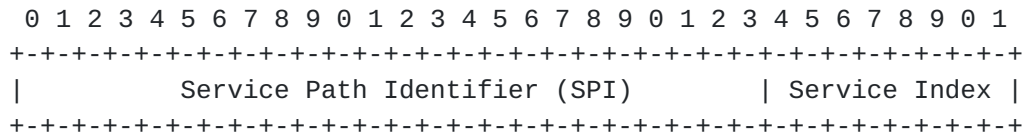
NSH implementations **MUST** support MD type = 0x1 and MD Type 0x2 (where the length is of value 0x2). NSH implementations **SHOULD** support MD Type 0x2 with length > 0x2. There exists, however, a middle ground, wherein a device will support MD Type 0x1 (as per the **MUST**) metadata, yet be deployed in a network with MD Type 0x2 metadata packets. In that case, the MD Type 0x1 node, **MUST** utilize the base header length field to determine the original payload offset if it requires access to the original packet/frame.

Next Protocol: indicates the protocol type of the encapsulated data. NSH does not alter the inner payload, and the semantics on the inner protocol remain unchanged due to NSH service function chaining. Please see IANA Considerations section below.

This document defines the following Next Protocol values:

0x1: IPv4
0x2: IPv6
0x3: Ethernet
0x4: NSH
0x5: MPLS

3.3. Service Path Header



Service Path Identifier (SPI): 24 bits

Service Index (SI): 8 bits

Figure 3: NSH Service Path Header

Service Path Identifier (SPI): identifies a service path. Participating nodes **MUST** use this identifier for Service Function Path selection. The initial classifier **MUST** set the appropriate SPI for a given classification result.

Service Index (SI): provides location within the SFP. The initial classifier for a given SFP **SHOULD** set the SI to 255, however the control plane **MAY** configure the initial value of SI as appropriate (i.e. taking into account the length of the service function path). Service Index **MUST** be decremented by a value of 1 by Service Functions or by SFC Proxy nodes after performing required services and the new decremented SI value **MUST** be used in the egress NSH packet. The initial Classifier **MUST** send the packet to the first SFF in the identified SFP for forwarding along an SFP. If re-classification occurs, and that re-classification results in a new SPI, the (re)classifier is, in effect, the initial classifier for the resultant SPI.

SI is used in conjunction with Service Path Identifier for Service Function Path Selection and for determining the next SFF/SF in the path. Service Index (SI) is also valuable when troubleshooting/reporting service paths. In addition to indicating the location within a Service Function Path, SI can be used for service plane loop detection.

3.4. NSH MD Type 1

When the Base Header specifies MD Type = 0x1, a Fixed Length Context Header (16-bytes) **MUST** be present immediately following the Service Path Header, as per Figure 4. A Fixed Length Context Header that carries no metadata **MUST** be set to zero.

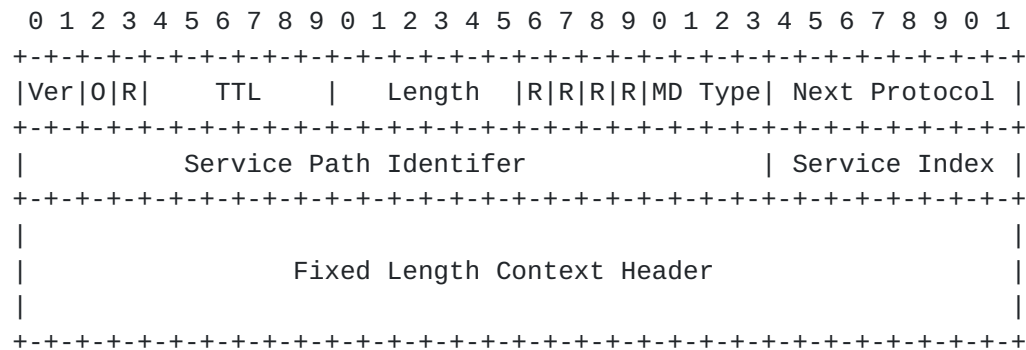


Figure 4: NSH MD Type=0x1

This specification does not make any assumptions about the content of the 16 byte Context Header that must be present when the MD Type field is set to 1, and does not describe the structure or meaning of the included metadata.

An SFC-aware SF MUST receive the data semantics first in order to process the data placed in the mandatory context field. The data semantics include both the allocation schema and the meaning of the included data. How an SFC-aware SF gets the data semantics is outside the scope of this specification.

An SF or SFC Proxy that does not know the format or semantics of the Context Header for an NSH with MD Type 1 MUST discard any packet with such an NSH (i.e., MUST NOT ignore the metadata that it cannot process), and MUST log the event at least once per the SPI for which the event occurs (subject to thresholding).

[dcalloc] and [[broadalloc](#)] provide specific examples of how metadata can be allocated.

3.5. NSH MD Type 2

When the base header specifies MD Type= 0x2, zero or more Variable Length Context Headers MAY be added, immediately following the Service Path Header. Therefore, Length = 0x2, indicates that only the Base Header followed by the Service Path Header are present. The optional Variable Length Context Headers MUST be of an integer number of 4-bytes. The base header Length field MUST be used to determine the offset to locate the original packet or frame for SFC nodes that require access to that information.

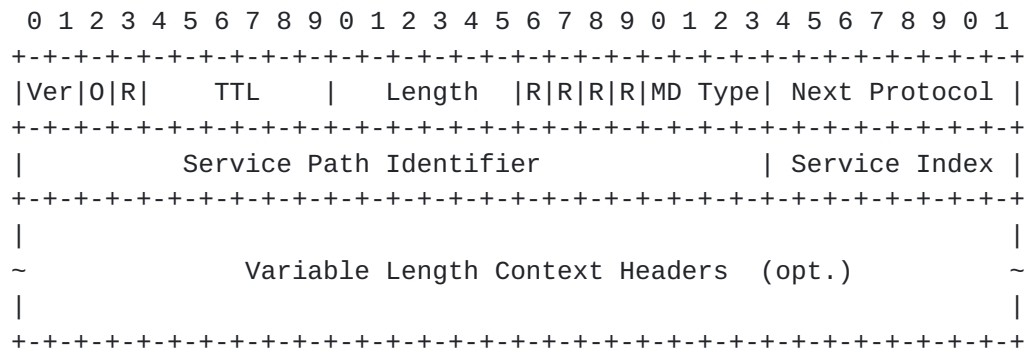


Figure 5: NSH MD Type=0x2

3.5.1. Optional Variable Length Metadata

The format of the optional variable length Context Headers, is as described below.

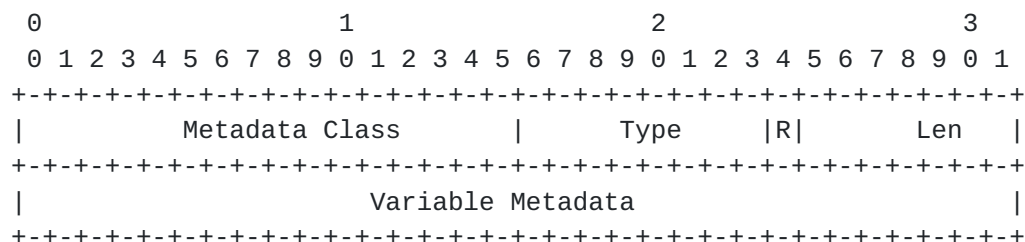


Figure 6: Variable Context Headers

Metadata Class (MD Class): The MD Class defines the scope of the 'Type' field to provide a hierarchical namespace. The IANA Considerations section defines how the MD Class values can be allocated to standards bodies, vendors, and others.

Type: indicates the explicit type of metadata being carried and is the responsibility of the MD Class owner.

Reserved bit: one reserved bit is present for future use. The reserved bits MUST be set to 0x0.

Length: Length of the variable metadata, in single byte words. In case the metadata length is not an integer number of 4-byte words, the sender MUST add pad bytes immediately following the last metadata byte to extend the metadata to an integer number of 4-byte words.

The receiver MUST round up the length field to the nearest 4-byte word boundary, to locate and process the next field in the packet. The receiver MUST access only those bytes in the metadata indicated by the length field (i.e. actual number of single byte words) and MUST ignore the remaining bytes up to the nearest 4-byte word boundary. The Length may be 0 or greater.

A value of 0x0 denotes a Context Header without a Variable Metadata field.

This specification does not make any assumption about Context Headers that are mandatory-to-implement or those that are mandatory-to-process. These considerations are deployment-specific. However, the control plane is entitled to instruct SFC-aware SFs with the data structure of context header together with their scoping (see [Section 3.3.3](#) of [[SFC-CP](#)]).

Upon receipt of a packet that belong to a given SFP, if a mandatory-to-process context header is missing in that packet, the SFC-aware SF MUST NOT process the packet and MUST log at least once per the SPI for which a mandatory metadata is missing.

If multiple mandatory-to-process context headers are required for a given SFP, the control plane MAY instruct the SFC-aware SF with the order to consume these Context Headers. If no instructions are provided, the SFC-aware SF MUST process these Context Headers in the order their appear in an NSH packet.

If multiple instances of the same metadata are included in an NSH packet, but the definition of that context header does not allow for it, the SFC-aware SF MUST process first instance and ignore subsequent instances.

4. NSH Actions

NSH-aware nodes are the only nodes that may alter the content of NSH headers. NSH-aware nodes include: service classifiers, SFF, SF and SFC proxies. These nodes have several possible header related actions:

1. Insert or remove NSH: These actions can occur at the start and end respectively of a service path. Packets are classified, and if determined to require servicing, NSH will be imposed. A service classifier **MUST** insert NSH at the start of an SFP. An imposed NSH **MUST** contain valid Base Header and Service Path Header. At the end of a service function path, a SFF, **MUST** be the last node operating on the service header and **MUST** remove NSH before forwarding or delivering the un-encapsulated packet

Multiple logical classifiers may exist within a given service path. Non-initial classifiers may re-classify data and that re-classification **MAY** result in the selection a different Service Function Path. When the logical classifier performs re-classification that results in a change of service path, it **MUST** remove the existing NSH and **MUST** impose a new NSH with the Base Header and Service Path Header reflecting the new service path information and set the initial SI. Metadata **MAY** be preserved in the new NSH.

2. Select service path: The Service Path Header provides service path information and is used by SFFs to determine correct service path selection. SFFs **MUST** use the Service Path Header for selecting the next SF or SFF in the service path.
3. Update NSH: SFs **MUST** decrement the service index by one. If an SFF receives a packet with an SPI and SI that do not correspond to a valid next hop in a valid Service Function Path, that packet **MUST** be dropped by the SFF.

Classifiers **MAY** update Context Headers if new/updated context is available.

If an SFC proxy is in use (acting on behalf of a NSH unaware service function for NSH actions), then the proxy **MUST** update Service Index and **MAY** update contexts. When an SFC proxy receives an NSH-encapsulated packet, it **MUST** remove NSH before forwarding it to an NSH unaware SF. When the SFC Proxy receives a packet back from an NSH unaware SF, it **MUST** re-encapsulates it with the correct NSH, and **MUST** decrement the Service Index by one.

4. Service policy selection: Service Functions derive policy (i.e. service actions such as permit or deny) selection and enforcement from NSH. Metadata shared in NSH can provide a range of service-relevant information such as traffic classification.

Figure 7 maps each of the four actions above to the components in the SFC architecture that can perform it.

Component	Insert or remove NSH		Forward NSH Packets	Update NSH	Service policy selection	
	Insert	Remove		Dec. Service Index	Update Context Header	
Classifier	+	+			+	
Service Function Forwarder (SFF)		+	+			
Service Function (SF)				+	+	+
SFC Proxy	+	+		+	+	

Figure 7: NSH Action and Role Mapping

5. NSH Encapsulation

Once NSH is added to a packet, an outer encapsulation is used to forward the original packet and the associated metadata to the start of a service chain. The encapsulation serves two purposes:

1. Creates a topologically independent services plane. Packets are forwarded to the required services without changing the underlying network topology
2. Transit network nodes simply forward the encapsulated packets as is.

The service header is independent of the encapsulation used and is encapsulated in existing transports. The presence of NSH is indicated via protocol type or other indicator in the outer encapsulation.

6. Fragmentation Considerations

NSH and the associated transport header are "added" to the encapsulated packet/frame. This additional information increases the size of the packet.

As discussed in [[encap-considerations](#)], within an administrative domain, an operator can ensure that the underlay MTU is sufficient to carry SFC traffic without requiring fragmentation.

However, there will be cases where the underlay MTU is not large enough to carry the NSH traffic. Since NSH does not provide fragmentation support at the service plane, the transport/overlay layer **MUST** provide the requisite fragmentation handling. Section 6 of [[encap-considerations](#)] provides guidance for those scenarios.

7. Service Path Forwarding with NSH

7.1. SFFs and Overlay Selection

As described above, NSH contains a Service Path Identifier (SPI) and a Service Index (SI). The SPI is, as per its name, an identifier. The SPI alone cannot be used to forward packets along a service path. Rather the SPI provide a level of indirection between the service path/topology and the network transport. Furthermore, there is no requirement, or expectation of an SPI being bound to a pre-determined or static network path.

The Service Index provides an indication of location within a service path. The combination of SPI and SI provides the identification of a logical SF and its order within the service plane, and is used to select the appropriate network locator(s) for overlay forwarding. The logical SF may be a single SF, or a set of eligible SFs that are equivalent. In the latter case, the SFF provides load distribution amongst the collection of SFs as needed.

SI serves as a mechanism for detecting invalid service function path. In particular, an SI value of zero indicates that forwarding is incorrect and the packet must be discarded

This indirection -- path ID to overlay -- creates a true service plane. That is the SFF/SF topology is constructed without impacting the network topology but more importantly service plane only participants (i.e. most SFs) need not be part of the network overlay topology and its associated infrastructure (e.g. control plane, routing tables, etc.). SFs need to be able to return a packet to an appropriate SFF (i.e. has the requisite NSH information) when service processing is complete. This can be via the over or underlay and in some case require additional configuration on the SF. As mentioned above, an existing overlay topology may be used provided it offers the requisite connectivity.

The mapping of SPI to transport occurs on an SFF (as discussed above, the first SFF in the path gets a NSH encapsulated packet from the Classifier). The SFF consults the SPI/ID values to determine the appropriate overlay transport protocol (several may be used within a given network) and next hop for the requisite SF. Figure 8 below depicts an example of a single next-hop SPI/SI to network overlay network locator mapping.

SPI	SI	Next hop(s)	Transport
10	255	192.0.2.1	VXLAN-gpe
10	254	198.51.100.10	GRE
10	251	198.51.100.15	GRE
40	251	198.51.100.15	GRE
50	200	01:23:45:67:89:ab	Ethernet
15	212	Null (end of path)	None

Figure 8: SFF NSH Mapping Example

Additionally, further indirection is possible: the resolution of the required SF network locator may be a localized resolution on an SFF, rather than a service function chain control plane responsibility, as per figures 9 and 10 below.

Please note: VXLAN-gpe and GRE in the above table refer to [\[VXLAN-gpe\]](#) and [\[RFC2784\]](#), respectively.

SPI	SI	Next hop(s)
10	3	SF2
245	12	SF34
40	9	SF9

Figure 9: NSH to SF Mapping Example

SF	Next hop(s)	Transport
SF2	192.0.2.2	VXLAN-gpe
SF34	198.51.100.34	UDP
SF9	2001:db8::1	GRE

=

Figure 10: SF Locator Mapping Example

Since the SPI is a representation of the service path, the lookup may return more than one possible next-hop within a service path for a given SF, essentially a series of weighted (equally or otherwise) paths to be used (for load distribution, redundancy or policy), see Figure 11. The metric depicted in Figure 11 is an example to help illustrated weighing SFs. In a real network, the metric will range from a simple preference (similar to routing next-hop), to a true dynamic composite metric based on some service function-centric state (including load, sessions state, capacity, etc.)

+-----+				
SPI	SI	NH		Metric
+-----+				
10	3	203.0.113.1	1	
		203.0.113.2	1	
20	12	192.0.2.1	1	
		203.0.113.4	1	
30	7	192.0.2.10	10	
		198.51.100.1	5	
+-----+				

(encapsulation type omitted for formatting)

Figure 11: NSH Weighted Service Path

7.2. Mapping NSH to Network Transport

As described above, the mapping of SPI to network topology may result in a single path, or it might result in a more complex topology. Furthermore, the SPI to overlay mapping occurs at each SFF independently. Any combination of topology selection is possible. Please note, there is no requirement to create a new overlay topology if a suitable one already existing. NSH packets can use any (new or existing) overlay provided the requisite connectivity requirements are satisfied.

Examples of mapping for a topology:

1. Next SF is located at SFFb with locator 2001:db8::1
SFFa mapping: SPI=10 --> VXLAN-gpe, dst-ip: 2001:db8::1

2. Next SF is located at SFFc with multiple network locators for load distribution purposes:
SFFb mapping: SPI=10 --> VXLAN-gpe, dst_ip:203.0.113.1, 203.0.113.2, 203.0.113.3, equal cost
3. Next SF is located at SFFd with two paths from SFFc, one for redundancy:
SFFc mapping: SPI=10 --> VXLAN-gpe, dst_ip:192.0.2.10 cost=10, 203.0.113.10, cost=20

In the above example, each SFF makes an independent decision about the network overlay path and policy for that path. In other words, there is no a priori mandate about how to forward packets in the network (only the order of services that must be traversed).

The network operator retains the ability to engineer the network paths as required. For example, the overlay path between SFFs may utilize traffic engineering, QoS marking, or ECMP, without requiring complex configuration and network protocol support to be extended to the service path explicitly. In other words, the network operates as expected, and evolves as required, as does the service plane.

7.3. Service Plane Visibility

The SPI and SI serve an important function for visibility into the service topology. An operator can determine what service path a packet is "on", and its location within that path simply by viewing NSH information (packet capture, IPFIX, etc.). The information can be used for service scheduling and placement decisions, troubleshooting and compliance verification.

7.4. Service Graphs

While a given realized service function path is a specific sequence of service functions, the service as seen by a user can actually be a collection of service function paths, with the interconnection provided by classifiers (in-service path, non-initial reclassification). These internal reclassifiers examine the packet at relevant points in the network, and, if needed, SPI and SI are updated (whether this update is a re-write, or the imposition of a new NSH with new values is implementation specific) to reflect the "result" of the classification. These classifiers may also of course modify the metadata associated with the packet.

[RFC7665, section 2.1](#) describes Service Graphs in detail.

8. Policy Enforcement with NSH

8.1. NSH Metadata and Policy Enforcement

As described in [Section 3](#), NSH provides the ability to carry metadata along a service path. This metadata may be derived from several sources, common examples include:

Network nodes/devices: Information provided by network nodes can indicate network-centric information (such as VRF or tenant) that may be used by service functions, or conveyed to another network node post service path egress.

External (to the network) systems: External systems, such as orchestration systems, often contain information that is valuable for service function policy decisions. In most cases, this information cannot be deduced by network nodes. For example, a cloud orchestration platform placing workloads "knows" what application is being instantiated and can communicate this information to all NSH nodes via metadata carried in the context header(s).

Service Functions: A classifier co-resident with Service Functions often perform very detailed and valuable classification. In some cases they may terminate, and be able to inspect encrypted traffic.

Regardless of the source, metadata reflects the "result" of classification. The granularity of classification may vary. For example, a network switch, acting as a classifier, might only be able to classify based on a 5-tuple, whereas, a service function may be able to inspect application information. Regardless of granularity, the classification information can be represented in NSH.

Once the data is added to NSH, it is carried along the service path, NSH-aware SFs receive the metadata, and can use that metadata for local decisions and policy enforcement. The following two examples highlight the relationship between metadata and policy:

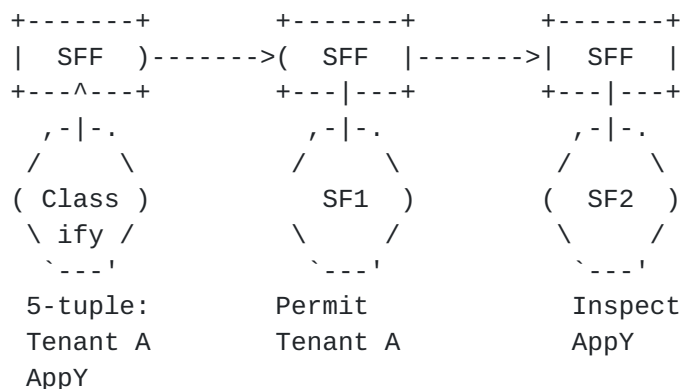


Figure 12: Metadata and Policy

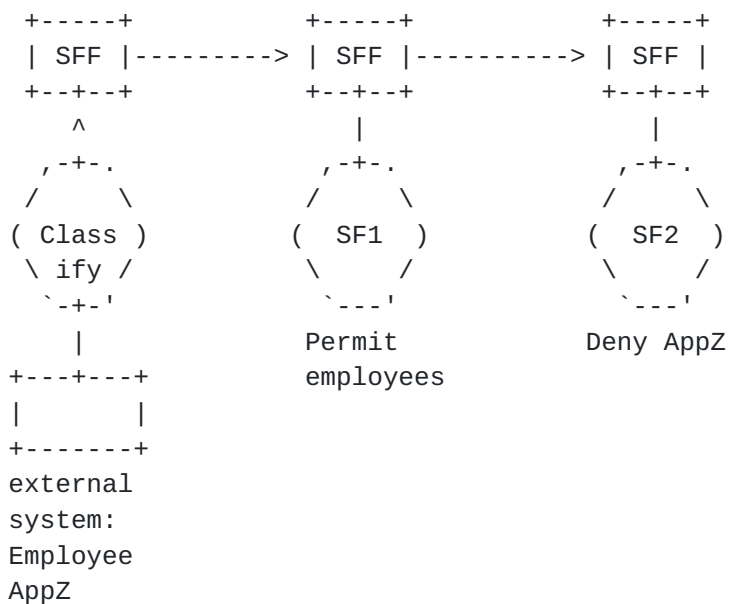


Figure 13: External Metadata and Policy

In both of the examples above, the service functions perform policy decisions based on the result of the initial classification: the SFs did not need to perform re-classification, rather they rely on a antecedent classification for local policy enforcement.

Depending on the information carried in the metadata, data privacy considerations may need to be considered. For example, if the metadata conveys tenant information, that information may need to be authenticated and/or encrypted between the originator and the intended recipients (which may include intended SFs only) . NSH

itself does not provide privacy functions, rather it relies on the transport/overlay layer. An operator can select the appropriate transport to ensure the confidentiality (and other security) considerations are met. Metadata privacy and security considerations are a matter for the documents that define metadata format.

8.2. Updating/Augmenting Metadata

Post-initial metadata imposition (typically performed during initial service path determination), metadata may be augmented or updated:

1. **Metadata Augmentation:** Information may be added to NSH's existing metadata, as depicted in Figure 14. For example, if the initial classification returns the tenant information, a secondary classification (perhaps co-resident with DPI or SLB) may augment the tenant classification with application information, and impose that new information in NSH metadata. The tenant classification is still valid and present, but additional information has been added to it.
2. **Metadata Update:** Subsequent classifiers may update the initial classification if it is determined to be incorrect or not descriptive enough. For example, the initial classifier adds metadata that describes the traffic as "internet" but a security service function determines that the traffic is really "attack". Figure 15 illustrates an example of updating metadata.

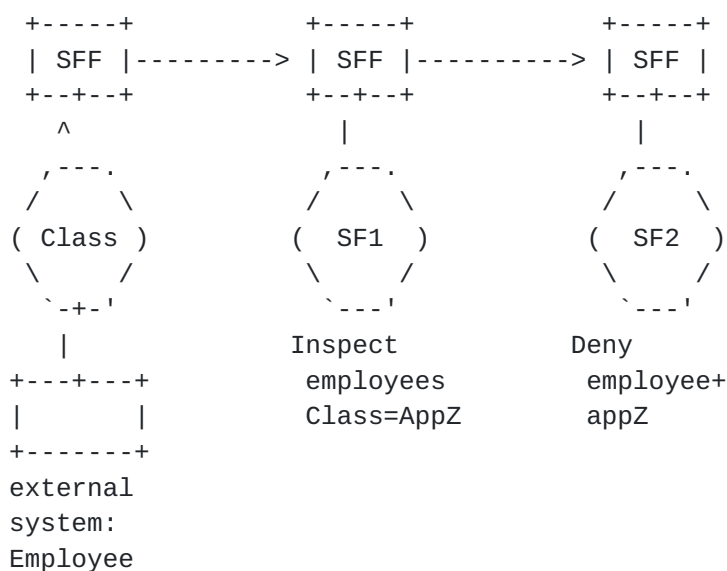


Figure 14: Metadata Augmentation

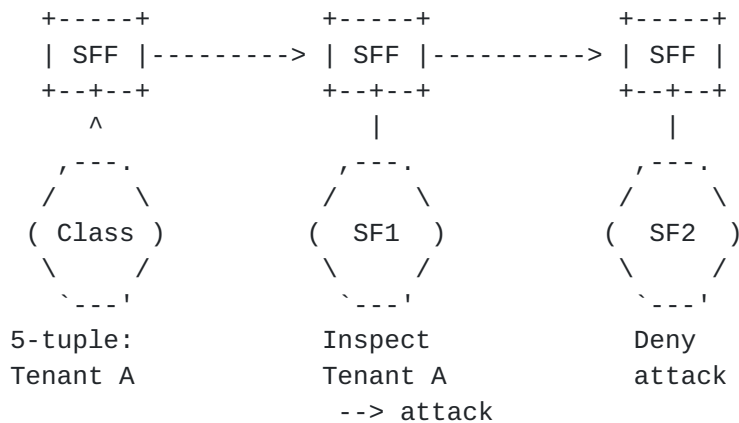


Figure 15: Metadata Update

8.3. Service Path Identifier and Metadata

Metadata information may influence the service path selection since the Service Path Identifier values can represent the result of classification. A given SPI can be defined based on classification results (including metadata classification). The imposition of the SPI and SI results in the packet being placed on the newly specified SFP at the position indicated by the imposed SPI and SI.

This relationship provides the ability to create a dynamic service plane based on complex classification without requiring each node to be capable of such classification, or requiring a coupling to the network topology. This yields service graph functionality as described in [Section 7.4](#). Figure 16 illustrates an example of this behavior.

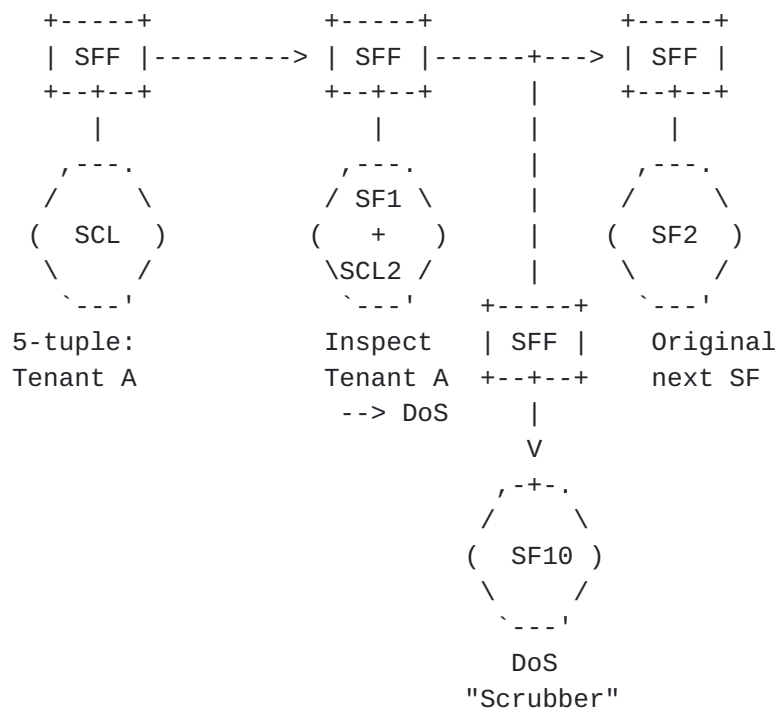


Figure 16: Path ID and Metadata

Specific algorithms for mapping metadata to an SPI are outside the scope of this document.

9. Security Considerations

As with many other protocols, NSH data can be spoofed or otherwise modified. In many deployments, NSH will be used in a controlled environment, with trusted devices (e.g. a data center) thus mitigating the risk of unauthorized header manipulation.

NSH is always encapsulated in a transport protocol and therefore, when required, existing security protocols that provide authenticity (e.g. [\[RFC6071\]](#)) can be used. Similarly, if confidentiality is required, existing encryption protocols can be used in conjunction with encapsulated NSH.

Further, existing best practices, such as [\[BCP38\]](#) should be deployed at the network layer to ensure that traffic entering the service path is indeed "valid". [\[encap-considerations\]](#) provides additional transport encapsulation considerations.

NSH metadata authenticity and confidentiality must be considered as well. In order to protect the metadata, an operator can leverage the aforementioned mechanisms provided the transport layer, authenticity and/or confidentiality. An operator **MUST** carefully select the transport/underlay services to ensure end to end security services, when those are sought after. For example, if [\[RFC6071\]](#) is used, the operator **MUST** ensure it can be supported by the transport/underlay of all relevant network segments as well as SFF and SFs. Further, as described in [\[section 8.1\]](#), operators can and should use indirect identification for personally identifying information, thus significantly mitigating the risk of privacy violation.

Lastly, SF security, although out of scope of this document, should be considered, particularly if an SF needs to access, authenticate or update NSH metadata.

10. Contributors

This WG document originated as [draft-quinn-sfc-nsh](#) and had the following co-authors and contributors. The editors of this document would like to thank and recognize them and their contributions. These co-authors and contributors provided invaluable concepts and content for this document's creation.

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11. Acknowledgments

The authors would like to thank Sunil Vallamkonda, Nagaraj Bagepalli, Abhijit Patra, Peter Bosch, Darrel Lewis, Pritesh Kothari, Tal Mizrahi and Ken Gray for their detailed review, comments and contributions.

A special thank you goes to David Ward and Tom Edsall for their guidance and feedback.

Additionally the authors would like to thank Larry Kreeger for his invaluable ideas and contributions which are reflected throughout this document.

Loa Andersson provided a thorough review and valuable comments, we thank him for that.

Reinaldo Penno deserves a particular thank you for his architecture and implementation work that helped guide the protocol concepts and design.

Lastly, David Dolson has provides significant review, feedback and suggestions throughout the evolution of this document. His contributions are very much appreciated.

12. IANA Considerations

12.1. NSH EtherType

An IEEE EtherType, 0x894F, has been allocated for NSH.

12.2. Network Service Header (NSH) Parameters

IANA is requested to create a new "Network Service Header (NSH) Parameters" registry. The following sub-sections request new registries within the "Network Service Header (NSH) Parameters " registry.

12.2.1. NSH Base Header Reserved Bits

There are five reserved bits in the NSH Base Header. New bits are assigned via Standards Action [[RFC5226](#)].

Bit 3 - Reserved

Bits 16-19 - Reserved

12.2.2. NSH Version

IANA is requested to setup a registry of "NSH Version". New values are assigned via Standards Action [[RFC5226](#)].

Version 00: This protocol version. This document.

Version 01: Reserved. This document.

Version 10: Unassigned.

Version 11: Unassigned.

12.2.3. MD Type Registry

IANA is requested to set up a registry of "MD Types". These are 4-bit values. MD Type values 0, 1, 2, 15, and 16 are specified in this document. Registry entries are assigned by using the "IETF Review" policy defined in [RFC 5226](#) [[RFC5226](#)].

MD Type	Description	Reference
0	Reserved	This document
1	NSH	This document
2	NSH	This document
3..14	Unassigned	
15	Experiment 1	This document
16	Experiment 2	This document

Table 1

[12.2.4.](#) MD Class Registry

IANA is requested to set up a registry of "MD Class". These are 16-bit values. New allocations are to be made according to the following policies:

0x0000 to 0x01ff: IETF Review
 0x0200 to 0xffff5: Expert Review
 0xffff6 to 0xffffe: Experimental
 0xfffff: Reserved

IANA is requested to assign the following value:

MD Class	Meaning	Reference
0x0000	IETF Base NSH MD Class	[This.I-D]

Designated Experts evaluating new allocation requests from the "Expert Review" range should principally consider whether a new MD class is needed compared to adding MD types to an existing class. The Designated Experts should also encourage the existence of an associated and publicly visible registry of MD types although this registry need not be maintained by IANA.

[12.2.5.](#) NSH Base Header Next Protocol

IANA is requested to set up a registry of "Next Protocol". These are 8-bit values. Next Protocol values 0, 1, 2, 3, 4 and 5 are defined

in this draft. New values are assigned via "Expert Reviews" as per [\[RFC5226\]](#).

Next Protocol	Description	Reference
0	Reserved	This document
1	IPv4	This document
2	IPv6	This document
3	Ethernet	This document
4	NSH	This document
5	MPLS	This document
6..253	Unassigned	
254	Experiment 1	This document
255	Experiment 2	This document

Table 2

[12.2.6.](#) New IETF assigned MD Type Registry

This document requests IANA to create a registry for the type values owned by the IETF (i.e., MD Class set to 0x0000) called the "IETF Assigned MD Type Registry."

The type values are assigned via Standards Action [\[RFC5226\]](#).

No initial values are assigned at the creation of the registry.

13. References

13.1. 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, <<http://www.rfc-editor.org/info/rfc2119>>.
- [RFC5226] Narten, T. and H. Alvestrand, "Guidelines for Writing an IANA Considerations Section in RFCs", [RFC 5226](#), DOI 10.17487/RFC5226, May 2008, <<http://www.rfc-editor.org/info/rfc5226>>.
- [RFC7665] Halpern, J., Ed. and C. Pignataro, Ed., "Service Function Chaining (SFC) Architecture", [RFC 7665](#), DOI 10.17487/[RFC7665](#), October 2015, <<http://www.rfc-editor.org/info/rfc7665>>.

13.2. Informative References

- [RFC2784] Farinacci, D., Li, T., Hanks, S., Meyer, D., and P. Traina, "Generic Routing Encapsulation (GRE)", [RFC 2784](#), DOI 10.17487/RFC2784, March 2000, <<http://www.rfc-editor.org/info/rfc2784>>.
- [RFC2827] Ferguson, P. and D. Senie, "Network Ingress Filtering: Defeating Denial of Service Attacks which employ IP Source Address Spoofing", [BCP 38](#), [RFC 2827](#), DOI 10.17487/RFC2827, May 2000, <<http://www.rfc-editor.org/info/rfc2827>>.
- [RFC6071] Frankel, S. and S. Krishnan, "IP Security (IPsec) and Internet Key Exchange (IKE) Document Roadmap", [RFC 6071](#), DOI 10.17487/RFC6071, February 2011, <<http://www.rfc-editor.org/info/rfc6071>>.
- [RFC7325] Villamizar, C., Ed., Kompella, K., Amante, S., Malis, A., and C. Pignataro, "MPLS Forwarding Compliance and Performance Requirements", [RFC 7325](#), DOI 10.17487/RFC7325, August 2014, <<http://www.rfc-editor.org/info/rfc7325>>.
- [RFC7498] Quinn, P., Ed. and T. Nadeau, Ed., "Problem Statement for Service Function Chaining", [RFC 7498](#), DOI 10.17487/[RFC7498](#), April 2015, <<http://www.rfc-editor.org/info/rfc7498>>.
- [SFC-CP] Boucadair, M., "Service Function Chaining (SFC) Control Plane Components & Requirements", 2016, <<https://>

datatracker.ietf.org/doc/draft-ietf-sfc-control-plane/>.

[VXLAN-gpe]

Quinn, P., Manur, R., Agarwal, P., Kreeger, L., Lewis, D., Maino, F., Smith, M., Yong, L., Xu, X., Elzur, U., Garg, P., and D. Melman, "Generic Protocol Extension for VXLAN", <<https://datatracker.ietf.org/doc/draft-ietf-nvo3-vxlan-gpe/>>.

[bcp38]

Ferguson, P. and D. Senie, "Network Ingress Filtering: Defeating Denial of Service Attacks which employ IP Source Address Spoofing", 2000, <<https://tools.ietf.org/html/bcp38>>.

[broadalloc]

Napper, J., Kumar, S., Muley, P., and W. Hendericks, "NSH Context Header Allocation -- Mobility", 2016, <<https://datatracker.ietf.org/doc/draft-napper-sfc-nsh-broadband-allocation/>>.

[dcalloc]

Guichard, J., Smith, M., and et al., "Network Service Header (NSH) Context Header Allocation (Data Center)", 2016, <<https://datatracker.ietf.org/doc/draft-guichard-sfc-nsh-dc-allocation/>>.

[encap-considerations]

Nordmark, E., Tian, A., Gross, J., Hudson, J., Kreeger, L., Garg, P., Thaler, P., and T. Herbert, "Encapsulation Considerations", <<https://datatracker.ietf.org/doc/draft-ietf-rtgwg-dt-encap/>>.

[nsh-env-req]

Migault, D., Pignataro, C., Reddy, T., and C. Inacio, "SFC environment Security requirements", 2016, <<https://www.ietf.org/id/draft-mglt-sfc-security-environment-req-02.txt>>.

[oam-frame]

Aldrin, S., Krishnan, R., Akiya, N., Pignataro, C., and A. Ghanwani, "Service Function Chaining Operation, Administration and Maintenance Framework", 2016, <<https://tools.ietf.org/html/draft-ietf-sfc-oam-framework-01/>>.

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