NSIS Working Group
Internet Draft

Ilya Freytsis
Cetacean Networks
Robert Hancock
Siemens/Roke Manor Research
Georgios Karagiannis
Ericsson
John Loughney
Nokia
Sven Van den Bosch
Alcatel

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Next Steps in Signaling: Framework

Status of this Memo

Abstract

The NSIS working group is considering protocols for signaling for resources for a traffic flow along its path in the network. The requirements for such signaling are being developed in [2]; this Internet Draft will propose a framework for such signaling.

This initial version provides a model of the entities that take part in the signaling. It discusses the considerations that must be taken into account in developing the framework, particularly the structural options for the structure of such a protocol, and the interactions between NSIS and other protocols and functions, including security

issues. Finally, it includes background material on how NSIS could support particular signaling applications.

It is expected that future versions of this document will distill these structural options into a concrete technical framework, and material on particular signaling applications and deployment scenarios will be moved into separate NSIS applicability statements.

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 RFC-2119 [3].

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1. Introduction

NSIS will work on signaling from an end point that follows a path through the net that is determined by layer 3 routing and is used to

convey information to the devices the signals pass through - the signaling can, for example, install soft state in the devices it passes through. A signaling end point could be a device along the path, which signals for a data flow that passes through it.

The intention is to allow for the NSIS protocol to be deployed in different parts of the Internet, for different needs, without requiring a complete end-to-end deployment.

There is no requirement that the per-flow information be QoS related. NSIS should only worry about how to do the signaling - what the signaling conveys should be opaque to NSIS. This document discusses 'where' the signaling takes place, with some discussion on 'how' the signaling can be done.

1.1 Scope of the NSIS Framework

The scope of this document will be to provide a framework for where a NSIS protocol can be used and deployed. It is not intended that NSIS will define an over-arching architecture for carrying out resource management in the Internet, nor is this intended to be used as a detailed protocol design document.

The framework is not about what NSIS should do but how it should do it. It is not intended that this places requirements on a future NSIS protocol, since requirements are already defined in [2]. The document discusses important protocol considerations, such as mobility, security, and interworking with resource management (in a broad sense). Discussions about lessons to be learned from existing signaling and resource protocols are assumed to be contained in a separate analysis document.

This initial version provides a model of the entities that take part in the signaling. It discusses the considerations that must be taken into account in developing the framework, particularly the structural options for the structure of such a protocol, and the interactions between NSIS and other protocols and functions, including security issues. Finally, it includes background material on how NSIS could support particular signaling applications.

It is expected that future versions of this document will distill these structural options into a concrete technical framework, and material on particular signaling applications and deployment

scenarios will be moved into separate NSIS applicability statements.

The purpose of this document is to develop the realms, domains and modes of operation where an NSIS protocol can be used; identify the relationship of an NSIS protocol to other protocols; and identify areas for future work.

2. Terminology

Classifier - an entity which selects packets based on the content of packet headers according to defined rules.

Interdomain traffic - Traffic that passes from one NSIS domain to another.

NSIS Domain (ND) - Administrative domain where an NSIS protocol signals for a resource or set of resources.

NSIS Entity (NE) - the function within a node which implements an NSIS protocol.

NSIS Forwarder (NF) - NSIS Entity on the path between a NI and NR which may interact with local resource management function (RMF). NSIS Forwarder also propagates NSIS signaling further through the network.

NSIS Initiator (NI) - NSIS Entity that initiates NSIS signaling for a network resource.

NSIS Responder (NR) - NSIS Entity that terminates NSIS signaling and can optionally interact with applications as well.

Path-coupled signaling - a mode of signaling where the signaling messages follow a path that is tied to the data messages. See also section 3.2.1.

Path-decoupled signaling - signaling with independent data and signaling paths.

Peer session - signaling relationship between two adjacent NSIS entities (i.e. NEs with no other NEs between them).

Resource - something of value in a network infrastructure to which

rules or policy criteria are first applied before access is granted. Examples of resources include the buffers in a router and bandwidth on an interface.

Resource Management Function (RMF) - an abstract concept, representing the management of resources in a domain or a node.

Service Level Agreement (SLA) - a service contract between a customer and a service provider that specifies the forwarding service a customer should receive.

[NSIS] Signaling application - the purpose of the NSIS signaling: a service could be QoS management, firewall control, and so on (see also [7]). Totally distinct from any specific user application.

Traffic characteristic - a description of the temporal behavior or a description of the attributes of a given traffic flow or traffic aggregate.

Traffic flow - a stream of packets between two end-points that can be characterized in a certain way.

3. Overall Framework Structure

3.1 Basic Signaling Entities and Interfaces

3.1.1 NSIS Entities

The NSIS protocol is intended to be used as a signaling control plane for the variety of network resources required for data traffic across the Internet. The most common NSIS signaling applications are QoS resources, firewalls and NATs resources, etc. The NSIS signaling itself does not depend on the signaling application it is used for but the information it carries does. This section discusses the basic signaling entities of the protocol as well as interfaces between them.

We can identify three different roles in the NSIS signaling for resources: initiator, forwarder and responder.

The NSIS Initiator (NI) is an entity that initiates NSIS signaling (request) for the network resource. The NSIS initiator can be triggered by the different "sources" - user applications, an instance

of NSIS Forwarder, other protocols, network management etc. - that need network resources for a data flow. For the purpose of the NSIS discussion all these sources can be called "applications" (note that this is entirely distinct from the specific term "signaling application"). The NSIS initiator can provide feedback information to the triggering application in respect to the requested network resources. The NSIS initiator uses NSIS signaling to interact with other NSIS entities (NFs and NRs).

The NSIS Forwarder (NF) is an entity that services NSIS resource requests from NSIS initiators and other NSIS forwarders. It may interact with local resource management function (RMF). How and if this interaction takes place depends on the deployed resource management mechanism and the specific role of the NF. The NSIS forwarder propagates NSIS signaling further through the network.

The NSIS Responder (NR) is an entity that terminates NSIS signaling and can optionally interact with local applications as well e.g. for the purpose of notification when network resources get allocated etc.

The signaling relationship between two NSIS entities (with no other NSIS entities between them) is called a 'Peer-session'. This concept might loosely be described as an 'NSIS hop'; however, there is no implication that it corresponds to a single IP hop.

Figure 1 depicts simplified interactions/interfaces between NI, NFs and NR as well as local applications and RMFs. Note that the NI and NR could also interact with an RMF; additionally, this could be modeled as co-location of NI&NF and NR&NF. This distinction should have no impact on the operation of the protocol. Also, there is no bar on placing an NI or NR in the interior of the network, to initiate and terminate NSIS signaling independently of the ultimate endpoints of the end to end flow, and NI and NR do not have to talk via intervening NFs. An example of NSIS being used in this way is given in section 7.5.

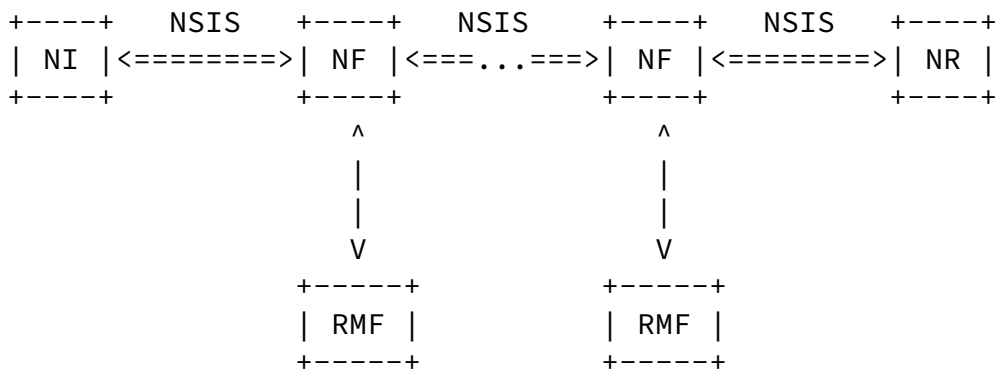


Figure 1: Basic NI/NF/NR Relationships

3.1.2 Placement of NSIS entities

The NI, NF and NR definitions do not make any assumptions about placements of NSIS signaling entities in respect to the particular part of the network or data-forwarding path.

They can be located along the data path (hosts generating and receiving data flows, edge routers, intermediate routers etc.) but it may not be the only one desirable location.

In some cases it is desired to be able to initiate and/or terminate NSIS signaling not from the end host that generates/receives the data flow, but from the some other entities on the network that can be

called NSIS signaling application proxies. There could be various reasons for this: signaling on behalf of the end hosts that are not enabled with NSIS, consolidation of the customer accounting (authentication, authorization) in respect to consumed application and transport resources, security considerations, limitation of the physical connection between host and network etc. The proxy can communicate the relevant information to the host in the application specific, maybe compressed, form.

Support for NSIS proxies affects the protocol in the following way:
*) The protocol should accommodate signaling with the scope of a single NSIS peer-session; the signaling could be propagated over multiple peer-sessions all the way toward the destination (end-to-end).

*) In the particular case where the proxy is not on the data path, NSIS might have to be extended to allow separated data and signaling paths, although this analysis is not initially in scope.

Further discussion of these issues is given in sections 3.2.1 and 3.3.3.

As it can be seen from the usage cases presented in the NSIS requirements draft [2] the NSIS signaling procedures may depend on the part/type of the network where NSIS is used. In fact to satisfy sometimes-conflicting requirements in [2], different procedures and possibly different kinds of the NSIS protocol can be used on different parts/types of the network. Sections 3.2 and 7.5 provide more details on this topic.

3.2 Modes of Operation

This section discusses several modes of NSIS protocol operation. Each mode of NSIS operation is briefly introduced and where needed analyzed and compared with other modes of NSIS operation.

3.2.1 Path-Coupled and Path-Decoupled Signaling

We can consider two basic paradigms for resource reservation signaling, which we refer to as "path-coupled" and "path-decoupled".

In the path-coupled case, signaling messages are routed only through nodes (NEs) that are in the data path. They do not have to reach all the nodes on the data path (for example, there could be proxies distinct from the sender and receiver as described in section 3.1.2, or intermediate signaling-unaware nodes); and between adjacent NEs, the route taken by signaling and data might diverge. The path-coupled case can be supported by various addressing styles, with messages either explicitly addressed to the neighbor on-path NE, or routed

identically to the data packets and intercepted. These cases are considered in section 3.3.4. In the second case, some network configurations may split the signaling and data paths (see section 5.2); this is considered an error case for path-coupled signaling.

In the path-decoupled case, signaling messages are routed to nodes (NEs) which are not assumed to be on the data path, but which are (presumably) aware of it. Signaling messages will always be directly addressed to the neighbor NE, and the NI/NR may have no relation at

all with the ultimate data sender or receiver.

There are potentially significant differences in the way that the two signaling paradigms should be analyzed, for example in terms of scaling behavior, failure recovery, security properties, mechanism for NSIS peer discovery, and so on. These differences might or might not cause changes in the way that the NSIS protocol operates.

The initial goal of NSIS and this framework is to concentrate mainly on the path-coupled case.

3.2.2 Inter-domain and Intra-domain Signaling

Inter-domain NSIS signaling is where the NSIS signaling messages are originated in one NSIS domain and are terminated in another NSIS domain.

In the path-coupled case, inter-domain NSIS signaling can be used to signal NSIS information to the edge nodes of one or more NSIS domains.

In the path-decoupled case, inter-domain NSIS signaling can be used to signal NSIS information to entities that are not on the data path (i.e., "out-of-band" NFs), and additionally to signal from off-path entities to on-path edge nodes .

NSIS inter-domain signaling has to fulfill several requirements, such as:
 *) Basic functionality, such as scalable, simple and fast signaling. Because different networks have different resource management characteristics, such as cost of bandwidth and performance, this basic functionality may differ from one NSIS domain to another.
 *) All other requirements specified in [2].

Intra-domain NSIS signaling is where the NSIS signaling messages are originated, processed and terminated within the same NSIS domain. Note that these messages could be handled within a local instance of NSIS signaling; another possibility could be to piggyback them on inter-domain NSIS messages.

Intra-domain signaling can be used to signal NSIS information to the edge nodes (i.e., routers located at the border of the NSIS domain) and to the interior nodes (i.e., routers located within the NSIS

domain that are not edge nodes).

The NSIS intra-domain signaling approach has to fulfill fewer requirements than inter-domain signaling. These are:
*) Basic functionality, such as scalable, simple and fast signaling. Due to the fact that different networks have different resource management characteristics, this basic functionality may differ from one NSIS domain to another.
*) Provides the necessary functionality to interact between inter-domain signaling and intra-domain signaling.

3.2.3 End-to-End, Edge-to-Edge, and End-to-Edge

End-to-end: When used end-to-end, the NSIS protocol is initiated by an end host and is terminated by another end host. In this context, NSIS can be applied as needed within all of the NSIS domains between the end hosts. In the end-to-end path, NSIS may be used both for intra-domain NSIS signaling, as well as for inter-domain signaling.

Edge-to-edge: In this scenario the NSIS protocol is initiated by an edge node of a NSIS domain and is terminated by another edge node of the same (or possibly different) NSIS domain. NSIS can be applied either within one single NSIS domain, which is denoted as edge-to-edge in a single domain, or within a concatenated number of NSIS domains, which is denoted as edge-to-edge in a multi-domain. When an appropriate security trust relation exists between two or more concatenated NSIS domains, these concatenated NSIS domains are considered, in terms of NSIS, to be a single, larger NSIS domain.

End-to-edge: In this scenario the NSIS protocol is either initiated by an end host and is terminated by an edge node or is initiated by an edge node and is terminated by an end host. In the path-coupled case, the edge node may be a proxy that is located on a boundary node of a NSIS domain. In the path-decoupled case, the edge node may be a proxy that is located on an off-path node that controls, or is associated with, a NSIS domain.

3.2.4 Global and Local Operation

It is likely that the appropriate way to describe the resources NSIS is signaling for will vary from one part of the network to another. In particular, resource descriptions that are valid for inter-domain links will probably be different from those useful for intra-domain

operation (and the latter will differ from one NSIS domain to another).

One way to describe this issue is to consider the resource description objects carried by NSIS as divided in globally-understood objects ("global objects") and locally-understood objects ("local objects"). The local objects are only applicable for intra-domain signaling, while the global objects are mainly used in inter-domain signaling.

The purpose of this division is to provide additional flexibility in defining the objects carried by the NSIS protocol such that only those objects that are applicable in a particular setting are used. An example approach for reflecting the distinction in the signaling is that local objects could be put into separate local messages that are initiated and terminated within one single NSIS domain and/or they could be "stacked" within the NSIS messages that are used for inter-domain signaling. These possibilities will be considered further during the protocol design activity.

3.2.5 Multicast versus Unicast

Multicast support, compared to unicast support, would introduce a level of complexity into the NSIS protocol mainly related to:
*) complex state maintenance to support dynamic membership changes in the multicast groups, such as reservation state merging and maintenance.
*) a state per flow has to be maintained that is used during backward routing.

3.2.6 Sender versus Receiver Initiated Signaling

A sender-initiated approach is when the sender of the data flow initiates and maintains the resource reservation used for that flow. In a receiver-initiated approach the receiver of the data flow initiates and maintains the resource reservation used for the data flow.

In the path-coupled case, and in the absence of NSIS proxies, the following relationships apply:
*) in the sender initiated case, the sender of the data is the NSIS Initiator, while the receiver of the data is the NSIS Responder;
*) in the receiver initiated case, the receiver of the data is the NSIS Initiator, while the sender of the data is the NSIS Responder.
In the path-decoupled case, the mapping is not necessarily clear cut (for example, if the NI and NR are not located at the end systems themselves).

The main differences between the sender-initiated and receiver-initiated approaches are the following:
*) Compared with the receiver-initiated approach, a sender using a sender-initiated approach can be informed faster when the reservation request is rejected. In other words, when using a sender-initiated approach, the reservation request response time can be shorter in the case of an unsuccessful reservation than with a receiver-initiated approach.
*) In a receiver-initiated approach, the signaling messages traveling from the receiver to the sender must be backward routed such that they follow exactly the same path as was followed by the signaling messages belonging to the same flow traveling from the sender to the receiver. This implies that a backward routing state per flow must be maintained. When using a sender-initiated approach, provided acknowledgements and notifications can be securely delivered to the sending node, backward routing is not necessary, and nodes do not have to maintain backward routing states.
*) In a sender-initiated approach, a mobile node can initiate a reservation for its incoming flows as soon as it has moved to another roaming subnetwork. In a receiver-initiated approach, a mobile node has to inform the receiver about its handover procedure, thus allowing the receiver to initiate a reservation.

3.2.7 Uni-Directional and Bi-Directional Reservations

It is possible that a resource will only be required for one direction of traffic, for example for a media stream with no feedback channel. Reservations for both directions of traffic may be required for other applications, for example a voice call. Therefore, the NSIS signaling protocol must allow for both uni- and bi-directional resource reservations.

The most basic method for bi-directional reservations is based on combining two uni-directional reservations. This means that the signaling messages from the sender of the bi-directional reservation towards a receiver are able to follow a different path from messages traveling in the opposite direction, which is necessary for path-coupled signaling in the presence of asymmetric routing. (Other more integrated approaches may be possible in constrained network topologies.) The bi-directional reservations can, for example, be used to make the NSIS signaling procedure required after a handover procedure more efficient.

3.3 Basic Assumptions and Conceptual Issues

3.3.1 Basic Assumptions

The following assumptions have been made during prior NSIS requirements work and initial framework discussions. They are summarized here for completeness. The subsequent subsections describe more generic conceptual assumptions and issues. Note that a complete overview of current open issues is contained in section 8.

*) The solution developed by NSIS must be sufficiently flexible and modular that it can be efficiently deployed and used with functionality appropriate to the part/type of the network. (Sections 3.2.2 and 3.2.3.)

*) The protocol developed by the NSIS working group will be path-coupled. Considerations related to a potential path-decoupled solution are part of this framework, because they are also needed in order to co-exist with existing solutions; however, the NSIS working group currently has no plans to develop path-decoupled signaling protocol. (Section 3.2.1.)

*) Multicast support introduces a level of complexity into the NSIS protocol that is not needed in support of unicast applications. Therefore, a working assumption is be that the NSIS protocol should be optimized for unicast. (Section 3.2.5.)

*) The NSIS protocol can be used for setup of both uni-directional and bi-directional reservations. (Section 3.2.7.)

3.3.2 NI, NF, NR functionality

The basic functions that can be fulfilled by an NSIS entity are request, accept, notify, modify and release of a reservation. At this point, it is not clear which responsibilities can be assumed by each of the NSIS entities. More in particular, it is not clear whether:
*) an NF can request, modify or release a reservation. If it cannot, it needs to notify the NI in order to perform these functions.
*) an NR can modify and release a reservation. Even if the NR can

reject or accept the reservation with modification, it might still be required to notify the NI to signal the release or modification.

3.3.3 NI, NF, NR relationship

An important open issue is related to the way in which NSIS entities maintain relations between each other. These relations could be purely local, where an NSIS entity only maintains relations with its direct neighbors (peers). In that case, messages will be sent to and

accepted from these neighbors only. Alternatively, the relations between NSIS entities could have a more global scope.

The type of NSIS peering relations may have an impact on the complexity involved with protocol security. In case of inter-domain signaling, the security relations are likely to be built between neighboring NSIS entities only for scalability reasons. In that case, each NSIS entity will establish and maintain a security relation with each of its peers and accept only messages from these peers.

Conversely, there may exist larger domains of NSIS entities that have a trust relationship (trusted domains). This may be the case for intra-domain signaling. In this case, an NE may accept messages from all other NSIS entities in the domain. Both alternatives need not be mutually exclusive. It is conceivable that different instances of the NSIS protocol (or different NSIS protocols) use the NSIS security model to a larger or lesser extent, provided that overall security is not impacted. An analysis of NSIS threats is available from [4].

The NSIS peering relations may also have an impact on the required amount of state at each NSIS entity. When direct interaction with remote NSIS peers is not allowed, it may be required to keep track of the path that an NSIS message has followed through the network. This can be achieved by keeping per-flow state at the NSIS entities or by maintaining a record route object in the NSIS messages.

3.3.4 NSIS Addressing

The are potentially two ways to establish a signaling connection by means of the NSIS protocol. On the one hand, the NSIS message could be addressed to a neighboring NSIS entity (NE) that is known to be closer to the destination NE. On the other hand, the NSIS message could be addressed to the destination directly, and intercepted by an intervening NE. We denote the latter approach as end-to-end

addressing and the former as peer-session addressing.

With peer-session addressing, an NE will determine the address of the next NE based on the payload of the NSIS message (and potentially also on the previous NE). This requires the address of the destination NE to be derivable from information present in the payload. This can be achieved through the availability of a local routing table or through participation in the routing protocol. Peer-session addressing inherently supports tunneling of NSIS signaling messages between NEs, and is equally applicable to the path-coupled and path-decoupled cases.

In case of end-to-end addressing, the NSIS message will be sent with the address of the NR, which then necessarily needs to be on the data

path. This requires (some of) the data-path entities to be upgraded (NSIS-aware) in order to be able to intercept the NSIS messages. The routing of the NSIS signaling should follow exactly the same path as the data flow for which the reservation is requested.

3.3.5 Service description

Although the service part of the NSIS message (the part that depends on the specific signaling application) is outside of the scope of the NSIS working group, it may be necessary to make some assumptions about its content in order to determine whether similar functionality needs to be foreseen in the NSIS-specific part of the message:
*) It is assumed that the service description will handle pre-emption and survivability issues. These are seen as a part of the offered service and need not be present in the NSIS control layer.
*) It is assumed that some flow description information is part of the NSIS control layer (see section 4.3.1 and 4.5.1). This might be needed by signaling application unaware entities located at address boundaries. It is not clear to which level of complexity, the flow description needs to be available at this level.
*) It is not assumed that the content of the service description is independent of the NSIS control layer. It seems appropriate to allow the content of the service description to be dependent on the type of message that is sent (request/response/refresh).

3.3.6 NSIS Acknowledgement and Notification Semantics

The semantics of the acknowledgement and notification messages are of particular importance. An NE sending a message can assume

responsibility for the entire downstream chain of NEs, indicating for instance the availability of reserved resources for the entire downstream path. Alternatively, the message could have a more local meaning, indicating for instance that a certain failure or degradation occurred at a particular NSIS entity.

4. Protocol Components

4.1 Lower Layer Interfaces

Within a signaling entity, NSIS interacts with the 'lower layers' of the protocol stack for two nearly independent purposes: sending and receiving signaling messages; and configuring the operation of the lower layers themselves.

For sending and receiving messages, this framework places the lower boundary of the NSIS protocol at the IP layer. (It is possible that NSIS could use a standard transport protocol above the IP layer to

provide some of its functionality; this is discussed in section 4.3.1.) The interface with the lower layers is therefore very simple:
*) NSIS sends raw IP packets
*) NSIS receives raw IP packets. In the case of peer-session addressing, they have been addressed directly to it. In the case of end-to-end addressing, this will be by intercepting packets that have been marked in some special way (by special protocol number or by some option interpreted within the IP layer, such as the Router Alert option [5] and [6].)

NSIS needs to have some information about the link and IP layer configuration of the local networking stack. For example, NSIS needs to know about:
*) [in general] how to select the outgoing interface for a signaling message, in case this needs to match the interface that will be used by the corresponding flow. This might be as simple as just allowing the IP layer to handle the message using its own routing table.
*) [in the case of IPv6] what address scopes are associated with the interfaces that messages are sent and received on (to interpret scoped addresses in flow identification, if these are to be allowed).

The way in which NSIS actually configures the lower layers to handle the flow depends on the particular NSIS signaling application; for example, if NSIS is being used for QoS signaling, this might involve

configuration of traffic classification and conditioning parameters, for example local packet queues, type of filters, type of scheduling, and so on. However, none of this is directly related to the NSIS protocol itself; therefore, this interaction is handled indirectly via a resource management function, as described in section 5.1.

4.2 Upper Layer Services

NSIS provides a signaling service, which can be used by multiple upper layers, or signaling applications. We describe this service here as an abstract set of capabilities. A later version of this framework could illustrate the use of these capabilities within a broader context (e.g. how NSIS signaling could be used within a complete set of message flows that signal a voice over IP call).

We can loosely define the boundary between NSIS and these signaling applications from three views:
 *) What basic control primitives are available at the interface;
 *) What information is exchanged within these primitives;
 *) What assumptions NSIS makes about operations carried out above the interface.

The set of control primitives required is quite small.
At the initiating (NI) end:

 *) Signaling application requests signaling for a new resource;
 *) Signaling application requests modification or removal of an existing resource.
 *) Signaling application receives progress indications (minimally, success or failure).
At the responding (NR) end:
 *) Notification to signaling application that a resource has been set up.
At either end:
 *) Notification to signaling application that something has changed about the available resource and other error conditions.

This description is in terms of a 'hard state' interface, without explicit refresh messages between the signaling application and NSIS, although this is an implementation issue. In any case, NSIS implementations will need to be able to detect conditions when instances of signaling applications fail without issuing explicit resource removal requests.

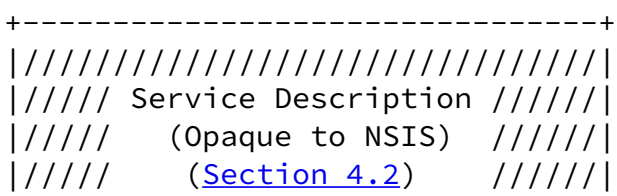
The information in the control primitives consists essentially of two parts. The first is the definition of the data flow for which the resource is being signaled. The format (e.g. socket id or packet fields or whatever) is an implementation issue; it has to be interpreted into a 'wire format' (as in section 4.5). Since NSIS could support both sender and receiver initiation, the flow definition must also state whether it is incoming or outgoing over a particular interface (this can be inferred when the initiator is colocated with the flow endpoint). The second part of the information exchanged is the service definition (e.g. QoS description in the case of a QoS request). This is opaque to NSIS, with the possible exception of identifying the signaling application in use (i.e. the resource type being signaled.)

We have a basic design goal not to duplicate functionality that is already present in (or most naturally part of) existing signaling protocols which could be used by the upper layers. Therefore NSIS (implicitly) assumes that certain procedures are carried out 'externally'. The main aspects of this are:
 *) Negotiation of service configuration (e.g. discovering what services are available to be requested);
 *) Agreement to use NSIS for signaling, and coordination of which end will be the initiator;
 *) (Potentially) discovery of the NSIS peer to be signaled with, especially if this is not directly on the data path. See also the security discussion in section 6.
Actually providing these functions might require enhancements to these other protocols. These are still to be identified.

4.3 Protocol Structure

4.3.1 Internal Layering

We can model NSIS in three layers, as shown in Figure 2. This is initially just a way of grouping associated functionality, and does not mean that all these layers could necessarily operate or even be implemented independently.



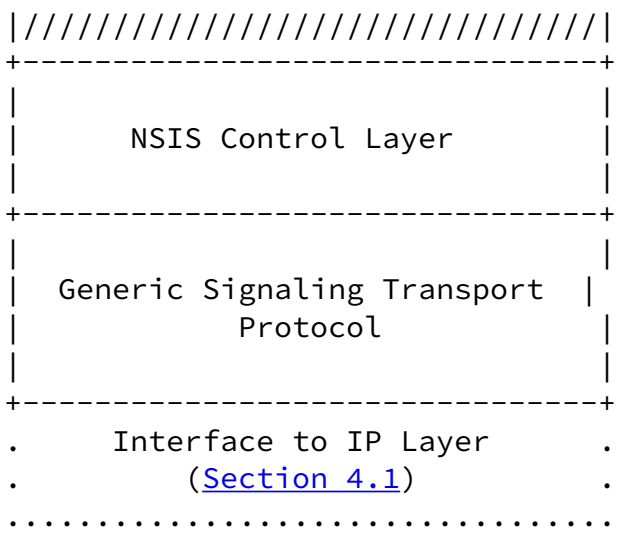


Figure 2: NSIS Layer Structure

The lower layer interface (to IP) has been described in section 4.1. The service description information is essentially the same as provided by the signaling application, as described in section 4.2. It isn't clear if the service description can be independent of the lower parts of the protocol or whether different descriptions would be valid at different stages of protocol operation. This depends on the particular signaling application, and therefore to make NSIS signaling application independent we must allow that the service description part may be explicitly dependent on the 'NSIS' fields which lie below. This is similar to the ALSP/CSTP coupling described in [7].

The distinction between the 'NSIS layer' and the 'Generic Signaling' layer is not functionally clear cut, but one of convenience. In outline:
*) The 'generic' layer provides (at most) functionality which might be available from existing protocols, such as SCTP [8] or IPSec [9].

An extreme case could be the binding update messages of mobility signaling (section 5.3.4).
*) The 'NSIS' layer provides (at least) functionality which is somehow specific to path-coupled signaling.

Functionality reasonable to re-use from existing protocols might include reliability and re-ordering protection, dead peer detection (keepalive), multihoming support, payload multiplexing (piggybacking), and security services, such as establish a security

context and carrying out key exchange.

Functionality which would probably have to be in the NSIS layer would include flow and reservation identification, some error handling, demultiplexing between different signaling applications, as well as the basic NSIS messages. More details on the messages are in section 4.3.2 and the identifier aspects in section 4.5.

The choice of using functionality from an existing protocol or re-specifying it as part of NSIS is for further analysis. It probably depends on the function in question, and in the end might be left flexible to allow optimization to local circumstances. (For example, Diameter allows the use of IPSec for security services, but also includes its own CMS application as an alternative.) Whichever approach is taken, the combination of NSIS and supporting transport protocol must provide a uniform protocol capability to the upper layers which contain the actual signaling application.

4.3.2 Protocol Messages

The NSIS specific part will include a set of messages to carry out particular operations along the signaling path. Initial work for RSVP concentrated on the particular case of QoS signaling, although in principle, the necessary basic messages could depend on the signaling application NSIS is being used for. However, the implication of the analysis in [7] is that this message set generalizes to a wide variety of scenarios, and so we use it as a starting point. A very similar set was generated in [10].

Note that the 'direction' column in the table below only indicates the 'orientation' of the message. The messages can be originated and absorbed at NF nodes as well as the NI or NR; an example might be NFs at the edge of a domain exchanging NSIS messages to set up resources for a flow across a it.

Note the working assumption that responder as well as the initiator can release a reservation (comparable to rejecting it in the first place). It is left open if the responder can modify a reservation, during or after setup. This seems mainly a matter of assumptions

about authorization, and the possibilities might depend on resource type specifics.

+-------+---------+---+

Name	Direction	Semantics
Request	I-->R	Create a new reservation for a flow
Modify	I-->R (&R-->I?)	Modify an existing reservation
Release	I-->R & R-->I	Delete (tear down) an existing reservation
Accept/ Reject	R-->I	Confirm (possibly modified?) or reject a reservation request
Notify	I-->R & R-->I	Report an event detected within the network (e.g. congestion condition or end of condition)
Refresh	I-->R	State management (see section 4.4)

The table also explicitly includes a refresh message. This does nothing to a reservation except extend its lifetime, and is one possible state management mechanism for NSIS. This is considered in more detail in section 4.4.

4.4 State Management

The prime purpose of NSIS is to manage state information along the path taken by a data flow. There two critical issues to be considered in building a robust protocol to handle this problem:

*) The protocol must be scalable. It should minimize the state storage demands that it makes on intermediate nodes; in particular, storage of state per 'micro' flow is likely to be impossible except at the very edge of the network.

*) The protocol must be robust against failure and other conditions, which imply that the stored state has to be moved or removed.

The total amount of state that has to be stored depends both on NSIS and on the specific signaling application in use. The signaling application might require per flow or lower granularity state; examples of each for the case of QoS would be IntServ or RMD (per 'class' state) respectively. The NSIS protocol should not overburden an application that was otherwise lightweight in state requirement. However, depending on design details, it might require storage of

per-flow state including reverse path peer addressing, simply for sending NSIS messages themselves.

There are several robustness problems, which roughly align with the 'layers' of the NSIS protocols of Figure 2, that can be handled by the soft state principle. (Independence of these layers therefore implies the danger of duplication of functionality.) This relies on periodic refresh of the state information with the current context, relying on invalid state being timed out. Soft state can be used either as the primary mechanism to handle the problem, or sometimes as a backup to some other approach.

*) At the lowest level, soft state can be used to detect dead NSIS peers - loss of several periodic messages implies termination of the signaling. (The same inference can be made e.g. if failure is detected at the link layer.) The assumption is then that the corresponding reservation should be automatically deleted, and the deletion propagated along the remainder of the path.

*) At the next level, in the event of a routing change (for example caused by network changes or end host mobility), reservation state should be removed from the old path and added to the new one. This will be handled automatically by periodic messaging, provided that the entities on the new path accept a Refresh message to install a new reservation. (A partial alternative is to have a routing-aware NSIS implementation, if the route change takes place at an NSIS-aware node.)

*) At the highest level, a particular signaling application might have timing limits associated with a particular reservation (e.g. credit limited network access). Periodic re-authorized requests can be used as part of the time control.

All of these can be handled with a single soft state mechanism, although it may be hard to choose a single refresh interval and message loss threshold appropriate for all of them. Even where alternative approaches are possible, for example using knowledge of the fact that a routing change has occurred to trigger an explicit NSIS release message, it seems that a soft state mechanism is always necessary as a backup.

4.5 Identity Elements

NSIS will carry certain identifiers within the NSIS layer. The most significant identifier needs seem to be the following.

4.5.1 Flow Identification

The flow identification is a method of identifying a flow in a unique way. All packets and/or messages that are associated with the same flow will be identified by the same flow identifier. In principle, it could be a combination of the following information (note that this is not an exclusive list of information that could be used for flow identification):

*) source IP address;
*) destination IP address;
*) protocol identifier and higher layer (port) addressing;
*) flow label (typical for IPv6);
*) SPI field for IPSec encapsulated traffic;
*) DSCP/TOS field

We've assumed here that the flow identification is not hidden within the service definition, but is explicit as part of the basic NSIS protocol. The justification for this is that it might be valuable to be able to do NSIS processing even at a node which was unaware of the specific signaling application; this would be a case of an NSIS forwarder with no interface to any resource management function. An example scenario would be NSIS messages passing through an addressing boundary where the flow identification had to be re-written.

The very flexibility possible in flow classification is a possible source of difficulties: when wildcards or ranges are included, it is probably unreasonable to assume a standard classification capability in routers; on the other hand, negotiating this capability would be a significant protocol complexity.

4.5.2 Reservation Identification

There are several circumstances where it is important to be able to refer to a reservation independently of whatever other information is associated with it. The prime example is a mobility-induced address change (handover) which required the flow identifier associated with a reservation to be rewritten without installing a totally new reservation (see section 5.3.1 for some security and scoping implications of this use). The same capability could also be used to simplify refresh or release messages in some circumstances, and might be useful within the protocol to resolve reservation collisions (where both sender and receiver initiate for the same flow).

A reservation identifier performs these roles. It is open how the reservation identifier space should be defined and managed, and what the scope of the identifier should be (only peer-peer, or end-end,

when interpreted in conjunction with some of the addressing information). Some of the necessary identifier functions, especially to do with local operation of NSIS, may also be provided by lower layer signaling transport protocols.

4.5.3 Signaling Application Identification

Since NSIS can be used to support several signaling applications, there is a need to identify which one a particular NSIS invocation is being used for, and this needs to be done outside the (opaque) service description:
*) processing incoming request messages at a responder - the NSIS layer should be able to demultiplex these towards the appropriate application;
*) processing general NSIS messages at an NSIS aware intermediate node - if the node does not handle the specific signaling application, it should be able to make a forwarding decision without having to parse the service description.

Signaling application identifiers would probably require an IANA registry.

5. NSIS Protocol Interactions

So far as possible, the NSIS protocol(s) should be usable in isolation, without explicitly depending on other protocols to operate. However, in many cases, NSIS functionality overlaps with the problem spaces of other protocols. In order to determine the boundaries which minimize any explicit interdependencies, these protocol interactions must be analyzed.

This is different from considering the use of NSIS protocols to support a particular signaling application, or example configurations in which NSIS might be deployed. These subjects are discussed in section 7.

5.1 Resource Management Interactions

The NSIS protocol is used for signaling resource requests from an NSIS Initiator to an NSIS Responder. The NSIS protocol should be useful for many signaling applications, but should not be involved in any specific resource allocation or management techniques. As such, we need to define the interaction between an NSIS entity and what we

will call the Resource Management Function (RMF). The RMF is responsible for all resource provisioning, monitoring and assurance functions in the network.

The RMF may interact with NSIS entities in two different ways: as a client or as a server.

First, the RMF can act as a client towards the NSIS protocol, as a particular application triggering NSIS signaling for resources in the

network. This is a special case of general NSIS triggering and will not be elaborated here. This case could for instance apply with multi-level NSIS signaling (section 7.5).

Second, the RMF can act as a server towards the NSIS protocol. In that case, the signaling decision taken by the NF may depend on the content or processing of the NSIS payload.

The RMF may or may not be co-located with the NSIS protocol processing. To cater for both cases, we define a (possibly logical) NF-RMF interface, see Figure 3. (As mentioned in section 3.1.1, the NI and NR could also interact with an RMF. Note that this could also be modeled as co-location of the NI&NF and NR&NF. This distinction should have no impact on the operation of the protocol.) Over this interface, information may be provided from the RMF about monitoring, resource availability, topology, configuration, and so on. Additionally, resource provisioning requests may be issued towards the RMF. Note that the actual implications for NSIS as a protocol are the same, regardless of whether the RMF is centralized or distributed, since NSIS sees the same interface towards the RMF in each case.

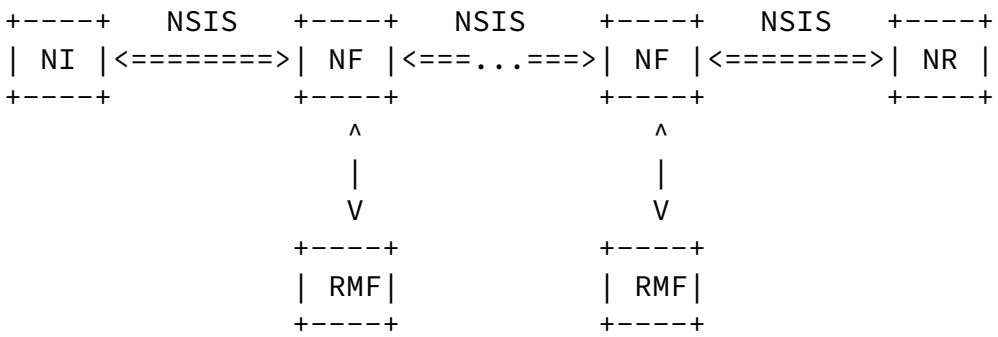


Figure 3: Basic NSIS-RMF Relationship

One way to formalize the interface between the NF and the RMF is via a Service Level Agreement (SLA). The SLA may be static or it may be dynamically updated by means of a negotiation protocol. Such a protocol is outside the scope of NSIS.

5.2 IP Routing Interactions

Several situations may occur when routing diverges from standard layer 3 routing. These are summarized in the sections below.

5.2.1 Load Sharing

Load sharing or load balancing is a network optimization technique that exploits the existence of multiple paths to the same destination in order to obtain benefits in terms of protection, resource efficiency or network stability. The significance of load sharing in the context of NSIS is that, if the load sharing mechanism in use will forward packets on any basis other than source and destination address, routing of NSIS messages using end-to-end addressing does not guarantee that the messages will follow the data path. In this section, we briefly survey what standard methods have been used for load sharing within standard routing protocols.

In OSPF, load balancing can be used between equal cost paths [11] or unequal cost paths. An example of the latter approach is Optimized Multi Path (OMP). OMP discovers multiple paths, not necessarily equal cost paths, to any destinations in the network, but based on the load reported from a particular path, it determines which fraction of the traffic to direct to the given path. Incoming packets are subject to a (source, destination address) hash computation, and effective load sharing is accomplished by means of adjusting the hash thresholds.

BGP [12][13] advertises the routes chosen by the BGP decision process to other BGP speakers. In the basic specification, routes with the same Network Layer reachability information (NLRI) as previously advertised routes implicitly replace the original advertisement, which means that multiple paths for the same prefix cannot exist. Recently, however, a new mechanism was defined that will allow the advertisement of multiple paths for the same prefix without the new

paths implicitly replacing any previous ones [14]. The essence of the mechanism is that each path is identified by an arbitrary identifier in addition to its prefix.

The distribution of traffic over the available path may be done per destination, per message in a round-robin fashion or with a predefined hashing function. The determination of the hashing image may take into account the source/destination IP address, QoS information such as the DSCP or protocol ID. When the routing decision is no longer based on the destination address only, however, there is a risk that data plane messages and control plane messages will not follow the same route.

5.2.2 QoS Routing

The are several proposals for the introduction of QoS awareness in the routing protocols. All of these essentially lead to the existence of multiple paths (with different QoS) towards the same destination.

As such, they also contain an inherent risk for a divergence between control plane and data plane, similar to the load sharing case.

For intra-domain traffic, the difference in routing may result from a QoS-aware traffic engineering scheme, that e.g. maps incoming traffic to LSPs based on multi-field classification. In BGP, several techniques for including QoS information in the routing decision are currently proposed. A first proposal is based on a newly defined BGP-4 attribute, the QoS_NLRI attribute [15]. The QoS_NLRI attribute is an optional transitive attribute that can be used to advertise a QoS route to a peer or to provide QoS information in along with the Network Layer Reachability Information (NLRI) in a single BGP update. A second proposal is based on controlled redistribution of AS routes [16]. It defines a new extended community (the redistribution extended community) that allows a router to influence how a specific route should be redistributed towards a specified set of eBGP speakers. The types of redistribution communities may result in a specific route not being announced to a specified set of eBGP speakers, that it should not be exported or that the route should be prepended n times.

5.2.3 Route pinning

Route pinning refers to the independence of the path taken by certain

data packets from reachability changes caused by routing updates from an Interior Gateway Protocol (OSPF, IS-IS) or an Exterior Gateway Protocol (BGP). This independence may for instance be caused by the configuration of static LSPs or by the establishment of explicitly routed LSPs by means of a signaling protocol (RSVP-TE or CR-LDP). If the NSIS signaling messages follow standard Layer 3 routing, this may cause a divergence between control plane and data plane. If reservations are made on the control plane, this may result in sending data along an unreserved path while maintaining a reservation on a path that is not used.

5.2.4 Route Changes

In this section, we will explore the expected interworking between a signaling for resource BGP routing updates, although the same applies for any source of routing updates. The normal operation of the NSIS protocol will lead to the situation depicted in Figure 4, where the reserved resources match the data path.

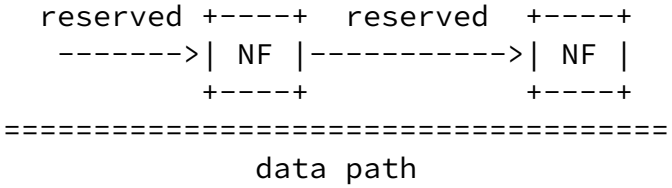
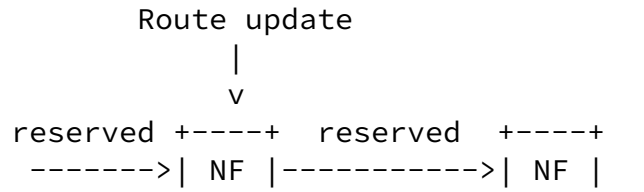


Figure 4: Normal NSIS protocol operation

A route change (triggered by a BGP routing update for instance) can occur while such a reservation is in place. In case of RSVP, the route change will be installed immediately and any data that is sent will be forwarded on the new path. This situation is depicted Figure 5.



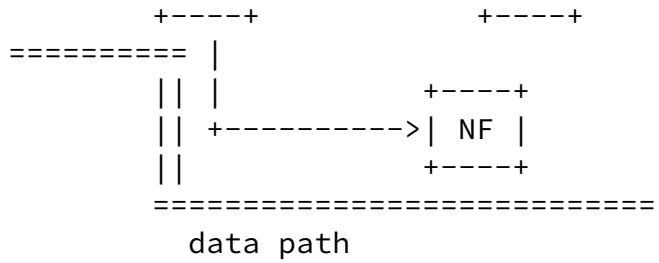


Figure 5: Route Change

Resource reservation on the new path will only be started once the next control message is routed along the new path. This means that there is a certain time interval during which resources are not reserved on (part of) the data path. To minimize this time interval several techniques could be considered. As an example, RSVP [17] has the concept of local repair, where the router may be triggered by a route change. In that case the RSVP node can start sending PATH messages directly after the route has been changed. Note that this option may not be available for NSIS if no per-flow state is kept in the NF.

It is not guaranteed that the new path will be able to provide the same guarantees that were available on the old path. Therefore, in a more desirable scenario, the NF should wait until resources have been reserved on the new path before installing the route change. The route change procedure then consists of the following steps:

1. NF receives a route announcement,
2. Refresh messages are forwarded along the current path,

3. A copy of the refresh message is remarked as request and send along the new path that was announced,
4. When the NF has been acknowledged about the reservations on the new path the route will be installed and the traffic will flow along the new path.

Another example related to route changes is denoted as severe congestion and is explained in [18]. This solution adapts to a route change, when a route change creates a congestion on the new routed path.

5.2.5 Router Redundancy

In some environments, it is desired to provide connectivity and per

flow or per class resource management with high-availability characteristics, i.e. with rapid transparent recovery even in the presence of route changes. This may involve interactions with the basic protocols which are used to manage the routing in this case, such as VRRP [19]. A future version of this document may consider interactions between NSIS and such protocols in support of high availability functionality.

5.3 Mobility Interactions

The interactions between mobility and resource signaling protocols have been quite extensively analyzed in recent years, primarily in the context of RSVP and Mobile IP interaction (e.g. [20]), but also in the context of other types of network (e.g. [21]). This analysis work has shown that some difficulties in the interactions are quite deep seated in the detailed design of these protocols; however, the problems and their possible solutions fall under five broad headings. The main issue is to limit the period after handovers during which the resource state has not been installed on the path, in particular the new part of the path.

We can use this work as the starting point for considering the framework aspects of a new signaling protocol like NSIS, which will need to interwork with mobility signaling, from Mobile IP to mobility paradigms based on micromobility or application layer approaches.

5.3.1 Addressing and Encapsulation

A mobility solution typically involves address reallocation on handover (unless a network supports per host routing) and may involve special packet formats (e.g. the routing header and Home Address option of MIPv6). Since NSIS may depend on end system addresses for forwarding signaling messages and defining flows (section 4.5.1), the special implications of mobility for addressing

need to be considered. Examples of possible approaches that could be used to solve the addressing and encapsulation problem are as follows:

*) Use a filter definition based on low level IP addresses (e.g. the Care of Address) and other 'standard' fields in the IP header. This makes least demands on the packet classification engines within the network. However, it means that even on a part of the flow path which is unchanged, the reservation will need to be modified to reflect the changed flow identification (see section 5.3.3).

*) Use a flow definition that does not change (e.g. based on Home Address); this is the approach assumed in [22]. This simplifies the problem of reservation update, at the likely cost of considerably complicating the flow identification requirements.

In the first approach, to prevent double reservation, NSIS nodes need to be able to recognize that a reservation with the new flow identifier is to be correlated with an existing one. The reservation identifier (section 4.5.2) was introduced for exactly this purpose. Note that this would require the reservation identifier to have (secure) end to end significance. (An additional optimization here would be use a local mobility management scheme to localize the visibility of the address change.)

The feasibility and performance of this first approach needs to be assessed, including a detailed analysis of the signaling scenarios after a handover. However, given the high impact of requiring more sophisticated packet classifiers, initially it still seems more plausible than the second approach. This implies that the NSIS initiator should define flows in terms of real (care of) addresses rather than virtual (home) addresses. Thus, it would have detailed access to lower layer interface configuration (cf. section 4.1), rather than operating as a pure application level daemon as is commonplace with current RSVP implementations.

5.3.2 Localized Path Repair

In any mobility approach, a handover will cause at least some changes in the path of upstream and downstream packets. NSIS needs to install new state on the new path, and remove it on the old. Provided that some NSIS node on the joined path - the crossover router - can recognize this situation (which again depends on reservation identification), state installation and teardown can be done locally between it and the mobile node. (This may have implications for which entities are allowed to generate which message types, see section 4.3.2). It seems that the basic NSIS framework already contains the fundamental components necessary for this.

A critical point here is the signaling that is used to discover the crossover router. This is a generalization of the problem of finding next-NSIS-hop nodes: it requires extending the new path over several hops until it intersects the old one. This is easy for uplink traffic

(where the mobile is the sender), but much harder for downlink traffic without signaling via the correspondent. There is no reason for the crossover routers for uplink and downlink flows to be the same, even for the same correspondent. The problem is discussed further in [23].

5.3.3 Reservation Update on the Unchanged Path

On the path between the crossover router(s) and the correspondent, it is necessary to avoid, if possible, double reservations, but rather to update the reservation state to reflect new flow identification (if this is needed, which is the default assumption of section 5.3.1). Examples of approaches that could be used to solve this problem are the following:

*) Use a reservation state definition that does not change even if the flow definition changes (see Section 4.5.2). In this case this problem is solved.

*) Use signaling all the way to the correspondent node (receiver end host), accepting the additional latency that this might impose.

*) Use an NSIS-capable crossover router that manages this reservation update autonomously (more efficiently than the end nodes), with similar considerations to the local path repair case.

5.3.4 Interaction with Mobility Signaling

In existing work on mobility protocol and resource signaling protocol interactions, several framework proposals describing the protocol interactions have been made. Usually they have taken existing protocols (Mobile IP and RSVP respectively) as the starting point; it should be noted that an NSIS protocol might operate in quite a different way. In this section, we provide an overview of how these proposals would be reflected in framework of NSIS. The mobility aspects are described using Mobile IP terminology, but are generally applicable to other network layer mobility solutions. The purpose of this overview is not to select or prioritise any particular approach, but simply to point out how they would fit into our framework and any major issues with them.

We can consider that two signaling processes are active: mobility signaling (e.g. binding updates or local micromobility signals) and NSIS. The discussion so far considered how NSIS should operate. There is still a question of how the interactions between the NSIS and mobility signaling should be considered.

The basic case of totally independent specification and implementation seems likely to lead to ambiguities and even interoperability problems (see [22]). At least, the addressing and encapsulation issues for mobility solutions that use virtual links or their equivalents need to be specified in an implementation-neutral way.

A type of 'loose' integration is to have independent protocol definitions, but to define how they trigger each other - in particular, how the mobility protocol triggers NSIS to send refresh/modify/tear messages. A pair of implementations could use these triggers to improve performance, primarily reducing latency. (Existing RSVP modification consider the closer interaction of making the RSVP implementation mobility-routing aware, e.g. so it is able to localize refresh signaling; this would be a self contained aspect of NSIS.) This information could be developed for NSIS by analyzing message flows for various mobility signaling scenarios as was done in [20].

An even tighter level of integration is to consider a single protocol carrying both mobility and resource information. Logically, there are two cases:

1. Carry mobility routing information (a 'mobility object') in the resource messages, as is done in [22]. (The prime purpose in this approach is to enable crossover router discovery.)
2. Carry resource signaling in the mobility messages, typically as a new extension header. This was proposed in [24] and followed up in [25]; [26] also anticipates this approach. In our framework, we could consider this a special case of NSIS layering, with the mobility protocol playing the role of the signaling transport (as in 4.3.1).

The usefulness of this class of approach depends on a tradeoff between specification simplicity and performance. Simulation work is under way to compare the performance of the two approaches in the case of RSVP and micromobility protocols.

Other modes of interaction might also be possible. The critical point with all these models is that the general solutions developed by NSIS should not depend fundamentally on the choice of any particular mobility protocol. Especially if it has interdomain scope, tight integration would have major deployment issues (even loose integration could require NSIS implementations to hook into multiple different mobility protocols). Therefore, any tightly integrated solution should be considered out of scope of initial NSIS development, and even in the long term is probably only applicable if it can be localized within a particular part of the network.

5.3.5 Interaction with Fast Handoff Support Protocols

In the context of mobility between different access routers, it is common to consider performance optimizations in two areas: selection of the optimal access router to handover to, and transfer of state information between the access routers to avoid having to regenerate it in the new access router after handover. The seamoby working group is developing solutions for these protocols for pure IP based networks (CARD and CT respectively); other networks, which use NSIS for resource signaling within the network, may use different types of solution.

In this section, we consider how NSIS should interact with these functions, however they are implemented. Detailed solutions are not proposed, but the way in which interaction these functions is seen within the NSIS framework is described. NSIS should be able to operate independently of these protocols. However, significant performance gains could be achieved if they could be made to cooperate. In addition, the resource signaling aspects of these protocols could profitably use a common set of resource types and definitions, since they will probably be supporting the same overall signaling application.

The question arises, what the mode of interaction should be: independent operation, NSIS triggering access router discovery and state transfer, or vice versa. The questions for the two cases seem to be independent.

For access router discovery, a typical model of operation is that the mobile carries out an information gathering exercise about a range of capabilities. In addition, where those capabilities relate purely to the AR and mobile, there is no role for NSIS (its special functionality is not relevant). However, considering resource aspects, one aspect of the AR 'capability' is resource availability on the path between it and the correspondent, and NSIS should be able to fulfill this part. Indeed, this is effectively precisely the application considered in [25], where it is a sort of special case of resource signaling during handover.

Therefore, a possible model of access router discovery/NSIS relationship is that some entity in a candidate AR triggers NSIS using resource and reservation information (including reservation id) from the current AR to find out about what would be available on the new path. Note that this should be a query rather than an actual

reservation; this semantic could be included either in the service definition or NSIS itself.

The case of state transfer is more complex. There are two obvious options, corresponding to whether one transfers just signaling application state or NSIS state as well:

1. "State transfer triggering NSIS": A state transfer process passes the 'raw' resource state to the new AR. This triggers a new instance of NSIS to request that resource.
2. "NSIS using state transfer": NSIS transfers its own state information from the old to the new AR. It can then carry out the same update signaling as though it was a single 'virtual AR' which had just had a topology change towards the correspondent. (This is essentially the conceptual model of [20].)

The first model is simpler, and maybe more in line with the basic state transfer expectation; however, it seems hard to avoid double reservations since the two NSIS protocol instances are not coordinated. Therefore, the second model seems more appropriate. An advantage of the 'virtual AR' model is that it ensures that the impact of the interaction is limited to the NSIS instances at ARs themselves, since the rest of the network must be able to handle a topology change anyway.

Note that there is an open issue of who is responsible between the mobile and AR to decide that the state transfer procedures have not happened for whatever reason - e.g. because they were not even implemented - and take recovery action to have the mobile refresh reservations promptly. It appears this has to be an NSIS responsibility in the AR, and probably requires a custom notification message for this circumstance.

5.4 NSIS Interacting with NATs

Because at least some NSIS messages will almost inevitably contain address and possibly higher layer information as payload (see section 4.5.1), we must consider the interaction between NSIS and address translation devices (NATs). As well as 'traditional' NATs of various types (as defined in [27]) very similar considerations would apply to some IPv4/v6 transition mechanisms such as SIIT [28].

In the simplest case of an NSIS unaware NAT in the signaling path,

payloads will be uncorrected and the signaling will be for the incorrect flow. Applications could attempt to use STUN [29] or similar techniques to detect and recover from the presence of the NAT. Even then, NSIS would have to use a well known encapsulation (TCP/UDP/ICMP) to avoid being dropped by the more cautious low-end NAT devices.

A simple 'NSIS-aware' NAT would require flow identification information to be in the clear and not integrity protected. An

alternative conceptual approach is to consider the NAT functionality being part of NSIS message processing itself, in which case the translating node can take part natively in any NSIS security mechanisms. Depending on NSIS layering, it could be possible for this processing to be done in an NSIS node which was otherwise ignorant of any particular NSIS signaling applications.

Note that all of this discussion is independent of the use of NSIS for general control of NATs (and firewalls). This is considered in section 7.4.

6. Security and AAA Considerations

A framework is meant to create boundaries for a later protocol and to describe the interaction between the protocol and its environment. Security issues usually turn out to have impacts in the interaction of these protocols and must therefore be appropriately addressed in such a framework. This section describes these general security issues, and in particular considers the interactions between NSIS and authentication, authorization and accounting. Together with authentication the protection of the signaling messages is addressed - namely replay and integrity protection.

An initial analysis of the major security threats that apply in the typical of scenario where NSIS is expected to be used is given in [4]; these threats are described at the overall scenario level, in terms of the impact on users and networks. However, in any given scenario, NSIS will be just one protocol or component of the overall solution. Ultimately, the framework will need to define which of these threats need to be handled by NSIS and which by the other components. Currently, we can only make initial scoping assumptions of this sort.

6.1 Authentication

Authentication and key establishment for a signaling protocol should be seen as a two-phase process. The first-phase is usually more performance intensive because of a larger number of roundtrips, denial of service protection, cross-realm handling, interaction with other protocols and the likely larger cryptographic computation associated with it. As stated in section 4.3, this functionality could be provided externally to NSIS, e.g. by reusing a standard protocol which already included this functionality.

At the end of this phase it should be possible to create or derive security associations that are usable for the protection of the NSIS signaling messages themselves. The functionality required here relates to (data origin) authentication (including integrity and

replay protection) of individual signaling messages. Key establishment, rekeying, synchronization issues are issue that may be addressed here depending on the specific method. In any case the protection applied to each signaling message must be fast and efficient.

When using cryptography to protect signaling messages, it is obvious that a node must be able to select the appropriate security association in order to be able to apply signaling message protection. This should just be a general point about endpoint identity issues. Hence the identifier must be available to the transmitting node. Regarding identities there is a need to support different identity types to enable the flexible usage of several signaling initiators and receivers. Supporting static configuration and dynamic learning of these identities should be provided.

6.2 Authorization

Authorization information can be seen in an abstract form as "Can the resource requestor be trusted to pay for the reservation?". This abstraction is supported by the fact that reservations require some form of incentive to use some 'default' resource (or vice versa - penalty for not reserving too many resources). In general, the semantics of the authorisation will depend on the signaling application in use. The implication of this is that NSIS will not directly make authorisation decisions; instead, the authorisation information must be fed into the resource management function (section 5.1) which actually decides on the request.

Some negotiation needs to take place to determine which node will take responsibility for authorising a resource request, the implication being that the same node will ultimately be accounted to for it. Such a negotiation needs to be flexible enough to support most currently deployed schemes (e.g. reverse charging, etc.) while keeping efficiency and simplicity in mind. This negotiation might be executed before starting resource signaling (assumed in section 4.2), although it could also be part of the NSIS signaling messages (as in some proposals dealing with charging and RSVP). Since information needs to be sent to the networks, some information needs to be included to provide the network with the necessary information to start the authorisation process. Hence fully opaque objects might not always be the proper choice.

It is not clear if 'initiation' of a reservation is related to willingness to accept authorisation responsibility. (Current practices tend to assume that flow originators are responsible.) In any case, it seems unlikely that a domain will make a cost-incurring request of a peer domain without already having received a matching

request from the peer in the other direction - in other words, requests must propagate between domains in the same direction as authorisation responsibility.

If this argument is correct, and if NSIS initiation and authorisation responsibility are decoupled, it must be possible for the authorisation responsibility to propagate both in the direction initiator->responder and vice versa. Also, if both [flow] sender and receiver initiation are possible, service descriptions must include information about the authorisation policy to be applied, which must be imposed consistently along the whole path. These issues should be analyzed to determine if 1, 2 or 4 alternative scenarios are possible and realistic.

A second question is that of which entities actually authorise which. One end user must ultimately get authorisation for the request (this may or may not be assumed to be the NSIS initiator, see below). There are then two possible models for how this authorisation is done throughout the path.

The first model assumes that each network along the path is able to authenticate and authorise the user directly. The implication for a signaling protocol is that the user credentials cannot be removed after the first hop and have to be further included in the message

when forwarded to other networks. Every node along the path is then able to verify the user and to provide policy based admission control.

The second model assumes that the user credentials are removed at the first hop. The first network knows the user identity requesting the resources but does not include this information further along the path. The first network can therefore be seen as acting on behalf of the originator to take responsibility to enable further reservations to be done along the path i.e. in particular to the next network only. This procedure is then applied on a hop-by-hop basis.

Note that both models are independent of whether a traditional subscription based approach or an alternative means of payment (such as pre-pay on on-line charging by the visited network) is used. These issues only have an impact for the transmission of accounting records and for a requirement to execute an online verification whether a user still has sufficient credits/funds; therefore, these details do not affect NSIS operation.

6.3 Accounting

It is obvious that accounting/charging is an important part for the success and the acceptance of a resource signaling protocol. Most of

the thinking in this area is derived from the specific case of signaling for QoS; however, we make an initial working assumption that the same paradigm should apply to any signaling application for which accounting is necessary. We make the general assumption here that accounting records are generated by the resource management function based entirely on traffic measurements and processed in accordance with the authorisation information that was used in deciding to grant the request in the first place.

Therefore, NSIS plays no further part in this activity; the accounting records are transmitted using the AAA infrastructure, and charging and billing for the overall service is carried out at some higher layer. This would include feedback to applications (and users) about total session cost (of which the network resource cost might be only a part). An open issue is whether a query (without actually making a reservation) to the network should also generate a chargeable event; this could be considered as an aspect of the service definition.

6.4 End-to-End vs. Peer-Session Protection

It is reasonable to assume that peer-session security (with chain-of-trust) is used for most signaling environments relevant to NSIS. Especially the separation of signaling into different network parts (intra-domain within the access network, end-node to access network, intra-domain, and so on) and new proposals regarding mobility and proxy support show that traditional end-to-end signaling is not applicable in every environment (or possibly only in a minor number of environments). End-to-end security in a signaling protocol is actually problematic for two reasons:

1. Even if the messages use the address of the end-host (to support routing), the messages still have to be interpreted and modified along the path.

2. The only property that can be achieved by using end-to-end security is that one end-host can be assured that the other end-host included some parameters (possibly resource parameters) that have not been modified along the path. Nodes along the path usually do not have the possibility to cryptographically verify the protected message parts. If the two end-points negotiate which side has to pay for the reservation (or possibly how much and other parameters) within the signaling protocol then there is a need to protect this information. This leads to the question which protocols are executed before the signaling message exchange starts. If resource parameters and payment/charging related information are already exchanged beforehand as part of a separate protocol (possibly SIP) then there is little need to protect (and possibly retransmit) this information

at the NSIS level basis. In most cases an opaque token to link the different protocols may be sufficient.

7. NSIS Application Scenarios

This section considers various application scenarios or deployment configurations for NSIS. Our goal is that an NSIS protocol designed according to the framework presented in the previous sections should be able to support these scenarios if implemented appropriately; therefore, this section does not form part of the framework definition, but rather provides examples of how NSIS can be used to do something interesting. In the long term, some of this material may be contained in specific NSIS applicability statements.

7.1 NSIS and Existing Resource Signaling Protocols

It is hoped that an NSIS protocol could eventually achieve widespread use for resource signaling. However, it is bound to have to inter-operate with existing resource signaling protocols at least during transition and possibly long term. The prime example for QoS is RSVP, although other proprietary or domain specific protocols (e.g. bandwidth broker related) may also be considered. A related issue is that NSIS will be only one part of the solution: it will always need to interwork with other resource-related protocols (e.g. COPS).

Analyzing the constraints on NSIS that come from these requirements is hard before further refinement of the framework has been carried out and critical assumptions pinned down. However, we can identify various modes of interoperation, and the attributes of the framework that will make them easy.

Firstly, we allow for NSIS use over a 'long range', in conjunction with a different protocol locally (e.g. intra-domain); or, the two roles could be reversed. This is actually very similar to the case of use of NSIS layered over itself (section 7.5). In the case where the 'inter-layer' interaction is mediated via resource management, the same should approach should work with non-NSIS protocols. What needs to be validated here is whether NSIS layering requires the exchange of NSIS specific information between the layers.

A second issue is that NSIS should be deployable within an environment without radical changes to supporting resource (or AAA) related protocols. The main issue here is that NSIS should be flexible in its ability to support different service definitions (and possibly flow classifications). This is already one of the main goals of the framework presented here.

The final point is that it should be possible to use NSIS over one network region, concatenated with another protocol over an adjacent region. The main issue here, apart from the flexible service and flow capabilities already mentioned, is that NSIS should be adaptable in what it assumes about signaling paths (e.g. to interwork with both path-coupled and decoupled solutions), and in initiation paradigms (e.g. to interwork with sender and receiver initiated solutions).

7.2 NSIS Supporting Centralized QoS Resource Management

One area of application for the NSIS protocol is for QoS resource reservation and provisioning. The NSIS protocol may be used to provide intra-domain or inter-domain QoS bandwidth reservation setup by means of its interaction with the RMF. In what follows we assume that the NEs are colocated with an admission control entity that has a logical (abstract) view on the resources managed by the RMF, as described in section 5.1.

The NEs in a domain can interface with an RMF managing the complete domain, in which case, the abstract topology view provided between NSIS and RMF can be formalized as a Service Level Agreement (SLA). This situation is depicted schematically in Figure 6.

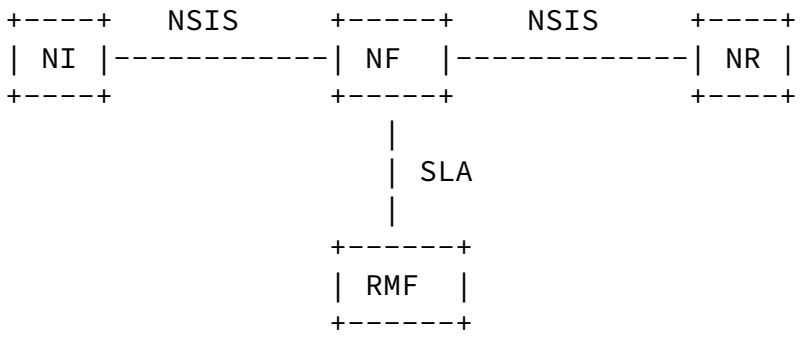


Figure 6: Resource Reservation using RMF as a Server to NSIS

In case of centralized RMF, the SLA or its technical part, the Service Level Specification (SLS) [30] specifies the resource guarantees that the RMF needs to provide to the NF. These guarantees apply between one or more ingress and egress points of the network. The SLS also specifies the availability and reliability of the service. In the case of QoS signaling, it may refer to a bandwidth service with certain performance guarantees regarding delay, jitter or packet loss. The SLS interface can be automated by means of an SLS negotiation protocol. This allows for more dynamical SLS modifications and the exchange of notification messages with the NF. These can for instance be used to provide monitoring feedback from the RFM to the NF.

The decoupling of NSIS signaling and network management by means of an SLS has some attractive properties:
*) It allows a Network Provider to easily share the use of its infrastructure between several Service Providers using NSIS signaling

to provide their service.
*) It allows a clear separation between resource provisioning and management and reservation signaling and admission control.
*) It relieves the NF from several tasks, making it potentially more scalable in the core of the network.

The NF can perform either per-flow or per-class admission control decisions based on the requested QoS information and on the reservation state it keeps regarding active flows (or classes). Keeping per-flow state may be required for policing, accounting/billing and explicit reservation teardown. These functions are mandatory in the access or edge of the network. Conveniently, this is also where the processing needed to maintain per-flow state will remain manageable. In the core, this approach may not scale very well and per-class state may be used as an alternative that is very scalable and allows for a lightweight processing of signaling messages. With per-class state, however, we lose the ability to directly notify the NI in case of unsolicited network events because the affected flows cannot be identified. Instead, the NI needs to be indirectly notified in response to a refresh message which in turn mandates the use of soft-state with separate messages or message structure for requests and refreshes.

The RMF can execute its network provisioning functions according to its internal policies. In the easiest case, it may run an overprovisioned network with only monitoring capabilities in order to follow up on the delivered performance. In more complex scenarios, it may use a whole array of network optimization tools in order to deliver and maintain service quality according to the SLS. This may require network monitoring, the installation and use of appropriate protection mechanisms and providing feedback regarding actual traffic performance to the NSIS entity.

Alternatively, the NSIS protocol may be used for resource provisioning. In that case, the RMF acts as a client towards the NSIS protocol, as a particular "application" triggering an NI for resources in the network. This situation is depicted in Figure 7.

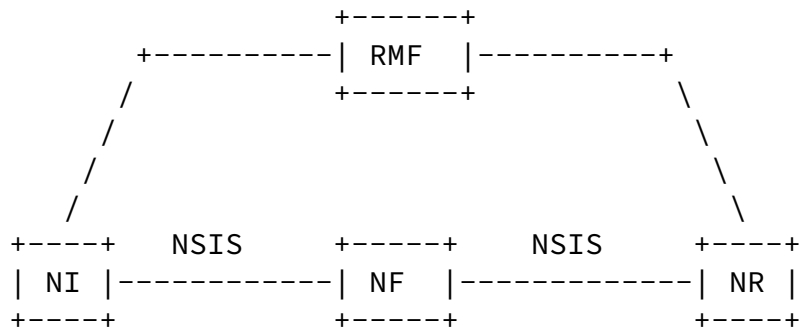


Figure 7: NSIS for Resource Provisioning

In this case the RMF is providing traffic classification and conditioning functions. An example of such functionality is described in [31]. The packet "classifiers" select the packets in a traffic stream based on the content of some portion of the packet header. The traffic "conditioner" performs metering, shaping, policing, scheduling and/or re- marking of packets to ensure that the traffic entering a node conforms to a certain predefined policy.

7.3 NSIS Supporting Distributed Resource Management

Section 7.2 described the situation where NSIS is supporting a centralized RMF. This section introduces the situation where NSIS is supporting a distributed RMF. When the RMF is distributed in the network, a protocol for communication with the NI, NF, NR may not be required. In this case the RMF is providing traffic classification and conditioning functions; an example of such functionality is described in [31]. Figure 8 shows how a distributed RMF could interact with the NSIS protocol.

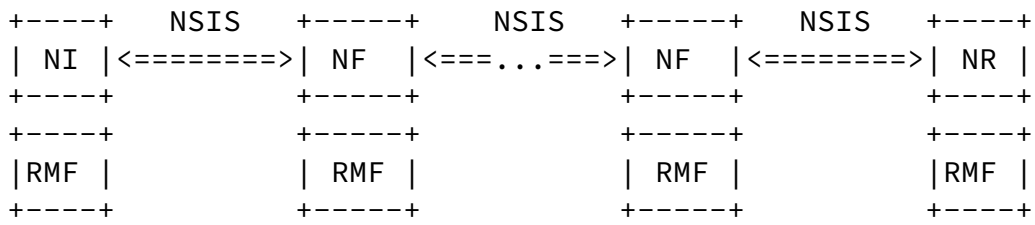


Figure 8: Distributed RMF as a server for NSIS

7.4 NSIS for Middlebox Signaling

As well as the use for 'traditional' QoS signaling, it should be possible to use NSIS to set up flow-related state in middleboxes (firewalls, NATs, and so on). Requirements for such communication are given in [32], and initial discussions of NSIS-like solutions are contained in [33] and [34]. A future version of this document may

contain more details on how an NSIS should be used for this type of signaling application.

7.5 Multi-Level NSIS Signaling

This section describes a way of separating the NSIS signaling protocol into more than one hierarchical level. In this section three levels of hierarchy are considered (see Figure 9); however, the approach is quite general to more (or fewer) levels: the important issue is the use of NSIS at more than one level at all.

The lowest hierarchical level ("level 1") provides basic resource management functionality related to scalable, simple and fast soft state maintenance and to transport functions, such as reliable delivery of signaling messages, congestion control notification and load sharing adaptation. Soft state that is maintained by this level is usually per traffic class based.

The second hierarchical level ("level 2") is more complex than level 1 as regards soft state maintenance. Soft state maintained by this hierarchical level is usually per flow. Note that this level, like level 1, also supports transport functions. When an NSIS edge-to-edge multi-domain protocol is used, level 2 stretches beyond domain boundaries and is applied on all the edges of the domains that are included in the multidomain region.

The third hierarchical level ("level 3") includes a set of upper-level signaling functions that are specific to particular signaling applications. Such functions could, for example, be security, policy, billing, etc.

As shown in Figure 9, the three hierarchical levels might be applied on different NSIS entities.

This three-level architecture for NSIS signaling can be provided by using:
 *) a single end-to-end NSIS protocol that supports all three hierarchical levels
 *) two independent NSIS protocols: Level 3 is supported by an end-to-end NSIS protocol, and levels 1 and 2 are supported by another edge-to-edge NSIS protocol.

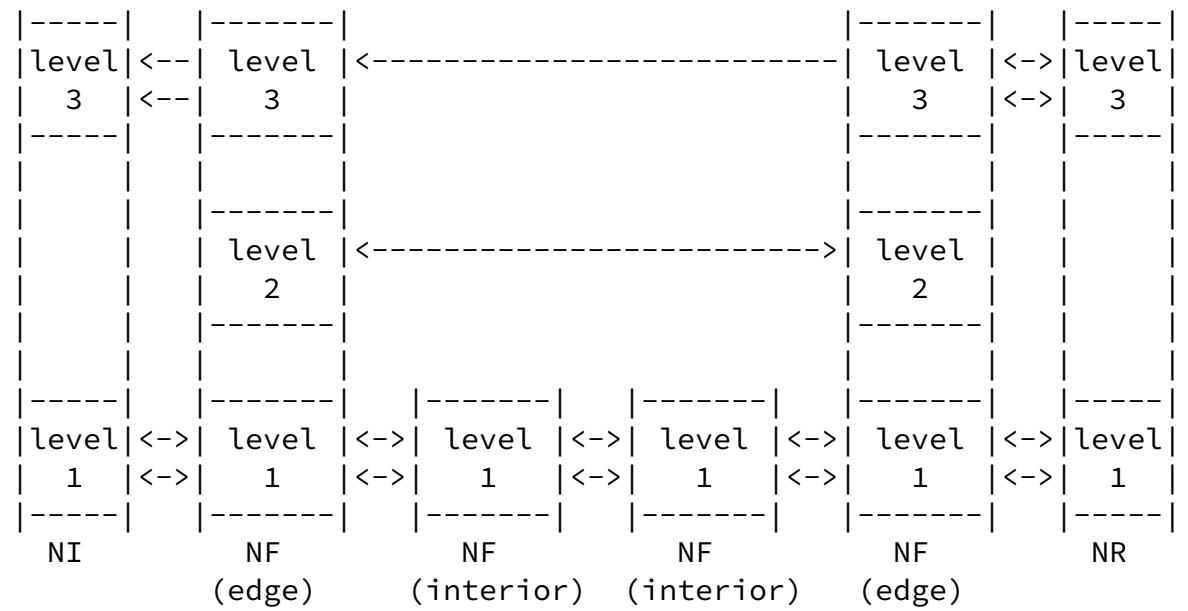


Figure 9: Three level architecture for NSIS signaling

The components in the scenario are as follows:
 *) NI (NSIS Initiator): can be an end-host or a proxy and can process and use the "level 1" and "level 3" protocol components
 *) NR (NSIS Responder): can be an end-host or a proxy and can process and use the "level 1" and "level 3" protocol components
 *) NF (NSIS Forwarder) (edge): can be a Diffserv edge, MPLS edge, etc. It can process and use the "level 3", "level 2" and "level 1" protocol components. Usually, "level 2" provides an interworking between "level 1" and "level 3" protocol components.
 *) NF (interior): can be any router within a domain. It can process and use only the "level 1" protocol component. The "level 3" and "level 2" protocol components are not processed (used or checked).

The hierarchical level separation can be provided by supporting a hierarchical object structure. In other words, the NSIS protocol objects should be structured and positioned within the NSIS messages in a hierarchical way, i.e., first the "level 1" objects, then the "level 2" objects and finally the "level 3" objects.

8. Open Issues

The following issues are currently open points within the framework. They are summarized here to provide a single overview.

1. It is not clear which of the NI, NF and NR can modify or release existing reservations (this is essentially an authorisation issue). (Section 3.3.2.)

2. It is not clear whether NSIS entities relate to each other only locally (peer-peer) or whether longer distance, non-local interactions and state have to be managed and stored. (Section 3.3.3.)

3. NSIS messages could be addressed either explicitly (to the neighboring peer) or implicitly, using the flow endpoint addresses. (Section 3.3.4.)

4. It is not clear whether the service description semantics (in theory, opaque to NSIS) need to be analysed in more detail to determine requirements on the protocol. (Section 3.3.5.)

5. If NSIS has explicit acknowledgement and notification messages, it is open whether they should relate to anything beyond the immediate peer-session. (Section 3.3.6.)

6. To function as part of a complete system, the NSIS protocol may need to be supported by extensions to other protocols. These extensions are still to be identified. (Section 4.2.)

7. The NSIS protocol could be constructed on the services offered by lower layer protocols, but the dividing line between NSIS and these lower layers is not fixed. Use of standard lower layer protocols may be difficult if 'end-to-end addressing' (see section 3.3.4) is used. (Section 4.3.1.)

8. It is commonly expected that a future resource signaling protocol would need to use abstract reservation identifiers. However, the precise properties needed of these identifiers are unclear, and enabling their secure use may be hard. (Sections 4.5.2 and 5.3.2.)

9. Use of some routing techniques (e.g. load sharing or QoS routing), even in remote parts of the network, could be incompatible

with naive use of end-to-end addressing. (Sections 5.2.1 and 5.2.2.)

10. The correct flow identification semantics need to be defined in the case where mobility encapsulations might make it ambiguous which addresses to use. (Section 5.3.1.)

11. The interactions between mobility and resource signaling during path updating need to be further analyzed, especially from the point of view of combined overall latency. (Section 5.3.2 and 5.3.3.)

9. Change History

9.1 Changes from draft-hancock-nsis-fw-00.txt

1. Changed title, document name and dates.
2. Updated references.
3. Editorial fix in NSIS Forwarder definition (section 2).
4. Revised section 3.2.1 (path-coupled terminology), now used consistently in the rest of the document. Likewise, 'signaling application' terminology used consistently in remainder of document.
5. Split old section 5 into new sections (new 5 "real interactions", new 7 "how to use NSIS to do something useful").
6. Added new resource management text for section 5.1; slight smoothing to balance centralized and distributed, and comment on NI/NF/NR distinction.
7. Added VRRP placeholder in routing section of section 5 (5.2.5).
8. Added section 5.4 on NSIS/NAT interactions based on Melinda's email.
9. Added new text for resource management in section 7.2; slightly trimmed and made clearer that it is mainly discussing the centralized case (and isn't specific to the inter-domain case). Comment that it's OK to use the Q-word here since we aren't talking about the NSIS protocol but a use of the NSIS protocol.
10. Added section 7.3 for discussion of how NSIS can be used in a distributed resource management environment.
11. Added a placeholder in section 7.4 for use of NSIS for midcom (no technical content, but references to the midcom requirements and the TIST and NEC drafts).
12. Moved open issues from section 3.3.1 to new section 8 (left

assumptions behind).
13. Added this changes section 9.

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Author's Addresses

Ilya Freytsis
Cetacean Networks Inc.
100 Arboretum Drive
Portsmouth, NH 03801
USA
email: ifreytsis@cetacean.com

Robert Hancock
Roke Manor Research
Old Salisbury Lane
Romsey
Hampshire
SO51 0ZN
United Kingdom
email: robert.hancock@roke.co.uk

Georgios Karagiannis
Ericsson EuroLab Netherlands B.V.
Institutenweg 25
P.O.Box 645
7500 AP Enschede
The Netherlands
email: georgios.karagiannis@eln.ericsson.se

John Loughney

Nokia Research Center
11-13 Italahdenkatu
00180 Helsinki
Finland
email: john.loughney@nokia.com

Sven Van den Bosch
Alcatel
Francis Wellesplein 1
B-2018 Antwerpen
Belgium
email: sven.van_den_bosch@alcatel.be

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