

ETSI TS 103 836-6-1 V2.1.1 (2024-07)



**Intelligent Transport Systems (ITS);
Vehicular Communications;
GeoNetworking;
Part 6: Internet Integration;
Sub-part 1: Transmission of IPv6 Packets over
GeoNetworking Protocols for ITS-G5;
Release 2**

Reference

RTS/ITS-003106

Keywordsaddressing, autonomic networking, IPv6, ITS,
network, protocol**ETSI**650 Route des Lucioles
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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Intelligent Transport Systems (ITS).

The present document is part 6, sub-part 1 of a multi-part deliverable. Full details of the entire series can be found in ETSI TS 103 836-1 [2].

Modal verbs terminology

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Executive summary

The present document specifies a set of mechanisms that allow the GeoNetworking protocol to transport IPv6 packets without introducing modifications to existing IPv6 protocol implementations. By deploying these mechanisms:

- 1) the coverage offered by points-of-attachment to the Internet, such as road-side ITS stations, is extended by means of sub-IP geographic routing; and
- 2) IPv6 multicast traffic can be geocasted, i.e. addressed and delivered to all ITS stations located within a geographic area.

Introduction

The ETSI GeoNetworking protocol as defined in ETSI TS 103 836-4-1 [6] and its media-specific extensions is a non-IP network-layer protocol that provides geographic addressing and forwarding and belongs to the position-based routing protocols category. Applications and facilities specifically designed for GeoNetworking exploit these functionalities, for example to disseminate warning or generic information messages to geographically scoped areas. The GeoNetworking protocol satisfies the requirements of several ITS services, whose application domain is limited to networks that are disconnected from large existing network infrastructures. However, several ITS applications require the integration of ITS stations with larger networks such as private transport networks or the Internet.

In order to connect networks based on GeoNetworking to networks running the Internet Protocol (IP), which represent the majority of currently deployed large networks, it is necessary to allow GeoNetworking ITS stations to act like Internet hosts or routers. The ETSI Technical Committee ITS recognizes IP version 6 as defined in IETF RFC 8200 [7] as the primary version of IP to be necessarily supported by ITS stations.

The present document introduces a set of mechanisms that allow the GeoNetworking protocol to transport IPv6 packets without introducing modifications to existing IPv6 protocol implementations. By deploying these mechanisms, the following two main advantages are achieved:

- 1) coverage offered by points-of-attachment to the Internet, such as road-side ITS stations, is extended by means of sub-IP geographic routing; and
- 2) IPv6 multicast traffic can be geocasted, i.e. addressed and delivered to all ITS stations currently located within a geographic area.

The present document includes a data SAP that enables an IPv6 protocol entity to send and receive packets over the GeoNetworking protocol. This SAP is described in the informative annex C. The present document does not include a management SAP towards the ITS station management entity.

The mechanisms specified in the present document utilize capabilities of IEEE 802 technologies, such as VLAN defined in IEEE 802.1Q [27]. Therefore, the present document is limited to the ITS-G5 access technology.

- NOTE: In the remainder of the present document, when the sole term "GeoNetworking" is used, it is to be regarded as the ETSI GeoNetworking protocol combining the media-independent part outlined in ETSI TS 103 836-4-1 [6] and at least one of the media-dependent parts (such as ETSI TS 103 836-4-2 [i.19]). It should be noted that the media-dependent extensions do not represent distinct protocol layers.

1 Scope

The present document specifies the transmission of IPv6 packets over the ETSI GeoNetworking protocol for ITS-G5 and as defined in ETSI TS 103 836-4-1 [6] via a protocol adaptation sub-layer referred to as the GN6ASL (GeoNetworking to IPv6 Adaptation Sub-Layer). The scope of the present document is limited to the GN6ASL.

NOTE 1: The mechanisms specified in the present document utilize capabilities of IEEE 802 technologies only, such as VLAN defined in IEEE 802.1Q [27].

The techniques specified in the present document fulfil the requirements for GeoNetworking and IPv6 integration described in ETSI TS 103 836-1 [2]. In particular, these techniques allow for the transport of IPv6 packets by ETSI GeoNetworking protocol given in ETSI TS 103 836-4-1 [6], enabling sub-IP multi-hop delivery of IPv6 packets, e.g. in a vehicular network. As a result, the connectivity provided by points-of-attachment to IPv6 infrastructure networks is extended by means of mobile relay nodes. In addition to that, the techniques described in the present document allow for geocasting of IPv6 multicast packets.

The scope of the GN6ASL is limited to the fulfilment of the requirements for GeoNetworking and IPv6 integration described in ETSI TS 103 836-1 [2], clause 5.9, by enabling an ITS station including a GeoAdhoc router as given in ETSI TS 103 836-4-1 [6] running the GeoNetworking protocol and an IPv6-compliant protocol layer to:

- exchange IPv6 packets with other ITS stations;
- acquire globally routable IPv6 unicast addresses and communicate with an arbitrary IPv6 host located in the Internet, whenever an ITS station including a GeoAdhoc router and including or connected to an access router [4] providing IPv6 connectivity to the Internet is reachable directly or via other relay ITS stations;
- perform the operations required by IETF RFC 3963 [13] for a Mobile Router whenever:
 - a. an ITS mobile router supporting Network Mobility Basic Support (NEMO BS) as defined in IETF RFC 3963 [13] is present in the ITS station and runs on top of the GN6ASL; and
 - b. an ITS station including a GeoAdhoc router and including or connected to an access router as defined in ETSI TS 103 836-3 [4] providing IPv6 connectivity to the Internet is reachable directly or via other relay ITS stations.

NOTE 2: The present document adopts the definition of "IPv6-compliant" and "sub-IP multi-hop delivery" introduced in clause 3.1.

Extending the IPv6 basic standards IETF RFC 8200 [7], IETF RFC 4291 [8], IETF RFC 4007 [9], IETF RFC 4861 [10] and IETF RFC 4862 [12] to support new features is outside the scope of the present document. Extensions to NEMO BS as given in IETF RFC 3963 [13] are outside the scope of the present document. Mechanisms for the dissemination of IPv6 routing information for hosts and routers not directly attaching to the network where GeoNetworking is used are outside the scope of the present document (e.g. discovery of IPv6 in-vehicle prefixes). However, the present document aims at providing the underlying support for the dissemination of such routing information, i.e. IPv6 multicast support for the network where the GeoNetworking protocol is used.

With respect to IPv6 multicast and anycast support, the present document is limited to the support required to enable distribution of IPv6 multicast and anycast traffic on a shared link. Amendments to specific IPv6 multicast forwarding mechanisms are out of the scope of the present document. However, the present document aims at not preventing existing IPv6 multicast forwarding mechanisms from being used in conjunction with the GN6ASL.

In order to facilitate the deployment of ITS systems, the present document aims at maintaining backward compatibility with pre-existent IPv6-compliant protocol implementations and NEMO BS implementations compliant with IETF RFC 3963 [13]. A usage example of NEMO BS with the GN6ASL is presented in the informative annex F.

The mechanisms specified in the present document are distinct from but compatible with the IPv6-related functionalities given in ISO 21210-2012 [i.16], which specifies how IPv6 networking is generally operated in ITS stations. The techniques described in the present document provide a way to transport IPv6 packets that is fully compatible with the IPv6 specifications and pre-existing implementations, and hence is compatible with ISO 21210-2012 [i.16].

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

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The following referenced documents are necessary for the application of the present document.

- [1] [ETSI EN 303 797](#): "Intelligent Transport Systems (ITS); ITS-G5 Access layer in the 5 GHz frequency band; Release 2".
- [2] [ETSI TS 103 836-1](#): "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 1: Requirements; Release 2".
- [3] [ETSI TS 103 836-2](#): "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 2: Scenarios; Release 2".
- [4] [ETSI TS 103 836-3](#): "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 3: Network architecture; Release 2".
- [5] [ETSI EN 302 931](#): "Intelligent Transport Systems (ITS); Vehicular Communications; Geographical Area Definition".
- [6] [ETSI TS 103 836-4-1](#): "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 1: Media-Independent Functionality; Release 2".
- [7] [IETF RFC 8200](#): "Internet Protocol, Version 6 (IPv6) Specification".
- [8] [IETF RFC 4291](#): "IP Version 6 (IPv6) Addressing Architecture".
- [9] [IETF RFC 4007](#): "IPv6 Scoped Address Architecture".
- [10] [IETF RFC 4861](#): "Neighbor Discovery for IP version 6 (IPv6)".
- [11] [IETF RFC 5942](#): "IPv6 Subnet Model: The Relationship between Links and Subnet Prefixes".
- [12] [IETF RFC 4862](#): "IPv6 Stateless Address Autoconfiguration".
- [13] [IETF RFC 3963](#): "Network Mobility (NEMO) Basic Support Protocol".
- [14] [IETF RFC 6724](#): "Default Address Selection for Internet Protocol version 6 (IPv6)".
- [15] [IETF RFC 2464](#): "Transmission of IPv6 Packets over Ethernet Networks".
- [16] Void.
- [17] [IETF RFC 3810](#): "Multicast Listener Discovery Version 2 (MLDv2) for IPv6".
- [18] [IETF RFC 7761](#): "Protocol Independent Multicast - Sparse Mode (PIM-SM): Protocol Specification (Revised)".
- [19] [IETF RFC 4605](#): "Internet Group Management Protocol (IGMP) / Multicast Listener Discovery (MLD)-Based Multicast Forwarding ("IGMP/MLD Proxying")".
- [20] [IETF RFC 3306](#): "Unicast-Prefix-based IPv6 Multicast Addresses".

- [21] Void.
- [22] [IETF RFC 1042](#): "Standard for the Transmission of IP Datagrams over IEEE 802 Networks".
- [23] [IETF RFC 3971](#): "SEcure Neighbor Discovery (SEND)".
- [24] [IETF RFC 4293](#): "Management Information Base for the Internet Protocol (IP)".
- [25] [IETF RFC 2526](#): "Reserved IPv6 Subnet Anycast Addresses".
- [26] [ISO/IEC 8802-2:1998](#): "Information technology - Telecommunications and information exchange between systems - Local and metropolitan area networks - Specific requirements - Part 2: Logical link control".
- [27] [IEEE 802.1Q™-2014](#): "IEEE Standard for Local and metropolitan area networks - Bridges and Bridged Networks".
- [28] [IEEE 802.11™-2020](#): "IEEE Standard for Information Technology - Telecommunications and Information Exchange Between Systems-Local and Metropolitan Area Networks - Specific Requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications".
- [29] [IEEE 802.11bd™-2022](#): "IEEE Standard for Information technology- Tele- communications and information exchange between systems Local and metropolitan area networks- Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 5: Enhancements for Next Generation V2X".
- [30] [IEEE 802.3™-2008](#): "IEEE Standard for Information Technology - Telecommunications and information exchange between systems-Local and metropolitan area networks - Specific requirements - Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications".
- [31] [IEEE Guidelines For 64-bit Global Identifier \(EUI-64\)](#).

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] IETF RFC 3753: "Mobility Related Terminology".
- [i.2] IETF RFC 4885: "Network Mobility Support Terminology".
- [i.3] IETF RFC 8504: "IPv6 Node Requirements".
- [i.4] IETF RFC 4903: "Multi-Link Subnet Issues".
- [i.5] IETF RFC 4840: "Multiple Encapsulation Methods Considered Harmful".
- [i.6] IETF RFC 3316: "Internet Protocol Version 6 (IPv6) for Some Second and Third Generation Cellular Hosts".
- [i.7] IETF RFC 5154: "IP over IEEE 802.16 Problem Statement and Goals".
- [i.8] IETF RFC 3549: "Linux Netlink as an IP Services Protocol".
- [i.9] IETF RFC 3314: "Recommendations for IPv6 in Third Generation Partnership Project (3GPP) Standards".

- [i.10] IETF RFC 1661: "The Point-to-Point Protocol (PPP)".
- [i.11] IETF RFC 2578: "Structure of Management Information Version 2 (SMIPv2)".
- [i.12] IETF RFC 2579: "Textual Conventions for SMIPv2".
- [i.13] IETF RFC 2491: "IPv6 over Non-Broadcast Multiple Access (NBMA) networks".
- [i.14] IETF RFC 6775: "Neighbor Discovery Optimization for IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs)".
- [i.15] [Virtual Point-to-Point\(TUN\) and Ethernet\(TAP\) devices](#).
- [i.16] ISO 21210-2012: "Intelligent Transport Systems - Communications access for land mobiles (CALM) - IPv6 networking".
- [i.17] ETSI TS 123 060: "Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); General Packet Radio Service (GPRS); Service description; Stage 2 (3GPP TS 23.060 Release 9)".
- [i.18] ISO/IEC Technical Report 11802-5:1997(E): "Information technology-Telecommunications and information exchange between systems-Local and metropolitan area networks-Technical reports and guidelines-Part 5: Medium Access Control (MAC) Bridging of Ethernet V2.0 in Local Area Networks" (previously known as IEEE Std 802.1H-1997).
- [i.19] ETSI TS 103 836-4-2: "Intelligent Transport Systems (ITS); Vehicular Communications; GeoNetworking; Part 4: Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Sub-part 2: Media-dependent functionalities for ITS-G5".
- [i.20] GeoNet D1.2: FP7 STREP N 216269 European Project GeoNet - Geographic addressing and routing for vehicular communications - Deliverable D1.2 v1.1: "Final GeoNet Architecture Design".
- [i.21] GeoNet D2.2: FP7 STREP N 216269 European Project GeoNet - Geographic addressing and routing for vehicular communications - Deliverable D2.2 v1.1: "Specification - Final Release".
- [i.22] GeoNet D7.1: FP7 STREP N 216269 European Project GeoNet - Geographic addressing and routing for vehicular communications - Deliverable D7.1 v1.0: "GeoNet Experimentation Results".
- [i.23] NemoROReqDraft: IETF draft-ietf-mext-nemo-ro-automotive-req-02 (July 2009): "Automotive Industry Requirements for NEMO Route Optimization".
- [i.24] Iana: "[Internet Protocol Version 6 \(IPv6\) Anycast Addresses](#)".

3 Definition of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in ETSI TS 103 836-3 [4], IETF RFC 4861 [10], IETF RFC 8504 [i.3], IETF RFC 4885 [i.2] and the following apply:

geographical virtual link: link-local multicast-capable virtual link spanning multiple physical links with geographically scoped boundaries

GN6 adaptation sub-layer: protocol adaptation sub-layer supporting the transmission of IPv6 packets over the GeoNetworking protocol

GVL area: geographical area associated with a GVL

IPv6-compliant: compliant with IETF RFC 8200 [7], IETF RFC 4291 [8], IETF RFC 4007 [9], IETF RFC 4861 [10] and IETF RFC 4862 [12]

IPv6 next hop: IPv6 node resulting from the next-hop determination described in IETF RFC 4861 [10], section 5.2

sub-IP multi-hop delivery: IP packet delivery traversing several ITS stations where the Hop Limit field of the IPv6 header given in IETF RFC 8200 [7] is not decreased

topological virtual link: link-local multicast-capable virtual link spanning multiple physical links with topologically scoped boundaries

3.2 Symbols

For the purposes of the present document, the following symbols apply:

GEO_{MAX}	Size of the largest GeoNetworking header
GN_{SAP}	GeoNetworking Service Access Point
MTU_{AL}	Maximum transmission unit offered by the protocol layer below GeoNetworking
MTU_{GN6}	Maximum transmission unit offered by GN6ASL to IPv6
MTU_{VI}	Typical maximum transmission unit associated to the type of a virtual interface
STALE	Stale state of an IPv6 Neighbor Cache entry
VL_ID	Virtual Link IDentifier

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AL	Access Layer
ASN.1	Abstract Syntax Notation One
BER	Basic Encoding Rules
CGA	Cryptographically Generated Addresses
DGVL	Dynamic Geographical Virtual Link
EDCA	Enhanced Distributed Channel Access
EGN6	Extended GeoNetworking-IPv6
EIID	Extended Interface Identifier
EUI	Extended Unique Identifier
GN6	GeoNetworking-IPv6
GN6ASL	GeoNetworking-IPv6 Adaptation Sub-Layer
GN6SDU	GN6 Service Data Unit
GPRS	General Packet Radio Service
GVL	Geographical Virtual Link
IANA	Internet Assigned Numbers Authority
ID	Identifier
IID	Interface Identifier
IP	Internet Protocol
IPv6	Internet Protocol Version 6
ITS	Intelligent Transport System
LAN	Local Area Network
LLC	Logical Link Control
MAC	Media Access Control
MIB	Managed Information Base
MID	MAC ID
MPEG-2	Moving Pictures Expert Group
MTU	Maximum Transmission Unit
NA	Neighbor Advertisement
ND	Neighbor Discovery
NEMO BS	NETwork MObility Basic Support
NH	Next Header
NIC	Network Interface Controller
NS	Neighbor Solicitation
NS/NA	Neighbour Solicitation/Neighbour Advertisement
NUD	Neighbor Unreachability Detection
OUI	Organizationally Unique Identifier
PDCP	Packet Data Convergence Protocol

PER	Packed Encoding Rules
PHY	PHYSical
PPP	Point-to-Point Protocol
QoS	Quality of Service
RA	Router Advertisement
SAP	Service Access Point
SDU	Service Data Unit
SEND	SEcure Neighbor Discovery
SGVL	Static Geographical Virtual Link
SLAAC	StateLess Address AutoConfiguration
SMI	Structure of Management Information
SNAP	SubNetwork Access Protocol
SNMPv2-TC	Simple Network Management Protocol version 2 - Textual Conventions
STA	STation
TAP	Terminal Access Point
TCP	Transmission Control Protocol
TSB	Topologically Scoped Broadcast
TUN	network TUNnel
TVL	Topological Virtual Link
UDP	User Datagram Protocol
UMTS	Universal Mobile Telecommunications Systems
VI	Virtual Interface
VL_ID	Virtual Link Identifier
VLAN	Virtual Local Area Network

4 GN6ASL in the ITS station architecture

With respect to the ITS station reference architecture, the present document only affects the Networking & Transport layer. As depicted in figure 1, within the Networking & Transport layer, the present document introduces GN6ASL, an adaptation sub-layer for the transmission of IPv6 packets over the GeoNetworking protocol. The other protocols depicted in figure 1 (e.g. TCP and UDP) are represented for sake of completeness in order to represent a typical usage of the present document.

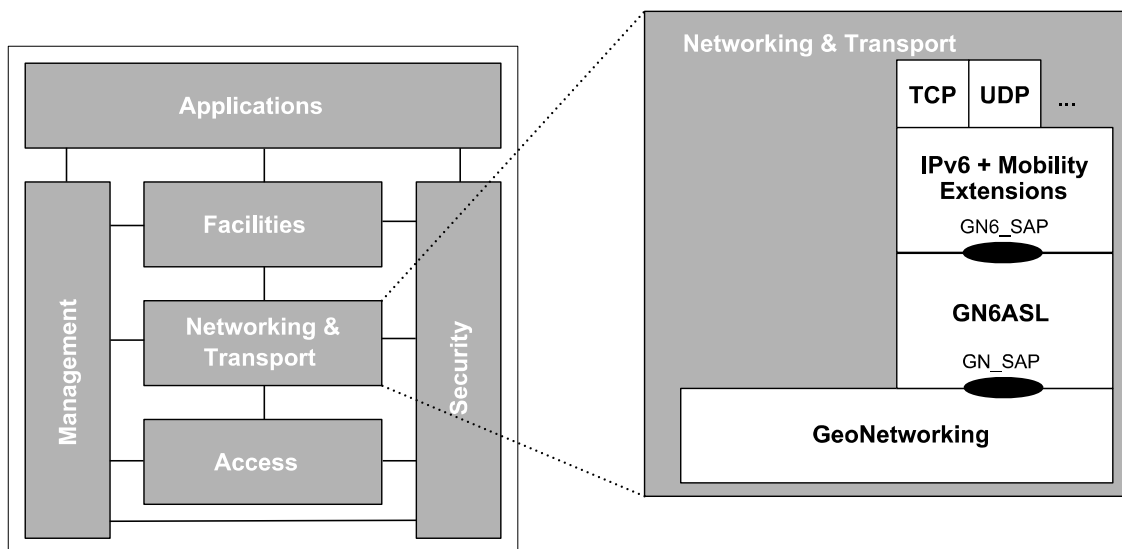


Figure 1: GN6ASL in the ITS station architecture

As depicted in figure 1, the present document builds an adaptation sub-layer (GN6ASL) between the ETSI GeoNetworking protocol defined in ETSI TS 103 836-4-1 [6] and an IPv6-compliant protocol layer with mobility extensions. The default IPv6 mobility is the Network Mobility Basic Support (NEMO BS) protocol defined in IETF RFC 3963 [13]. The present document enables the usage of NEMO BS over the ETSI GeoNetworking protocol given in ETSI TS 103 836-4-1 [6].

NOTE: With respect to figure 1, the scope of ISO 21210-2012 [i.16] includes the protocol layer IPv6 + Mobility Extensions, directly above the adaptation sub-layer specified in the present document.

5 IPv6 link models and interfaces

5.1 Rationale

The Neighbor Discovery (ND) protocol specified in IETF RFC 4861 [10] is a mandatory part of IPv6 stacks that includes functionalities such as Router and Prefix Discovery as well as Address Resolution and Neighbor Unreachability Detection. Some of ND's services use link-layer multicast addresses. This implies that the link-layer protocol is required to support multicast addressing in order to run the ND protocol as described in IETF RFC 4861 [10]. ND adaptations or alternative protocols or mechanisms to implement its services are commonly introduced for link-layer technologies that do not support multicast addressing (e.g. IETF RFC 2491 [i.13], IETF RFC 3316 [i.6], IETF RFC 5154 [i.7]).

In addition to link-local multicast support, ND also requires symmetric reachability (defined in IETF RFC 4861 [10]).

GN6ASL is presented to the IPv6 layer as a link-layer protocol which relies on the GeoNetworking protocol specified in ETSI TS 103 836-4-1 [6]. The GeoNetworking protocol provides both point-to-point and point-to-multipoint communications, as well as geographically scoped addressing such as GeoAnycast and GeoBroadcast specified in ETSI TS 103 836-2 [3]. Furthermore, the GeoNetworking protocol specified in ETSI TS 103 836-4-1 [6] provides upper layers with a sub-IP multi-hop delivery service as required by ETSI TS 103 836-1 [2].

The present document introduces three types of virtual link, one providing symmetric reachability by means of stable geographically scoped boundaries. The other two do not provide symmetric reachability but can be used when the dynamic definition of the broadcast domain is required. The combination of these types of virtual link in the same station allows running the ND protocol including SLAAC as specified in IETF RFC 4862 [12] as well as to distribute other IPv6 link-local multicast traffic and, at the same time, to reach nodes that are outside specific geographic boundaries.

EXAMPLE: In 3GPP Release 9, IPv6 is transported directly over PDCP, and optionally via PPP [i.10], see ETSI TS 123 060 [i.17]. In both cases, over PDCP and via PPP, virtual point-to-point links are used. ETSI TS 123 060 [i.17] uses some ND operations such as the issuing of a Router Solicitation although, as pointed out in IETF RFC 3314 [i.9], the IETF has not specified a point-to-point architecture, nor how the standard IPv6 address assignment mechanisms are applicable to IPv6 over point-to-point links. IETF RFC 3314 [i.9] called for the (at that time still existing) IPv6 WG to carry out these activities but to date no specification exists.

In the following, virtual links are distinguished from virtual interfaces. A virtual interface represents an instance of a virtual link that is presented to the IPv6 layer in an implementation-specific way.

5.2 Properties of supported IPv6 link models

5.2.1 Geographical virtual links

5.2.1.0 Overview

A Geographical Virtual Link (GVL) is a link-local multicast-capable virtual link spanning multiple physical links with geographically scoped boundaries. GN6ASL of a GeoAdhoc router shall support GVLs.

Each GVL shall be associated with one single GeoNetworking GEOBROADCAST/GEOANYCAST area (also called geoarea in ETSI TS 103 836-4-1 [6] and specified in ETSI EN 302 931 [5]) stored in the per-GVL MIB attributes `itsGn6asIGvlAreaCenterLatitude` `itsGn6asIGvlAreaCenterLongitude` `itsGn6asIGvlAreaDistA` `itsGn6asIGvlAreaDistB` `itsGn6asIGvlAreaAngle`. These attributes are referred to as the GVL Area.

A GVL is shared among several GeoAdhoc routers when all of the GeoAdhoc routers use the same GVL area.

The per-link MIB attributes of a GVL are specified in annex B.

Two sub-types of GVL exist: Static GVL (SGVL) and Dynamic GVL (DGVL).

5.2.1.1 Static geographical virtual links

A Static Geographical Virtual Link (SGVL) is a GVL whose GVL Area shall be:

- derived from a received GeoNetworking header encapsulating a Router Advertisements (RA) message (see IETF RFC 4861 [10]) as described in clause 10.2.1; or
- assigned by the ITS station management entity only in roadside ITS stations.

When no GVL Area is set, a SGVL shall be disabled. When the GVL Area is set, the SGVL shall be (re)enabled. While a GVL is enabled, the GVL Area may not be modified.

Multiple SGVLs may be enabled simultaneously per entry in the GeoNetworking interface table (ItsGnIfEntry, see ETSI TS 103 836-4-1 [6]). The maximum number of simultaneously enabled SGVLs per ItsGnIfEntry shall be `itsGn6asIVLIndexMax - 1`.

SGVLs provide symmetric reachability. IPv6 ND shall be supported by SGVLs with the amendments specified in clause 10.

No restrictions apply to the scope of IPv6 addresses that may be assigned to SGVLs.

5.2.1.2 Dynamic geographical virtual links

A Dynamic Geographical Virtual Link (DGVL) is a GVL whose GVL Area may be modified. If the default SAP described in clause C.1 is adopted (GN6_SAP), the GVL Area shall be assigned by the ITS station management entity. If the experimental SAP described in clause C.2 is adopted (EGN6_SAP), the GVL Area shall be assigned on a per-packet basis by using the geographical area specified in the destination parameter of the EGN6-UNITDATA.request primitive.

One and only one DGVL shall exist per ItsGnIfEntry. The DGVL shall be automatically created when the interface associated to the ItsGnIfEntry is enabled.

When no GVL Area is set, the DGVL may not be used to send link-local or global multicast IPv6 traffic.

The DGVL does not guarantee symmetric reachability. IPv6 ND shall be disabled on the DGVL.

The DGVL may only be assigned the link-local IPv6 address.

5.2.2 Topological virtual links

A Topological Virtual Link (TVL) is a link-local multicast-capable virtual link spanning multiple physical links with topologically scoped boundaries.

One and only one TVL shall exist per ItsGnIfEntry. The TVL shall be automatically created when the interface associated to the ItsGnIfEntry is enabled.

The TVL does not guarantee symmetric reachability. IPv6 ND shall be disabled on the TVL.

The per-link MIB attributes of a TVL are specified in annex B.

The TVL may only be assigned the link-local IPv6 address.

5.2.3 Virtual links indexing

Given an ItsGnIfEntry, each virtual link shall be uniquely identified by the index `itsGn6asIVLIndex`.

The TVL shall have `itsGn6asIVLIndex` equal to 0.

The DGVL shall have `itsGn6asIVLIndex` equal to 1.

SGVLs shall have `itsGn6asIVLIndex` values between 2 and `itsGn6asIVLIndexMax`. When enabled, a SGVL shall be assigned the lowest unused value. When disabled, the SGVL shall release the value.

NOTE: The maximum value of `itsGn6asIvlIndexMax` is 4 093 because it is used as the value of the 12-bit `VL_ID` field of the Extended Interface Identifier (see clause 5.3.2.1). 4 094 cannot be used because it collides with the Modified EUI-64 format IID.

5.3 Properties of virtual interfaces

5.3.1 Number and types of virtual interfaces

The IPv6 virtual link types described in clause 5.2 shall be provided by GN6ASL to IPv6 in the form of virtual network interfaces.

Virtual network interfaces may be associated to either GVLs or TVLs. One single virtual interface shall be associated to one GVL or one TVL. One or several virtual interfaces can be associated to one single `ItsGnIfEntry`. Given an `ItsGnIfEntry`:

- only one TVL can be associated to the `ItsGnIfEntry` and only one virtual interface can be associated to that TVL;
- multiple SGVLs can be associated to the `ItsGnIfEntry` and only one virtual interface can be associated to each SGVL;
- only one DGVL can be associated to the `ItsGnIfEntry` and only one virtual interface can be associated to that DGVL.

GN6ASL shall support virtual network interfaces of type Ethernet V2.0/IEEE 802.3 as specified in IEEE 802.3:2008 [30] LAN in the way described in clause 5.3.2.1. This allows for backward compatibility with pre-existing IPv6 protocol implementations as well as for support of IEEE 802-based passing bridge IPv6 packets.

In the current version of the present document, no other types of virtual interfaces are supported.

Virtual interfaces used to implement GVLs and TVLs and the underlying operating system shall support bidirectional communications. This is required in order to maintain symmetric reachability in a GVL.

5.3.2 Usage of specific virtual interfaces

5.3.2.1 Ethernet V2.0/IEEE 802.3 LAN virtual interfaces

Virtual network interfaces of type Ethernet V2.0/IEEE 802.3 LAN as specified in IEEE 802.3:2008 [30] shall be supported by GN6ASL for the transmission of IPv6 packets over GeoNetworking protocol specified in ETSI TS 103 836-4-1 [6].

The transmission of IPv6 packets over GeoNetworking protocol specified in ETSI TS 103 836-4-1 [6] via Ethernet V2.0/IEEE 802.3 LAN virtual interfaces shall be compliant with IETF RFC 2464 [15] regarding all operations undertaken by IPv6. The alternative encapsulation method described in IETF RFC 1042 [22] and utilizing the 802.2 Sub-Network Access Protocol (SNAP) header extension shall not be used. As depicted in figure 5, no virtual interface-specific protocol header shall be added between the GeoNetworking header(s) and the IPv6 header. Thus, the issues described in IETF RFC 4840 [i.5] do not arise.

The 48-bit MAC address of a virtual interface of type Ethernet V2.0/IEEE 802.3 LAN shall be set to the 48-bit `MID` field of the `GN_Addr` (see ETSI TS 103 836-4-1 [6]) of the local GeoAdhoc router. According to ETSI TS 103 836-4-1 [6], the address space of `GN_Addr` is 48 bits long. This means that the MAC address derived in this way maps to one and only one `GN_Addr`.

It should be noted that in order to protect the user's privacy, `GN_Addr` may be modified upon a request of the ITS station management entity. This implies that the 48-bit MAC address shall be modified accordingly. See clause 11.2.

As depicted in figure 2, the IID part of the IPv6 link-local address and of IPv6 addresses generated by means of SLAAC as described in clause 10.2.1 shall be set as follows:

- the IID of virtual interfaces associated to TVLs shall be the Modified EUI-64 format IID derived from the 48-bit MAC address as described in IETF RFC 2464 [15];

- the IID of virtual interfaces associated to GVLs shall be equal to the Extended Interface Identifier (EIID). The EIID shall consist of the fields described in table 1.

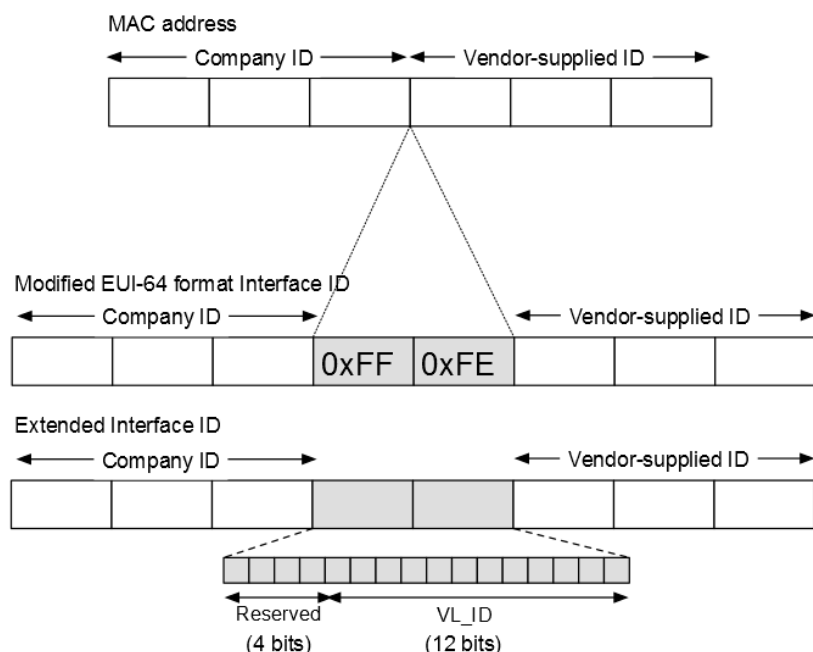


Figure 2: Creation of modified EUI-64 format IID and EIID from the MAC address

Table 1: Fields of the Extended Interface Identifier (EIID)

Field #	Field name	Octet/bit position		Type	Description
		First	Last		
1	company_id	Octet 0 Bit 0	Octet 2 Bit 7	24 bit address	The Organizationally Unique Identifier (OUI) part of the MAC address.
2	Reserved	Octet 3 Bit 0	Octet 3 Bit 3	4 bit unsigned integer	Reserved for future use. Shall be set to 0.
3	VL_ID	Octet 3 Bit 4	Octet 4 Bit 7	12 bit unsigned integer	Virtual link index. Shall be set to itsGn6asIVLIndex. See clause 5.2.3.
4	vendor_supplied_id	Octet 5 Bit 0	Octet 7 Bit 7	24 bit address	The Network Interface Controller (NIC) Specific part of the MAC address.

EXAMPLE: Examples of virtual interfaces of type Ethernet V2.0/IEEE 802.3 LAN are TAP virtual devices which are supported by several operating systems, see universal TUN/TAP driver for Linux, Solaris and FreeBSD [15].

6 Bridging support

6.1 Rationale

In the ETSI ITS GeoNetworking network architecture specified in ETSI TS 103 836-3 [4], IP connectivity of ITS stations is provided by mobile routers and access routers. In particular, an access router provides an ad hoc network with access to the Internet (see ETSI TS 103 836-3 [4]), while a mobile router provides IP connectivity of the ITS station's internal network to an access router. The GeoNetworking protocol specified in ETSI TS 103 836-4-1 [6] and the GN6ASL are implemented by the GeoAdhoc router.

According to ETSI TS 103 836-3 [4], the GeoAdhoc router, the mobile router and the access router are separate logical network components. Optionally, the GeoAdhoc router and the access router collapse into one single component of an ITS station. Likewise, the GeoAdhoc router and the mobile router optionally collapse into one single component of an ITS station.

If these functions are collapsed, the mobile router and the access router directly terminate the GeoNetworking protocol transport of IPv6 packets and no additional transport function is required. If GeoAdhoc router and the access router are in two separate components (see figure 3), or the GeoAdhoc router and the mobile router are in two separate components (see figure 4), it is necessary to extend the transport termination from the GeoAdhoc router to the access router or to the mobile router, respectively.

Since the transport of IPv6 packets has to be extended without modifying the IPv6 packets, a link-layer or a tunnelling transport mechanism shall be adopted. The present document provides a link-layer mechanism based on bridging that is specified in clause 6.2.

EXAMPLE 1: When a roadside ITS station provides vehicle ITS stations with connectivity to the Internet, vehicle ITS stations select the access router as the IPv6 default gateway (and therefore as IPv6 next hop for all IPv6 traffic targeted to addresses determined to be off-link). GeoNetworking protocol transport of IPv6 packets terminates in the GeoAdhoc router of a roadside ITS station. The separation of GeoAdhoc router and access router (see figure 3) allows for diversified deployment scenarios. In fact, the access router is not required to reside in the roadside ITS station but could be physically located far away from the road, e.g. in a traffic control operations center. A layer-2 tunnel transport technology can be adopted to connect a roadside ITS station with the access network where the access router resides.

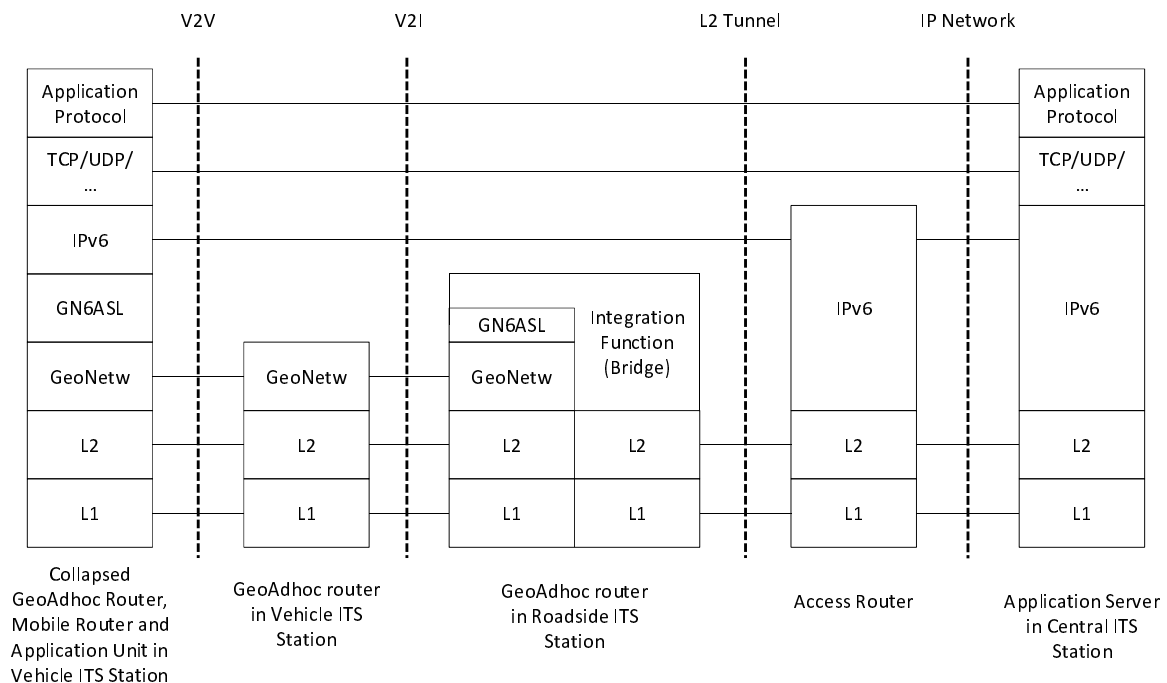


Figure 3: Separation of GeoAdhoc router and access router functions in a roadside ITS station

EXAMPLE 2: When a mobile router inside a vehicle ITS station provides applications units with connectivity to the Internet, the mobile router selects the access router as the IPv6 default gateway (and therefore as IPv6 next hop for all IPv6 traffic targeted to addresses determined to be off-link). GeoNetworking protocol transport of IPv6 packets terminates in the GeoAdhoc router of the vehicle ITS station.

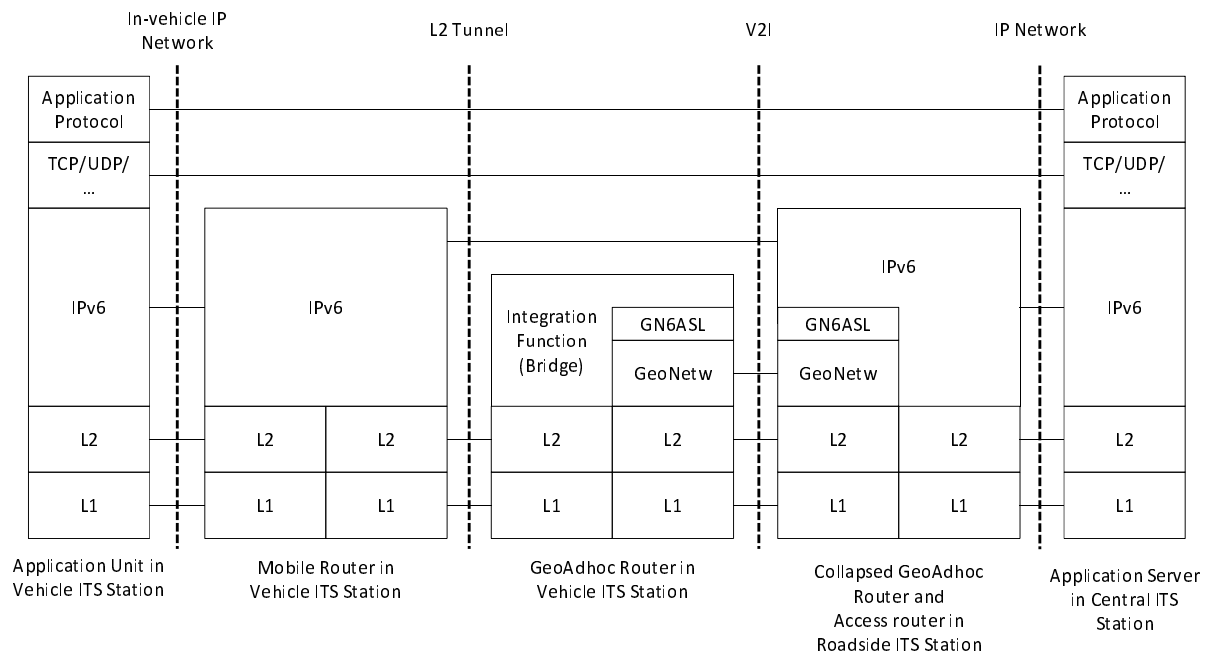


Figure 4: Separation of GeoAdhoc router and mobile router functions in a vehicle ITS station

6.2 Required properties

A GeoAdhoc router where the GeoNetworking protocol runs on top of a link-layer protocol that supports an integration function in accordance with IEEE 802.11:2020 [28] and IEEE 802.11bd:2022 [29] for passing bridge packets, shall provide at least one virtual interface that supports the same integration function at least for passing bridge IPv6 packets.

The above clause does not require an GeoAdhoc router to implement full bridge functionalities [i.18]. It requires these functionalities only for IPv6 packets. Furthermore, the above clause only applies if a standard integration function for passing bridge packets exists for the specific link-layer protocol on which the GeoNetworking protocol runs.

The media-dependent GeoNetworking extension defined in ETSI TS 103 836-4-2 [i.19], is designed for the access ETSI EN 303 797 [1]. This access layer commonly supports the 802 integration service specified in IEEE 802.11:2020 [28] and IEEE 802.11bd:2022 [29].

6.3 Media-dependent implementations

6.3.1 IEEE 802 integration service

IEEE 802.11:2020 [28] and IEEE 802.11bd:2022 [29] specify an integration service, which is a simplified version of the full 802.1D bridge functionality specified in IEEE 802.11Q:2014 [27] and supports the translation of IEEE 802.11:2020 [28]/IEEE 802.11bd:2022 [29] frames from/into Ethernet V2.0/IEEE 802.3:2008 [30] LAN frames.

According to clause 6.2 above, when ETSI TS 103 836-4-2 [i.19] is used at least one virtual interface shall be able to pass bridge IPv6 packets with other interfaces supporting Ethernet V2.0/IEEE 802.3:2008 [30] LAN frames.

It is also recommended that the virtual interface supports 802.1Q VLAN tagging as specified in IEEE 802.1Q:2014 [27].

EXAMPLE: The TAP virtual Ethernet devices (universal TUN/TAP driver for Linux, Solaris and FreeBSD [i.15]) already mentioned above provide 802.1D bridging support.

7 IPv6/GeoNetworking interface service specification

The services offered by GN6ASL to IPv6 are delivered through GN6_SAP, which is designed based on the service user/provider model described in ISO/IEC 8802-2:1998 [26].

GN6_SAP shall only provide unacknowledged connectionless-mode services to IPv6, which consist of a set of data transfer services by which IPv6 protocol entities of different GeoAdhoc routers can exchange IPv6 packets without the establishment of data link level connections.

The primitives associated with the data transfer services provided by GN6_SAP are as follows:

- GN6-UNITDATA.request
- GN6-UNITDATA.indication

The GN6-UNITDATA.request primitive is passed to GN6ASL to request that a GN6SDU be sent using unacknowledged connectionless-mode procedures. The GN6-UNITDATA.indication primitive is passed to IPv6 to indicate the arrival of an IPv6 packet.

The primitives parameters are specified in the informative annex C.

8 Encapsulation characteristics

8.1 Maximum transmission unit

The MTU of a virtual interface associated with a GVL or TVL (MTU_{GN6}) shall be set to a value that depends on the MTU of the access layer technology that transports the GeoNetworking protocol (MTU_{AL}). In particular, MTU_{GN6} shall be less than or equal to MTU_{AL} reduced by the size of the largest GeoNetworking protocol header used to transport IPv6 packets (GEO_{MAX} , corresponding to itsGnMaxGeoNetworkingHeaderSize in ITSGN-MIB specified in ETSI TS 103 836-4-1 [6]). Moreover, MTU_{GN6} shall also be less than or equal to the typical MTU supported by the specific type of virtual interface MTU_{VI} .

The previous clause is expressed by the following equation.

$$MTU_{GN6} = \min\{MTU_{VI}, MTU_{AL} - GEO_{MAX}\} \quad (1)$$

Since the minimum required MTU by IPv6 is 1 280 octets, IPv6 over GeoNetworking is enabled only when the access layer is such that:

$$MTU_{AL} \geq 1\,280 + GEO_{MAX} \quad (2)$$

EXAMPLE: When the media-dependent extension given in ETSI TS 103 836-4-2 [i.19] is used, the access layer is given by ETSI EN 303 797 [1] (i.e. ITS-G5 PHY, MAC and LLC). This combination is expected to result in a MTU_{AL} bigger than 2 000 octets, similarly to the combination of IEEE 802.11:2020 [28]/IEEE 802.11bd:2022 [29] and ISO/IEC 8802-2:1998 [26]. This guarantees not only that the condition expressed by equation 2 is fulfilled, but also that the Ethernet MTU (1 500) is supported, as soon as GEO_{MAX} is smaller than 720 octets. This condition is expected to be met easily.

8.2 Packet delivery

8.2.1 Outbound traffic

The following list describes the steps that shall be undertaken by the GN6ASL upon the transmission of an IPv6 packet over the GeoNetworking protocol. The procedure applies to both IPv6 packets generated by the ITS station itself and packets being forwarded by the IPv6 protocol layer residing in the ITS station.

The following procedure only describes the logical steps that shall be undertaken by the GN6ASL and not the steps undertaken by the virtual interfaces (which are implementation-specific). An example of virtual interface operations is provided in clause E.2.

Procedure:

- 1) IPv6 operations: the IPv6 layer shall execute the ordinary procedures according to the IPv6 base specifications IETF RFC 8200 [7] and IETF RFC 6724 [14]. These procedures include IPv6 header assembling, Routing and Forwarding Information Bases lookup, outgoing interface selection, and source address selection. These procedures are outside the scope of the present document. If the selected outgoing interface is one of the virtual interfaces associated with a virtual link provided by the GN6ASL, the next steps shall be executed.

NOTE 1: The IPv6 protocol layer does not distinguish an interface associated with a GVL/TVL from any other interface. However, an interface associated to a GVL/TVL may be automatically selected if a route is associated to that interface, e.g. as a consequence of SLAAC as described in clause 10.2.1. Alternatively, proper configuration of the IPv6 routing table is required, which is outside the scope of the present document.

- 2) Upon a GN6-UNITDATA.request primitive call, the GN6ASL shall determine the set of parameters to be passed to the GeoNetworking protocol as specified in table 2. In particular:
 - a) If the IPv6 destination address is an IPv6 unicast address (or an IPv6 anycast address), the GN6ASL shall uniquely derive the MID part of a unicast GN_Addr according to the address resolution procedure specified in clause 10.3.
 - b) If the IPv6 destination address is an IPv6 multicast address, the GN6ASL shall apply the procedures described in clause 9.2.1.
 - c) If the IPv6 destination address is a geographic IPv6 anycast address, the GN6ASL shall apply the procedures described in clause 9.4.
- 3) The GN6ASL shall invoke the GeoNetworking GN-Data.request service primitive with the parameters determined in the previous step.

NOTE 2: In various implementations of IPv6, the link-layer SAP invocation is implemented by IPv6 passing down a partially filled link-layer header. If such an implementation is used to deploy the GN6ASL, it should be noted that the link-layer header appended by IPv6 depends on the virtual interface type and is to be removed by the GN6ASL.

Table 2: Service primitive parameter determination for outbound traffic

GN-Data.request primitive parameter	Value set by the GN6ASL			
	If the IPv6 destination address is unicast or legacy anycast	If the IPv6 destination address is multicast		If the IPv6 destination address is anycast with anycast ID equals to itsGn6aslGeoAnycastID
		Sent via GVL	Sent via TVL	
Packet transport type	GeoUnicast	GeoBroadcast	TSB	GeoAnycast
Destination	MID derived as described in clause 10.3	GVL Area (see clause 9.2.1) of the outgoing virtual link	Null	GVL Area (see clause 9.2.1) of the outgoing virtual link
Maximum lifetime	0			
Repetition interval	0			
Traffic class (see note 2)	The priority parameter passed to GN6-UNITDATA.request			
Length	Length of the GN6SDU			
Data	The GN6SDU passed to GN6-UNITDATA.request			
<p>NOTE 1: As explained in ETSI TS 103 836-4-1 [6], clause 6.3, the address space of GN_Addr is 48-bits wide, i.e. the MID field alone is sufficient to uniquely identify a GeoAdhoc router. The GeoNetworking protocol recognizes that the destination parameter of the GN-Data.request primitive only contains the MID field. The GeoNetworking protocol is responsible for deriving a full GN_Addr from the MID.</p> <p>NOTE 2: At the time of writing the present document, no specification exists that mandates a certain usage of link-layer QoS facilities for IPv6. For example EDCA Access Categories are selected in implementation-specific ways for IPv6 over 802.2 LLC (see ISO/IEC 8802-2:1998 [26]) over 802.11 MAC/PHY (see IEEE 802.11:2020 [28] and IEEE 802.11bd:2022 [29]) by checking the traffic class field of the IPv6 header defined in IETF RFC 8200 [7]. The present document provides IPv6 with the priority primitive parameter for similar purposes. Mapping between IPv6 traffic class field values and the priority primitive parameter is outside the scope of the present document. The present table only specifies the mapping between the primitive parameter received from IPv6 and the primitive parameter passed to GeoNetworking.</p>				

8.2.2 Inbound traffic

The following list describes the steps that shall be undertaken by the GN6ASL upon the reception of a GeoNetworking header transporting an IPv6 header.

The following procedure only describes the logical steps that shall be undertaken by the GN6ASL and not the steps undertaken by the virtual interfaces (which are implementation-specific). An example of virtual interface operations is provided in clause E.2.

Procedure:

- 1) Initial GeoNetworking operations: the GeoNetworking protocol header shall perform the regular operations described in ETSI TS 103 836-4-1 [6] regarding header checks, optional security checks, update of data structures and packet forwarding. If the GeoAdhoc router belongs to the addressed ITS stations and the NH field of the GeoNetworking header indicates the presence of an IPv6 header, the GN6ASL shall be notified via a GN-Data.indication primitive call and execute the next steps.
- 2) Virtual link selection: in this step, the GN6ASL determines which virtual link the packet belongs to. The following selection criteria shall be applied in sequence and if one criterion is matched, the selection process shall end:
 - a) If the GeoNetworking header is of type TSB, the GN6ASL shall select the TVL as inbound virtual link.
 - b) If the GeoNetworking header is of type GEOBROADCAST, the GN6ASL shall first check if a GVL exists in the itsGn6aslVlTable whose GVL Area matches the destination area specified in the GEOBROADCAST header. If such a GVL exists, it should be selected as inbound virtual link. If such a GVL is not found and the GEOBROADCAST header carries an IPv6 Router Advertisement, a new GVL link shall be created as specified in clause 10.2.1 and selected as inbound virtual link.

NOTE 1: In order to determine if the GEOBROADCAST header carries an IPv6 Router Advertisement, the GN6ASL has to inspect the IPv6 packet, determine if it carries an ICMPv6 message and if the ICMPv6 message is of type Router Advertisement.

- c) If the GeoNetworking header is of type GEOANYCAST, the GN6ASL shall first check if a GVL exists in the itsGn6asIvLTable whose GVL Area matches the destination area specified in the GEOANYCAST header. If such a GVL exists, it should be selected as inbound virtual link.
- d) If the GeoNetworking header is of type GEOUNICAST, the GN6ASL shall inspect the IPv6 destination address. If the IPv6 destination address is assigned to one and only one of the virtual interfaces related to GN6ASL, GN6ASL shall select that virtual interface and the associated virtual link.
- e) If the GeoNetworking header is of type GEOUNICAST and one and only one GVL exists in the itsGn6asIvLTable whose GVL Area contains the GeoNetworking source node's position, the GN6ASL shall select that GVL.
- f) If the GeoNetworking header is of type GEOUNICAST and multiple GVLs exist in the itsGn6asIvLTable whose GVL Areas contain the GeoNetworking source node's position, the GN6ASL shall, among those GVLs, select one (if present) that is associated to a virtual interface for which the IPv6 source address prefix is considered to be on-link. If the IPv6 source address prefix is considered to be on-link for more than one GVL, the GVL associated to the prefix with the highest invalidation timer value in the Prefix List (see IETF RFC 4861 [10] and IETF RFC 5942 [11]) shall be selected as inbound GVL.

NOTE 2: The IPv6 on-link determination is defined in IETF RFC 4861 [10] and updated in IETF RFC 5942 [11]. Checking if a prefix is considered to be on-link for a certain interface corresponds to checking the IPv6 Prefix List or ipv6AddrPrefixTable in the IPv6 MIB specified in IETF RFC 4293[24]. See clause 10.1 for on-link determination.

NOTE 3: According to other IPv6 deployments outlined in IETF RFC 4903 [i.4], it is recommended to avoid that a prefix is considered to be on-link for multiple links. The present document also recommends to avoid this situation by proper IPv6 prefixes assignment and access router configuration. In particular, clause 10.2.1 recommends that the same prefix is not advertised in a Router Advertisement Prefix Information option with the L-bit set on different GVLs by one or more IPv6 routers.

- g) If none of the above selection criteria are matched, GN6ASL shall select the DGVL as inbound virtual link. IPv6 shall not treat the packet reception as a neighbour reachability confirmation.
- 3) The GN6ASL shall invoke the GN6-UNITDATA.indication primitive.

8.3 Frame format

The present document does not introduce new frame formats. Neither modifications to the IPv6 headers defined in IETF RFC 8200 [7], IETF RFC 4291 [8], IETF RFC 4007 [9], IETF RFC 4861 [10] and IETF RFC 4862 [12] are introduced, nor changes to the format of the GeoNetworking header as defined in ETSI TS 103 836-4-1 [6] are made. The structure of GeoNetworking header transporting an IPv6 header and its payload is derived:

- a) as depicted in figure 5, by appending the IPv6 header and its payload to the GeoNetworking header if GeoNetworking security is not used; or
- b) as depicted in figure 6, by including the IPv6 header and its payload in the secured packet field if GeoNetworking security is used.

The format of the GeoNetworking headers and the GeoNetworking security mechanisms are defined in ETSI TS 103 836-4-1 [6].

MAC Header	LLC Header	GeoNetworking Header	IPv6 Header	IPv6 Payload (Optional)
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Figure 5: Generic packet format of an IPv6 header and payload transported by the GeoNetworking protocol (without security)

MAC Header	LLC Header	GeoNetworking Basic Header	Secured Packet with GeoNetworking Common Header, Extended Header, IPv6 Header and Optional IPv6 Payload
------------	------------	----------------------------	---

Figure 6: Generic packet format of an IPv6 header and payload transported by the GeoNetworking protocol (with security)

EXAMPLE 1: As shown in figure 7, the IPv6 Payload field depicted in figures 5 and 6 can consist of IPv6 extension headers, followed by a transport header and the transport protocol payload.

IPv6 Extension Header(s)	Transport Header (UDP, TCP, other transport protocols)	Transport Payload
--------------------------	--	-------------------

Figure 7: Generic packet format of an IPv6 header and payload transported by the GeoNetworking protocol

EXAMPLE 2: As shown in figure 8, in the case of IPv6-in-IPv6 tunnelling, the IPv6 Payload field depicted in figures 5 and 6 can consist of an inner IPv6 header followed by inner extension headers, transport header and transport protocol payload.

IPv6 Inner Header	IPv6 Inner Extension Header(s)	Transport Header (UDP, TCP, other transport protocols)	Transport Payload
-------------------	--------------------------------	--	-------------------

Figure 8: Generic packet format of an IPv6 header and payload transported by GeoNetworking

9 IPv6 multicast and anycast support

9.1 Overview

This clause describes how standard IPv6 multicast addressing is supported over the GeoNetworking protocol. Standard IPv6 multicast addressing refers to non-geographic IPv6 multicast addressing, i.e. multicast addresses that are created according to IPv6 specifications and that do not embed any sort of specification of a geographical area. Geographic IPv6 multicast, instead, is an experimental type of IPv6 multicast addressing where IPv6 addresses contain an encoding of geographical areas. Geographic IPv6 multicast support is affected by drawbacks and is therefore considered experimental and described in annex D for informative purposes.

Unlike geographic IPv6 multicast described in annex D, the mechanisms specified in clause 9.2.3 allow for geocasting of IPv6 multicast traffic by hiding the geographic addressing from IPv6. Consequently, these mechanisms can be easily deployed as they do not require changes to existing IPv6 protocol implementations.

9.2 IPv6 multicast support

9.2.1 IPv6 link-local multicast

IPv6 link-local multicast traffic may be transmitted via the GN6ASL on GVLs or TVL.

An IPv6 packet with a link-local multicast destination address being transmitted via a GVL shall be transmitted by the GeoNetworking protocol using a GEOBROADCAST header as defined in ETSI TS 103 836-4-1 [6]. The fields describing the destination area of the GEOBROADCAST header shall be set to the values of the equivalent fields of GVL Area of the outgoing GVL.

NOTE: GeoNetworking (see ETSI TS 103 836-4-1 [6]) GEOBROADCAST headers do not contain a destination GN_Addr by design. This implies that the group ID of an IPv6 multicast address is not encapsulated into a sub-IP layer address that is actually transmitted (link-layer headers of virtual interfaces are removed before sending, see note 2 in clause 8.2.1). Consequently, all IPv6 multicast/anycast traffic will be received by every GeoAdhoc router attached to the GVL and the IPv6 layer will filter out incoming IPv6 multicast packets whose target groups it has not joined.

EXAMPLE: In an example implementation using virtual interfaces of type Ethernet V2.0/IEEE 802.3 LAN, an outgoing IPv6 packet with a IPv6 link-local multicast destination can be recognized by the GN6ASL implementation from the first 2 bytes of the destination MAC address that are set to 0x3333 according to IETF RFC 2464 [15].

An IPv6 packet with a link-local multicast destination address being transmitted via the TVL shall be transmitted by the GeoNetworking protocol using a TSB header specified in ETSI EN 103 836-4-1 [6].

The behaviour described above shall apply to any outgoing IPv6 packets with IPv6 link-local multicast addresses, including pre-defined, permanently and non-permanently assigned addresses.

The IPv6 layer of an ITS station implementing the present document should support the MLDv2 protocol specified in IETF RFC 3810 [17] for group membership management. Based on the distribution of IPv6 link-local multicast traffic described above, distribution of MLDv2 signalling messages is fully supported. However, bandwidth-sensitive and highly-mobile technology-specific deployments may be required to limit or even completely disable any IPv6 multicast group membership management.

9.2.2 IPv6 wider-scope multicast

IPv6 multicast traffic with scope wider than link-local shall be transmitted over the GeoNetworking protocol only on GVLs.

The GN6ASL specified in the present document is affected by the transmission of wider-scope IPv6 multicast traffic only with regard to the multicasting of this traffic on a GVL. In fact, the IPv6 protocol layer above the GN6ASL deals with forwarding of IPv6 multicast traffic. Should the IPv6 layer determine that this traffic is to be distributed to GVL on-link nodes (e.g. by one access router of the GVL), the GN6ASL shall utilize the same technique as for IPv6 link-local multicast traffic described in clause 9.2.1 for GVLs, i.e. the traffic shall be transmitted by the GeoNetworking protocol in a GEOBROADCAST header.

Standard IPv6 mechanisms for IPv6 multicast traffic forwarding as specified in IETF RFC 7761 [18] and IETF RFC 4605 [19] are expected to work properly on the virtual links provided by the GeoNetworking protocol. However, their usage is deployment-dependent and an ITS station implementing the present document may also not support these protocols. In particular, bandwidth-sensitive and highly-mobile technology-specific deployments may be required to limit or even completely disable any signalling caused by IPv6 multicast forwarding mechanisms.

9.2.3 Geocasting of IPv6 multicast traffic

Based on the properties of GVLs, it is possible to realize geocasting of IPv6 traffic without introducing new IPv6 multicast groups or address types. Both link-local and wider-scope multicast IPv6 traffic can be used. With the first, any GeoAdhoc router attached to a shared GVL can geocast IPv6 traffic by simply addressing the "all nodes on link" IPv6 pre-defined address FF02::1 specified in IETF RFC 4291 [8]. With the latter, wider-scope IPv6 multicast traffic originated by remote hosts can be distributed to all nodes on a GVL link, once it has reached a router attached to the GVL which supports multicast forwarding.

NOTE: According to clause 9.2.1 IPv6 multicast traffic sent through a GVL will be sent as GEOBROADCAST by the GeoNetworking protocol to all nodes attached to the GVL, generating an amount of load that depends on the size of the GVL Area.

EXAMPLE: A road-side ITS station providing access to a wider IPv6 network can be associated with a geographical area by enabling at least one GVL and administratively setting its GVL Area. The road-side ITS station is then capable of geocasting IPv6 traffic to the associated area. The IPv6 traffic could be generated by the road-side ITS station itself or by a remote node located in the Internet. In the latter case, several techniques are available to convey the data traffic from the remote host to the road-side ITS station. For instance, global-scoped unicast-prefix-based IPv6 multicast addresses specified in IETF RFC 3306 [20] can be used to address all ITS stations in the subnet identified by the network prefix of the unicast subnet owning the multicast address, e.g. all GeoAdhoc routers on the GVL. The network prefix is uniquely assigned to the GVL and is the only information that a source node located in the Internet is required to know, i.e. the GVL is opaque to nodes in the Internet. Alternatively, wider-scope multicast into unicast encapsulation can be used. Another alternative is the usage of application-level protocols to instruct a road-side ITS station to issue link-local multicast traffic.

9.3 IPv6 anycast support

IPv6 anycast traffic addressed to IPv6 addresses different than the IPv6 reserved subnet anycast address specified in IETF RFC 2526 [25] containing the anycast identifier `itsGn6aslGeoAnycastID` cannot be distinguished from IPv6 unicast traffic. Therefore the same procedures described in clause 8.2 for IPv6 unicast traffic shall apply.

9.4 Geographic IPv6 anycast support

The present document introduces the usage of an IPv6 reserved subnet anycast address specified in IETF RFC 2526 [25] for geographic IPv6 anycast support. This IPv6 reserved subnet anycast address is characterized by the anycast identifier to be assigned by IANA here referred to as `itsGn6aslGeoAnycastID`.

IPv6 anycast traffic addressed to the IPv6 reserved subnet anycast address specified in IETF RFC 2526 [25] containing the anycast identifier `itsGn6aslGeoAnycastID` shall be transmitted via the GN6ASL only on GVLs. An outgoing IPv6 packet with such anycast destination address shall be transmitted by the GeoNetworking protocol using a GEOANYCAST header. The fields describing the destination area of the GEOANYCAST header shall be set to the values of the equivalent fields of GVL Area of the outgoing GVL.

IPv6 ND procedures for IPv6 anycast traffic addressed to the IPv6 reserved subnet anycast address specified in IETF RFC 2526 [25] containing the anycast identifier `itsGn6aslGeoAnycastID` shall be omitted.

10 IPv6 neighbor discovery support

10.1 On-link determination

The IPv6 on-link determination is defined in IETF RFC 4861 [10] and updated in IETF RFC 5942 [11]. IPv6 determines a prefix to be on-link if it is included in the Prefix List specified in IETF RFC 4861 [10] for that link. A prefix is added to the Prefix List upon the receipt of a valid Router Advertisement (RA) that specifies a prefix with the L-bit set or via manual configuration. ITS stations compliant to the present document shall always set the L-bit when sending Router Advertisements.

IPv6 determines an address to be on-link if it is covered by one of the link's prefixes or if a neighbouring router specifies the address as the target of a Redirect message (as stated in the last two bullets of section 2.1 in IETF RFC 4861 [10], but deprecated by IETF RFC 6775 [i.14]). The same policy shall apply for SGVLs. Since DGVL and TVL are only assigned link-local addresses and the link-local prefix is effectively considered a permanent entry on the Prefix List specified in IETF RFC 4861 [10], no on-link determination is necessary for DGVL and TVL.

10.2 Address configuration

10.2.1 Stateless address autoconfiguration

IPv6 SLAAC as specified in IETF RFC 4862 [12] shall be supported by ITS stations compliant to the present document. The IPv6 router issuing Router Advertisements is typically the access router defined in ETSI TS 103 836-3 [4]. In a typical scenario, this access router is part of the road-side ITS station and allows vehicle ITS stations to automatically configure their addresses.

IPv6 SLAAC may only be used on SGVLs.

IPv6 routers issuing Router Advertisements shall always set the L-bit and the A-bit of the Prefix Information option. The same prefix should not be advertised in a Prefix Information option with the L-bit set on different SGVLs by one or more IPv6 routers. If a Source Link-layer Address option is appended to the Router Advertisement, it shall contain the link-layer address of the virtual interface associated to the SGVL on which the Router Advertisement is being sent.

NOTE: The recommendation to not advertise the same prefix on different GVLs is introduced in order to avoid that an ITS station considers a prefix to be on-link on multiple GVLs, which affects the inbound GVL selection (see clause 8.2.2).

An IPv6 router issuing Router Advertisements shall have permanently configured values of the GVL Area for each SGVL for which it is acting as a router.

Upon the reception of a Router Advertisement, GN6ASL shall create (if it does not exist yet) a new SGVL and assign a GVL Area equal to the destination area specified in the GEOBROADCAST header. The destination area specified in the GEOBROADCAST header is passed to the GN6ASL via the GN-DATA.indication primitive of the GN_SAP specified in ETSI TS 103 836-4-1 [6], as part of the destination address primitive parameter.

The GVL Area of a SGVL created as a consequence of the receipt of a Router Advertisement may not be modified. The GVL shall be destroyed whenever the invalidation timer expires for all of the Prefix List entries associated to that GVL (see IETF RFC 4861 [10]).

Both solicited and unsolicited Router Advertisements shall be supported. However, since no SGVL exists before receiving a Router Advertisement, Router Solicitations are only sent after an ITS station has already received one or more Router Advertisements.

Sending of Router Advertisements via IPv6 unicast shall be disabled. This restriction is introduced because unicast traffic does not carry a geographical destination area and therefore the receiving GN6ASL could not assign the GVL Area.

The IPv6 router parameters included in Router Advertisement carrying Prefix Information options (Router Lifetime, Reachable Time, Retrans Timer, prefix Valid Lifetime and Preferred Lifetime) shall be deployment-specific. In particular, these parameters become critical in bandwidth-sensitive and highly-mobile deployments (such as those envisaged for ETSI EN 303 797 [1]). Careful parameter tuning based on field trial results should be adopted.

For any aspect of SLAAC not mentioned in this clause, the standard mechanisms specified in IETF RFC 4862 [12] shall be used.

10.2.2 Stateful address configuration

IPv6 stateful address configuration should not be used in deployments of the present specification because of the higher latency due to the several round-trip signalling messages and the higher administrative effort required for the management of IPv6 routers.

10.2.3 Manual address configuration

In operational deployments, IPv6 addresses shall not be manually added to any virtual interface. Manually configured addresses shall only be used with administratively configured SGVLs on road-side ITS stations.

NOTE: The usage of manually configured addresses might decrease the effectiveness of pseudonym change schemes, as pointed out in clause G.2, and is therefore not recommended.

In experimental deployments and test environments, IPv6 addresses might be manually configured.

10.3 Address resolution

10.3.1 Non-ND-based address resolution

According to IPv6 ND as outlined in IETF RFC 4861 [10], address resolution is performed only on non-multicast addresses that are determined to be on-link and for which the sender does not know the corresponding link-layer address. In the case of transmission of IPv6 packets via the GN6ASL, whenever the IPv6 address of the IPv6 next hop contains an IID that resolves directly to a corresponding GN_Addr and the MIB attribute `itsGn6aslVIResolAddr` is true, for the purpose of saving wireless resources address resolution shall be omitted and the procedure described in this clause shall be adopted.

NOTE 1: Omitting address resolution when the destination link-layer address is known to the sender is not in conflict with any IPv6 specification (see IETF RFC 4861 [10], clause 7.2). It should also be noted that the IPv6 implementations supporting IETF RFC 3549 [i.8] already omit address resolution whenever an IPv6 interface has the flag `IFF_NOARP` as defined in IETF RFC 3549 [i.8] set. The MIB attribute `itsGn6aslVIResolAddr` has the same meaning as `IFF_NOARP` specified in IETF RFC 3549 [i.8].

EXAMPLE: An example of IPv6 usage with direct mapping between the IPv6 address IID and the link-layer address, in which address resolution based on IETF RFC 4861 [10] is omitted, can be found in IETF RFC 6775 [i.14].

If the MIB attribute `itsGn6aslVIResolAddr` is true, upon a `GN6-UNITDATA.request` call the GN6ASL shall ignore the destination parameter of the `GN6-UNITDATA.request` primitive and shall inspect the destination IPv6 address contained in the IPv6 header. If this is not a multicast address, GN6ASL shall first perform the IPv6 next hop determination.

NOTE 2: In order to perform the IPv6 next hop determination, GN6ASL needs read access to the IPv6 Routing and Forwarding Information Bases. These are accessible via the IPv6 MIB.

Next, if the IPv6 address of the IPv6 next hop contains an IID that is a 64-bit Global Identifier (EUI-64) [31], the GN6ASL shall derive the `GN_Addr` from the IID. The mechanism to derive the `GN_Addr` from the IID depends on the virtual interface type. The present document only defines it for virtual interfaces of type Ethernet V2.0/IEEE 802.3 LAN in clause 5.3.2.1.

If the MIB attribute `itsGn6aslVIResolAddr` is false, the GN6ASL shall not perform any address resolution and shall adopt as destination `GN_Addr` a value uniquely derived from the destination address parameter of the `GN6-UNITDATA.request` primitive, which may be for example a MAC address of a type that depends on the virtual interface type. If `itsGn6aslVIResolAddr` is false, IPv6 shall use the ND-based address resolution procedure specified in clause 10.3.2 to determine the destination address parameter of the `GN6-UNITDATA.request` primitive.

NOTE 3: When the MIB attribute `itsGn6aslVIResolAddr` is false, any other mechanism compliant with IPv6 can be adopted for the purpose of avoiding unnecessary IPv6 ND signalling for address resolution (i.e. when the GeoNetworking address is known by the sender). For example, the ITS station management entity can proactively populate the IPv6 Neighbor Cache based on any traffic transported by GeoNetworking protocol, e.g. based on Facilities layer protocols. A proactive population of the IPv6 Neighbor Cache will let IPv6 find the corresponding GeoNetworking address for destination addresses associated to neighbouring nodes and prevents IPv6 from using ND-based address resolution.

10.3.2 ND-based address resolution

An ITS station compliant with the present document should use IPv6 addresses containing IIDs that directly resolve to `GN_Addr`, such that non-ND-based address resolution described in clause 10.3.1 can be applied. When this is not possible, an implementation of the present document may adopt ND-based address resolution only on virtual interfaces associated with SGVLs. IPv6 addresses with IID that do not directly resolve to `GN_Addr` may also be used on virtual interfaces associated with SGVLs.

ND-based address resolution shall be compliant to IETF RFC 4861 [10]. Careful tuning of ND protocol constants listed in clause 10.5 based on field tests should be adopted in order to limit the resources consumed by ND-based address resolution in highly-dynamic and resource-sensitive deployments.

ND-based address resolution is only supported by SGVLs.

10.4 Neighbor unreachability detection

When IPv6 packets are transmitted over the GeoNetworking protocol via the GN6ASL, the IPv6 next hop may be several physical hops away from the source. In some deployments, e.g. where the connectivity is intermittent and available for short time intervals, frequent execution of the NUD procedure as specified in IETF RFC 4861 [10] is not desirable. For this reason this clause introduces some specific NUD behaviour for IPv6 over GeoNetworking.

In accordance with IETF RFC 4861 [10], clause 7.3.3, implementations of the present document shall not have an explicit timeout event associated with the expiration of `ReachableTime`.

Successful bi-directional exchange of GeoNetworking packets, even if not carrying IPv6 packets, shall be used as reachability confirmation.

When a GeoAdhoc router leaves the GVL Area associated to a GVL, Neighbor Cache entries corresponding to nodes on that GVL shall be purged. This behaviour is compliant with IETF RFC 4861 [10], clause 7.3.3, where link-specific information may indicate that a path to a neighbour has failed.

According to IETF RFC 4861 [10], the receipt of an unsolicited Router Advertisement may not be considered as a reachability confirmation since it does not guarantee that bi-directional connectivity exists. Therefore, upon the receipt of an unsolicited Router Advertisement, an IPv6 node sets the corresponding Neighbor Cache entry state to STALE. In deployment-specific implementations of the present document, performing NS/NA to ensure that a router is bi-directionally reachable after the receipt of an unsolicited RA is superfluous and may be omitted.

10.5 Protocol constants

IPv6 ND protocol constants are listed in IETF RFC 4861 [10], clause 10. Implementations of the present document may utilize different values of these parameters in a technology- and scenario-specific way. System specifications for the implementation of the present document shall provide such values.

NOTE: It is recommended that values of these protocol constants are selected based on field test results. Particular care should be taken for the parameters: RTR_SOLICITATION_INTERVAL, MAX_RTR_SOLICITATIONS, MAX_MULTICAST_SOLICIT, MAX_UNICAST_SOLICIT, REACHABLE_TIME.

11 Support for pseudonym change

11.1 Rationale

Location privacy concerns may arise due to the GVLs' binding between geographical areas and IPv6 prefixes. This means that a node, whose IID suffix is statically and permanently configured, could be geographically tracked by an attacker located in the Internet that gets to know the binding for a set of areas/IPv6 prefixes.

These attacks can be strongly limited by adopting temporary pseudonyms instead of constant identifiers. With respect to GeoNetworking, a pseudonym is in the form of a GN_Addr specified in ETSI TS 103 836-4-1 [6], which can be modified by means of the GN-MGMT primitives of the GeoNetworking protocol specified in ETSI TS 103 836-4-1 [6].

Whenever the GN_Addr changes, it is necessary that all IPv6 addresses derived from it change accordingly. This is required to allow for the address resolution mechanisms described in clause 10.3.2. Further, this is required in order to prevent attackers from linking consecutive pseudonyms by means of IPv6 addresses.

A change in the MAC address implies a change in the IPv6 address associated to a virtual interface. Consequently, sessions opened with the previous IPv6 address are interrupted. If NEMO BS is supported by the ITS station, the new IPv6 address can be registered by updating the binding at the Home Agent. This allows sessions to not be interrupted, as they are created using IPv6 addresses belonging to the Mobile Network Prefix, which does not change upon a GN_Addr change. However, NEMO BS needs to be notified about the IPv6 address change in an implementation-specific way.

NOTE: A management primitive for notifying the GN6ASL of a GN_Addr change is not introduced by design. Such interface would increase the level of complexity, since synchronization between the GN_Addr stored in the GeoNetworking protocol implementation and the GN_Addr stored in the GN6ASL implementation is required. Since the GeoNetworking protocol and the GN6ASL are expected to be coupled in an implementation, it is assumed that implementation-specific notification mechanisms are more appropriate than a management primitive.

Recommendations for the implementation of privacy protection measures that go beyond the scope of the present document are provided in clause G.2.

11.2 Required operations

In an implementation-specific way, the GN6ASL shall be notified every time the GN_Addr in use by the GeoNetworking protocol entity changes. Upon such a notification, the GN6ASL shall immediately modify the MAC address of each virtual interface.

If NEMO BS is supported by the ITS station implementing the GN6ASL and a virtual interface associated to a GVL is used by the NEMO BS Mobile Router as the egress interface, the NEMO BS Mobile Router shall be notified upon the MAC address change of the egress interface in an implementation-specific way.

Annex A (normative): ASN.1 encoding of the GN6ASL MIB

A.1 Modules

A.1.1 ITSGN6ASL-MIB

This ASN.1 module adopts textual conventions defined separately and imported as modules. Objects defined using textual conventions are always encoded by means of the rules that define their primitive type.

The present document does not amend any modification to the IPv6 MIB specified in IETF RFC 4293 [24]. The adapted subsets of ASN.1 notation described in IETF RFC 2578 [i.11] (SNMPv2-SMI) and IETF RFC 2579 [i.12] (SNMPv2-TC) are imported.

```
-- *****
-- * ETSI TC ITS TS 103 836-6-1 IPv6 over GeoNetworking Release 2 MIB
-- *****

ITSGN6ASL-MIB DEFINITIONS ::= BEGIN

IMPORTS
    MODULE-IDENTITY, OBJECT-TYPE, NOTIFICATION-TYPE,
    Unsigned32, Integer32, enterprises
        FROM SNMPv2-SMI
    Utf8String
        FROM SYSAPPL-MIB
    TEXTUAL-CONVENTION, TruthValue
        FROM SNMPv2-TC
    Ipv6IfIndex
        FROM IPV6-TC
    InterfaceIndex
        FROM IF-MIB
    itsGnIfIndex
        FROM ITSGN-MIB;

-- *****
-- * MODULE IDENTITY
-- *****

-- prefix for types: ItsGn6asl
itsGn6asl MODULE-IDENTITY
    LAST-UPDATED "201405190000Z"
    ORGANIZATION "ETSI Technical Committee ITS WG3"
    CONTACT-INFO "Email: info@ETSI.ORG"
    DESCRIPTION
        "The MIB module for TS 103 836-6-1 (IPv6 over GeoNetworking Release 2) entities
        itu-t(0).identified-organization(4).etsi(0).itsgn(263661)"
    ::= { enterprises 13019 26366 }

-- *****
-- * PRIMARY GROUPS
-- *****

itsGn6aslObjects      OBJECT IDENTIFIER ::= { itsGn6asl 1 }
itsGn6aslStatistics  OBJECT IDENTIFIER ::= { itsGn6asl 2 }
itsGn6aslConformance OBJECT IDENTIFIER ::= { itsGn6asl 3 }

-- *****
-- * SUB GROUPS
-- *****

itsGn6aslMgmt         OBJECT IDENTIFIER ::= { itsGn6aslObjects 1 }

-- *****
-- * SUB SUB GROUPS
-- *****

itsGn6aslSystem      OBJECT IDENTIFIER ::= { itsGn6aslMgmt 1 }
itsGn6aslConfig      OBJECT IDENTIFIER ::= { itsGn6aslMgmt 2 }
```

```

-- *****
-- * TEXTUAL CONVENTIONS
-- *****

-- Unsigned16 currently does not exist in SNMPv2-SMI
Unsigned16TC ::= TEXTUAL-CONVENTION
    STATUS      current
    DESCRIPTION
        "An Unsigned32 further restricted to 16 Bits. Note that
         the ASN.1 BER encoding may still require 24 Bits for
         some values."
    SYNTAX      Unsigned32 (0..65535)

-- Unsigned12 currently does not exist in SNMPv2-SMI
Unsigned12TC ::= TEXTUAL-CONVENTION
    STATUS      current
    DESCRIPTION
        "An Unsigned32 further restricted to 12 Bits. Note that
         the ASN.1 BER encoding may still require 24 Bits for
         some values."
    SYNTAX      Unsigned32 (0..4095)

-- Unsigned7 currently does not exist in SNMPv2-SMI
Unsigned7TC ::= TEXTUAL-CONVENTION
    STATUS      current
    DESCRIPTION
        "An Unsigned32 further restricted to 7 Bits. Note that
         the ASN.1 BER encoding may still require 24 Bits for
         some values."
    SYNTAX      Unsigned32 (0..127)

-- *****
-- * GN6ASL OBJECTS GROUP
-- *****

-- *****
-- * GN6ASL SYSTEM GROUP
-- *****

-- Virtual Links table
itsGn6aslVlTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF ItsGn6aslVlEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "GN6ASL Virtual Links Table."
    ::= { itsGn6aslSystem 1 }

-- Virtual Links table entry
itsGn6aslVlEntry OBJECT-TYPE
    SYNTAX      ItsGn6aslVlEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "An entry in the GN6ASL Virtual Links Table."
    INDEX      { itsGnIfIndex,
                 itsGn6aslVlIndex }
    ::= { itsGn6aslVlTable 1 }

ItsGn6aslVlEntry ::= SEQUENCE {
    itsGn6aslVlType          INTEGER,
    itsGn6aslGvlAreaCenterLatitude  Integer32,
    itsGn6aslGvlAreaCenterLongitude  Integer32,
    itsGn6aslGvlAreaDistA      Unsigned16TC,
    itsGn6aslGvlAreaDistB      Unsigned16TC,
    itsGn6aslGvlAreaAngle      Unsigned16TC,
    itsGn6aslVlIndex           Unsigned12TC,
    itsGn6aslVlIndex           Ipv6IfIndex,
    itsGn6aslVlGnIfIndex       InterfaceIndex
}

-- Fields of a Virtual Links table entry
itsGn6aslVlType OBJECT-TYPE
    SYNTAX      INTEGER {
        sgv1(1),
        dgv1(2),

```

```

        tvl(3)
    }
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
    "Indicates the type of the virtual link."
    ::= { itsGn6aslVLEntry 1 }

itsGn6aslGvlAreaCenterLatitude OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
    "The latitude of the center of the GVL Area."
    ::= { itsGn6aslVLEntry 2 }

itsGn6aslGvlAreaCenterLongitude OBJECT-TYPE
    SYNTAX Integer32
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
    "The longitude of the center of the GVL Area."
    ::= { itsGn6aslVLEntry 3 }

itsGn6aslGvlAreaDistA OBJECT-TYPE
    SYNTAX Unsigned16TC
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
    " The distance A that describes the GVL Area."
    ::= { itsGn6aslVLEntry 4 }

itsGn6aslGvlAreaDistB OBJECT-TYPE
    SYNTAX Unsigned16TC
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
    " The distance B that describes the GVL Area."
    ::= { itsGn6aslVLEntry 5 }

itsGn6aslGvlAreaAngle OBJECT-TYPE
    SYNTAX Unsigned16TC
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
    " The angle that describes the GVL Area."
    ::= { itsGn6aslVLEntry 6 }

itsGn6aslVLIndex OBJECT-TYPE
    SYNTAX Unsigned12TC
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
    "The index of the virtual link for a given GeoNetworking
    interface."
    ::= { itsGn6aslVLEntry 7 }

itsGn6aslVIIndex OBJECT-TYPE
    SYNTAX Ipv6IfIndex
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
    " The index of the IPv6 interface associated to the VL.
    This index is used to bind a virtual link with a virtual
    interface and e.g. to retrieve the Prefix List."
    ::= { itsGn6aslVLEntry 8 }

itsGn6aslVLGnIfIndex OBJECT-TYPE
    SYNTAX InterfaceIndex
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
    " The itsGnIfIndex of the GeoNetworking
    interface associated to the VL."
    ::= { itsGn6aslVLEntry 9 }

-- *****

```



```
-- * GN6ASL CONFIGURATION GROUP
-- *****

itsGn6aslVIResolAddr OBJECT-TYPE
    SYNTAX      TruthValue
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Indicates whether the GN6ASL shall resolve the
        destination link-layer address from the IPv6 address.
        If true, IPv6 shall not perform address resolution.
        If false, IPv6 shall perform address resolution."
    DEFVAL     { true }
    ::= { itsGn6aslConfig 1 }

itsGn6aslGeoAnycastID OBJECT-TYPE
    SYNTAX      Unsigned7TC
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "Anycast identifier for ETSI GeoAnycast
        Reserved IPv6 Subnet Anycast Address."
    ::= { itsGn6aslConfig 2 }

itsGn6aslVLIIndexMax OBJECT-TYPE
    SYNTAX      Unsigned12TC
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "Maximum virtual link index.
        Equivalent to the the maximum number of
        virtual links simultaneously active - 1"
    ::= { itsGn6aslConfig 3 }

itsgn6aslENversion OBJECT-TYPE
    SYNTAX      Utf8String
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "The version of the TS."
    DEFVAL     { "TS2.1.1" }
    ::= { itsGn6aslConfig 4 }

END
```

Annex B (normative): MIB attributes

B.1 ITSGN6ASL-MIB attributes values

Table B.1 specifies default values of MIB attributes values that shall be supported by ITS stations compliant with the present document.

Table B.1: GN6ASL MIB attributes

MIB attribute	Default / initial value	Remark
itsgn6asLENversion	EN1.2.1	Version of the present document.
itsGn6asIVIResolAddr	true	Indicates whether the GN6ASL shall resolve the destination link-layer address from the IPv6 address. If true, IPv6 shall not perform address. If false, IPv6 shall perform address resolution.
itsGn6asGeoAnycastID	125 (decimal) 0x7D (hexadecimal)	IPv6 over GeoNetworking geographic anycast, see [i.24]
itsGn6asIVLIndexMax	31	Maximum virtual interface index per ItsGnIfEntry. The maximum number of simultaneously enabled virtual links is itsGn6asIVLIndexMax + 1.

Annex C (informative): IPv6/GeoNetworking data SAP

C.1 Basic data SAP (GN6_SAP)

C.1.1 Overview

The services provided by the GN6ASL to IPv6 represent the GN6_SAP data service access point. In order to maintain backward compatibility with legacy IPv6 protocol implementations, GN6_SAP corresponds to the unacknowledged connectionless-mode data transfer service SAP provided by IEEE 802.2 [26].

C.1.2 Service primitives

C.1.2.1 GN6-UNITDATA.request

C.1.2.1.1 Semantics

The parameters of the primitive are as follows:

```
GN6-UNITDATA.request(
    destination address,
    source address,
    gn6sdu,
    priority
)
```

The field destination address may be either an individual or a group address. When it is an individual address, it should provide enough information to uniquely generate a GeoNetwork address as specified in ETSI TS 103 836-4-1 [6]. For example, source and destination address may contain MAC addresses whose type corresponds to the implementation-specific type of the virtual interfaces in use (see clause 5.3). The source address may be omitted and in that case it will be inserted by the media-independent GeoNetworking protocol entity.

The gn6sdu parameter specifies the GN6 service data unit to be sent, which contains the IPv6 header followed by its payload.

The priority parameter specifies the priority desired for the data unit transfer (similarly to ISO/IEC 8802-2:1998 [26]). Permitted values are between 0 and 255.

C.1.2.1.2 When generated

This primitive is passed from IPv6 to the GN6ASL to request that a GN6 SDU be sent to one or more GeoAdhoc routers.

C.1.2.1.3 Effect on receipt

Receipt of this primitive causes the GN6ASL to attempt to send the GN6 SDU by undertaking the operations described in clause 8.2.1.

C.1.2.2 GN6-UNITDATA.indication

C.1.2.2.1 Semantics

The parameters of the primitive are as follows:

```
GN6-UNITDATA.indication(  
    destination address,  
    source address,  
    gn6sdu  
)
```

The destination address parameter may be either an individual or a group address. The source address parameter is an individual address that provides enough information to uniquely generate a GeoNetwork address as specified in ETSI TS 103 836-4-1 [6]. For example, source and destination address may contain MAC addresses whose type corresponds to the implementation-specific type of the virtual interfaces in use (see clause 5.3).

The gn6sdu parameter specifies the GN6 service data unit which contains the IPv6 header followed by its payload as received by the GN6ASL.

C.1.2.2.2 When generated

This primitive passed from the GN6ASL to the IPv6 layer to indicate the arrival of a GeoNetworking packet carrying an IPv6 header frame to the local GeoNetworking protocol entity.

C.1.2.2.3 Effect on receipt

The effect on receipt of this primitive by IPv6 is unspecified.

C.2 Experimental extended data SAP (EGN6_SAP)

C.2.1 Overview

This clause defines the EGN6_SAP extended SAP as studied and specified by the European GeoNet project in GeoNet D2.2 ([i.21]), which introduced it as the C2C-IP SAP. EGN6_SAP allows an extended IPv6 protocol layer implementation to specify geographical information to be used by the GeoNetworking protocol. This extended SAP is necessary in order to support any of the experimental techniques for geographical IPv6 multicast support described in annex D. More details can be found in GeoNet D2.2 [i.21].

C.2.2 Service primitives

C.2.2.1 EGN6-UNITDATA.request

C.2.2.1.1 Semantics

The parameters of the primitive are as follows:

```
EGN6-UNITDATA.request(  
    destination,  
    source address,  
    scope,  
    gn6sdu,  
    priority  
)
```

The destination parameter may contain either a destination address as in the GN6-UNITDATA.request primitive or a fully specified geographical area in the format specified by ETSI EN 302 931 [5]. The source address may be omitted and in that case it will be inserted by the media-independent GeoNetworking protocol entity.

The scope parameter contains one of the following values: GEOUNICAST, TSB, GEOBROADCAST, GEOANYCAST.

The gn6sdu parameter specifies the GN6 service data unit which contains the IPv6 header followed by its payload as received by the GN6ASL.

C.2.2.1.2 When generated

This primitive is passed from IPv6 to the GN6ASL to request that a GN6 SDU be sent to one or more GeoAdhoc routers.

C.2.2.1.3 Effect on receipt

Receipt of this primitive causes the GN6ASL to attempt to send the GN6 SDU by undertaking the operations described in clause 8.2.1, with the amendments specified here.

Instead of the steps described in the step 3) of clause 8.2.1, the GN6ASL should set the Packet transport type of the GN-Data.request primitive to the value of the scope parameter received with EGN6-UNITDATA.request.

If the primitive is called for a DGVL and the scope parameter is equal to GEOBROADCAST and the destination parameter contains a fully specified geographical area in the format specified by ETSI EN 302 931 [5], the DGVL is expected to use the geographical area specified by the destination parameter as the GVL Area for the packet being transmitted.

C.2.2.2 EGN6-UNITDATA.indication

C.2.2.2.1 Semantics

The parameters of the primitive are as follows:

```
EGN6-UNITDATA.indication(  
    destination,  
    source address,  
    gn6sdu  
)
```

The destination address parameter may be either an individual or a group address. It may contain either a destination address as in the GN6-UNITDATA.request primitive or a GVL Area. The source address parameter is an individual address that provides enough information to uniquely generate a GeoNetwork address as specified in ETSI TS 103 836-4-1 [6].

The gn6sdu parameter specifies the GN6 service data unit which contains the IPv6 header followed by its payload as received by the GN6ASL.

C.2.2.2.2 When generated

This primitive passed from the GN6ASL to the IPv6 layer to indicate the arrival of a GeoNetworking packet carrying an IPv6 header frame to the local GeoNetworking protocol entity.

C.2.2.2.3 Effect on receipt

The effect on receipt of this primitive by IPv6 is unspecified.

Annex D (informative): Geographic IPv6 multicast support (experimental)

D.1 Overview

This annex describes experimental addressing schemes, studied and specified by the European GeoNet project in GeoNet D2.2 [i.21], that aim at providing IPv6 applications with ways to specify target geographical areas as IPv6 group destination addresses. For example, this allows IPv6 hosts connected to an ITS station including a GeoAdhoc router to specify a desired geographical area as the target of IPv6 multicast traffic. It should be noted that achieving this functionality by making IPv6 geo-aware is outside the scope of the present document. However, the techniques studied by GeoNet for this specific purpose are overviewed in this annex as subject of further research and to facilitate further discussions.

The mechanisms specified in this annex have drawbacks which make them not suitable for immediate deployment. The recommended technique for the geographic distribution of IPv6 packets is described in clause 9.2.3.

The techniques described in this clause were studied and specified by the European GeoNet project. More information can be found in annex H GeoNet D2.2 [i.21].

The techniques described in this clause require IPv6 to pass information regarding geographical areas to the GN6ASL. This is accomplished by the experimental EGN6_SAP specified in clause C.2.

D.2 Pre-defined geographical IPv6 multicast groups

The GeoNet project implemented a simplified solution to allow the IPv6 layer to specify a target area as part of the IPv6 destination address. This solution consists of a pre-defined static table embedded in each ITS station running a GeoAdhoc router, containing the matching between pre-defined geographical areas and their corresponding multicast group IDs. Geographical areas are specified relatively to the GeoAdhoc router position, e.g. a 1 000 m range circle around the GeoAdhoc router.

Two main drawbacks affect this solution:

- 1) The IPv6 multicast groups corresponding to the pre-defined group IDs are moving targets due to the fact that the position is specified relatively to the GeoAdhoc router position. This implies that the characterizing aspect of the multicast group changes over time, which conflicts with the assumptions of IPv6 multicasting and multicast group management.
- 2) The management of the table matching group IDs and geographical areas introduces further complexity. GeoNet adopted a statically defined table which limits the capability of nodes to choose the area. Dynamic management of the table would still require homogeneity across nodes and would therefore increase complexity.

D.3 Other studied mechanisms

The GeoNet project studied alternative solutions to the one described in clause D.2, which are briefly recalled here. More information can be found in GeoNet D2.2 [i.21].

- a) IPv6-in-IPv6 tunnel with areas encoded in the outer header and multicast groups in the inner header. With this solution, IPv6 nodes do not subscribe to relatively defined multicast groups but only to absolutely defined group. Therefore, the IPv6 host originating the packets need to know the absolute destination position. The granularity of the position encoding in the IPv6 group ID is deemed as too coarse. Additional overhead is caused by the IPv6-in-IPv6 tunnel.

- b) Geographical area encoded in an IPv6 Hop-by-Hop option. This solution does not exploit IPv6 multicast group IDs as containers of the target group and therefore does not require IPv6 multicast group management. However, this solution introduces a new IPv6 option and therefore is not compatible with existing IPv6 protocol implementations.
- c) IPv6-in-IPv6 tunnel with areas encoded in an IPv6 Hop-by-Hop option of the outer header. In this solution, the outer header is removed when the packet is received by the GeoAdhoc router. This solution reduces the overhead but introduces a new IPv6 option and therefore is not compatible with existing IPv6 protocol implementations.
- d) Encoding of geographic information in group ID. In this solution, the destination area is encoded in the 112-bit IPv6 multicast group ID. If absolute positions are encoded, the limited space offers too coarse granularity. If relative positions are encoded, IPv6 multicast group membership management becomes ineffective.

Annex E (informative): Implementation examples

E.1 Virtual links and interfaces

Figure E.1 shows an implementation example of GVLs and TVL. In this example three virtual interfaces are presented to IPv6: veth0, veth1 and veth2 of type Ethernet V2.0/IEEE 802.3 LAN. Each of them is associated to a single virtual link. GVL1 and GVL2 are two distinct virtual links associated to two rectangular areas. For example, STA1 could be a road-side ITS station serving the two areas depicted in figure E.1. As another example, STA1 could be a vehicle ITS station at a geographical position that is included in both areas.

It is important to note that, from the perspective of IPv6, STA2/3/4 are neighbors reachable via veth0 and veth2 and STA5/6 are neighbors reachable via veth1 and veth2.

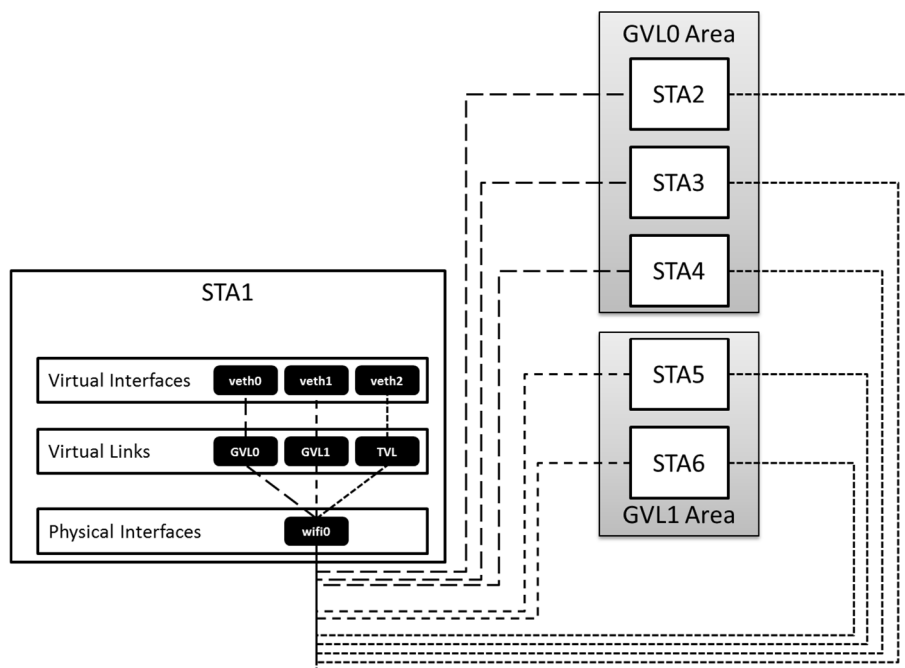


Figure E.1: Example usage of GVL, TVL and virtual interfaces

E.2 Packet delivery with Ethernet V2.0/IEEE 802.3 LAN virtual interfaces

E.2.0 Introduction

This clause describes the steps that should be undertaken by an implementation of the GN6ASL based on virtual interfaces of type Ethernet V2.0/IEEE 802.3 LAN.

Examples of virtual interfaces of type Ethernet V2.0/IEEE 802.3 LAN are TAP virtual devices which are supported by several operating systems (see [i.15]).

E.2.1 Outbound traffic

In a particular implementation using a virtual interface of type Ethernet V2.0/IEEE 802.3 LAN, the GN6-UNITDATA.request primitive used for outgoing traffic may consist of the IPv6 protocol implementation creating and passing down an Ethernet V2.0 frame already containing the resolved destination MAC address. This approach is followed e.g. in the Linux kernel.

The GN6ASL implementation relying for example on TAP devices could obtain the Ethernet V2.0 frame containing the IPv6 packet. The GN6ASL implementation should then proceed by stripping off the Ethernet V2.0 header and deriving a destination GN_Addr from the Ethernet destination MAC address in compliance with clause 8.2.1.

E.2.2 Inbound traffic

After selection of inbound virtual link and virtual interface uniquely assigned to it (clause 8.2.2), the GN6ASL implementation should deliver the IPv6 packet to the IPv6 protocol implementation via the virtual interface. For virtual interfaces of type Ethernet V2.0/IEEE 802.3 LAN, the GN6ASL implementation should generate an Ethernet V2.0 header. This header should contain:

- 1) an Ethernet source MAC address derived by copying the MID field of the source GN_Addr obtained from the implementation of the GN-DATA.indication primitive of the GN_SAP specified in ETSI TS 103 836-4-1 [6];
- 2) an Ethernet destination MAC address derived from the destination GN_Addr obtained from the implementation of the GN-DATA.indication primitive of the GN_SAP specified in ETSI TS 103 836-4-1 [6]. If the destination GN_Addr is a unicast address, the Ethernet destination MAC address should be derived by copying the MID field of the destination GN_Addr. If the destination GN_Addr is not a unicast address, the GN6ASL implementation should inspect the IPv6 destination address and derive an Ethernet destination MAC address according to IETF RFC 2464 [15];
- 3) an EtherType (Length/Type field as defined in IEEE 802.3:2008 [30], clause 3.2.6) equal to 0x86DD (IPv6).

E.3 GeoNet project implementations results

The European GeoNet project (see GeoNet D1.2 annex H [i.20] and GeoNet D2.2 [i.21]) specified and implemented several mechanisms described in the present document, including the experimental approach described in clause D.2. A detailed report of the implementation and experimentation results is provided in GeoNet D7.1 annex H [i.22].

Annex F (informative): Support for Network Mobility Basic Support

F.1 Overview

As pointed out in clause 1, extensions to NEMO BS specified in IETF RFC 3963 [13] are outside the scope of the present document. However, the present document aims at providing full compatibility with NEMO BS, including pre-existing implementations. This annex briefly presents how NEMO BS can be utilized with GN6ASL.

F.2 Mode of operation via GN6ASL

NEMO Basic Support specified in IETF RFC 3963 [13] can be used in conjunction with the GeoNetworking protocol and the GN6ASL in order to provide session continuity and global reachability at a constant network prefix (the Mobile Network Prefix) for an entire moving network.

In particular, NEMO BS can be used on virtual interfaces associated to SGVLs, since they provide link-local multicast support and SLAAC. Via a SGVL, a NEMO BS Mobile Router can establish an IPv6-in-IPv6-in-GeoNetworking tunnel. In this configuration, access to an infrastructure network is provided by an ITS station including a GeoAdhoc router and an access router (these functions may be collapsed into one or may also be separate, see clause 6.1). The GeoAdhoc router represents the end point of the IPv6-in-GeoNetworking tunnel or, in other terms, the "GeoNetworking next hop". The access router represents the "IPv6 next hop" and the NEMO BS Home Agent represents the end point of the IPv6-in-IPv6 tunnel.

Via SGVLs, a NEMO BS Mobile Router included in an ITS station receives IPv6 Router Advertisements and configures an address via SLAAC. Router Advertisements are the most commonly used mechanism for Movement Detection procedures in both NEMO BS and Mobile IPv6 (see IETF RFC 3753 [i.1]). In addition to the basic usage, SGVLs can also be used to deploy sophisticated Movement Detection procedures, e.g. including make-before-break approaches by utilizing slightly overlapping geographical areas associated to SGVLs and announced by road-side ITS stations.

More information about NEMO operation over the GeoNetworking protocol can also be found in annex H GeoNet D2.2 [i.21] and GeoNet D7.1 [i.22], including experimental results.

F.3 Sub-optimal routing issues

At the time of writing the present document, a standardized Route Optimization technique for NEMO BS has not been produced by the IETF. An ITS-specific effort (see NemoRORReqDraft [i.23]) to provide specific requirements for automotive deployments of NEMO BS has been initiated and still needs to be completed. The issues related to the sub-optimal routing caused by the lack of Route Optimization techniques in NEMO BS are described in NemoRORReqDraft [i.23]. Deployments of the present document would extremely benefit from a standardized Route Optimization technique which specifically addressed the ITS requirements described in NemoRORReqDraft [i.23].

Annex G (informative): Security and privacy considerations

G.1 Recommendations for security mechanisms

The GeoNetworking protocol defined in ETSI TS 103 836-4-1 [6] supports asymmetric cryptography-based authentication of packets by means of specifically designed and administered digital certificates. This mechanism also secures IPv6 over GeoNetworking traffic, including the Neighbor Discovery messages. Consequently, SEND as specified in IETF RFC 3971 [23] is not required.

A potential limitation of the applicability of SEND to the transmission of IPv6 over GeoNetworking is related to CGAs. Non-repudiation of messages requires the Certificate Authority to be able to match pseudonyms with real identity. This may limit the applicability of CGAs.

G.2 Recommendations for privacy-protecting deployment

The usage of temporary GeoNetworking identifiers (GN_Addr) with the GN6ASL is explained in clause 11. By using these pseudonyms with an appropriate changing scheme, location privacy threats are strongly limited. However, these countermeasures might become ineffective as soon as other identifiers are transmitted in clear text that do not vary over time and might enable attackers to link different pseudonyms to the user's identity.

Consequently, it is highly recommended to not utilize manually generated IPv6 addresses on the interfaces assigned to GVLs and TVLs. Only automatically generated addresses should be used, so that a change in the GN_Addr will be reflected in a change in the IPv6 address (see clause 11.2).

Without proper management of pseudonym change, observing IPv6 traffic might allow an attacker to link different pseudonyms of the same ITS station, despite the operations specified in clause 11.2. For example, traffic generated by an application unit and forwarded by a mobile router via GN6ASL would carry the application unit's IPv6 address which does not change. Proper management of pseudonym change operations taking into account ongoing IPv6 traffic and other situation-dependent factors is therefore necessary.

Similarly, particular care should be put in avoiding that other information or identifiers that might be used to link pseudonyms are transmitted in clear-text. These include NEMO BS (see IETF RFC 3963 [13]) signalling information such as the Mobile Network Prefix and the Home Address.

Annex H (informative): Bibliography

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Harsch2007: C. Harsch, A. Festag, P. Papadimitratos: "Secure Position-Based Routing for VANETs", 66th IEEE Vehicular Technology Conference (IEEE VTC 2007 Fall), Baltimore, USA, October 2007.

ITU-T- Recommendation X.691:2008: "Information technology - ASN.1 encoding rules: Specification of Packed Encoding Rules (PER)".

IETF RFC 4213: "Basic Transition Mechanisms for IPv6 Hosts and Routers".

IETF RFC 4968: "Analysis of IPv6 Link Models for IEEE 802.16 Based Networks".

IETF RFC 4259: "A Framework for Transmission of IP Datagrams over MPEG-2 Networks".

IETF RFC 2009: "GPS-Based Addressing and Routing".

IETF RFC 3775: "Mobility Support in IPv6".

Annex I (informative): Change History

Date	Version	Information about changes
February 2022	0.0.1	Initial version based on ETSI EN 302 636-6-1 v1.2.1
January 2024	0.0.2	Updated references
March 2023	0.0.3	Update based on discussions in ITSWG3#65 - limit scope to ITS-G5
March 2023	0.0.3	Clean version after ITSWG3#65 for remote consensus

History

Document history		
V2.0.0	November 2022	Publication
V2.1.1	July 2024	Publication