Geographic addressing and routing
for vehicular communications
http://www.geonet-project.eu/

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vehicles and mobility services

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D8.3 GeoNet Handbook

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1. Executive Summary

The GeoNet project objective is to provide a standard solution for IPv6 GeoNetworking to all Intelligent Transportation Systems (ITS), relying on the IPv6 standard and Car-to-Car Communication Consortium's (C2C-CC) GeoNetworking. GeoNet aims at defining a reference specification and developing two prototype implementations of a geographical-based vehicular communication protocol.

To clarify the scope of GeoNet project, C2C-CC architecture is outlined in Figure 1, given that this reference architecture was assumed in GeoNet as the starting point. As it can be seen, scenarios not involving IPv6 or communications in IPv6 not involving C2C-CC's GeoNetworking are out of scope of the GeoNet project. In addition, the GeoNet project is tasked to work only on the network layer. This is reflected by the red box in Figure 1.

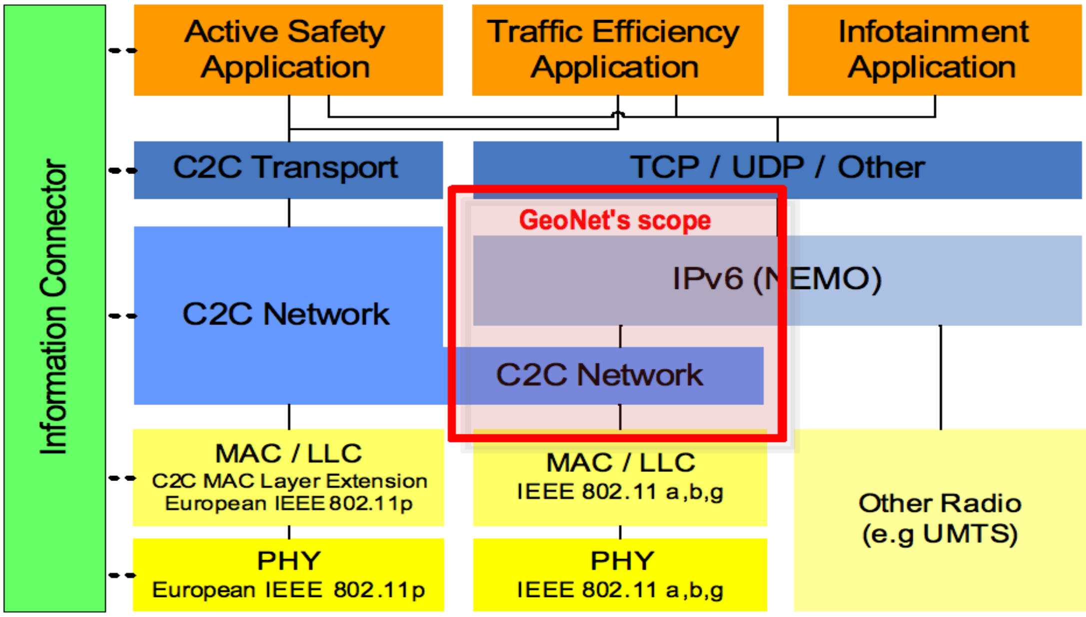

Figure 1: C2C-CC architecture and scope of GeoNet

The main purpose of this Handbook is to present the GeoNet project outcome to potential users interested in using, experimenting, or porting GeoNet results. It should be kept in mind that one of the GeoNet main goals is to make the project results available to other EU and national ITS projects.

The document allows interested readers to get an insight into the main aspects of the GeoNet work. To this end, it walks the reader through the different aspects of the project. It provides an overview of the scope and architecture of GeoNet project; briefly describes the reference specification and prototype implementations developed in the project, and additionally the description of a typical IPv6 GeoNetworking scenario is presented. The reader will also find a short user guide and, some integration and porting guidelines.

Finally the software licensing aspects are covered and the main contributions to standardisation work are highlighted.

The GeoNet Handbook is not meant to present all the details of GeoNet work, hence for more information about the project outcome, readers are referred to the project deliverables. Both the architecture and specification are described in [GeoNetD1.2] and [GeoNetD2.2], respectively. Two independent prototype implementations of the C2CNet layers are provided and integrated in a multicast-enabled IPv6 stack with some extensions for location privacy (pseudonyms) and direct V2V communications [GeoNetD3.1]. A TTCN-3 based conformance test tool is available [GeoNetD4.1] to proof compliance of implementations with respect to the specification [GeoNetD2.2].

All results of the GeoNet project are available on the web site: www.geonet-project.eu/.

2. Structure of the Document

The present document is structured as follows:

- Section 3 gives an overview of GeoNet Architecture.
- Section 4 describes the main aspects of GeoNet Specification.
- Section 5 gives an example of a possible IPv6 GeoNetworking Scenario.
- Section 6 presents the development results of implementation work carried out within GeoNet.
- Section 7 introduces a guide for users.
- Section 8 gives some integration and porting guidelines.
- Section 9 discusses the software licensing aspects.
- Section 10 highlights GeoNet contributions to standardisation work.
- Annex A lists the contributors of this document.
- Annex B lists the terms and acronyms used in the document.
- Annex C lists the references.

3. GeoNet Architecture Overview

In an effort towards harmonisation, the European Commission's COMeSafety Specific Support Action has issued an European ITS Communication Architecture [COMeSafety2008] (see Figure 2). The GeoNet architecture complies with this architecture by relying on the IPv6 suite of protocols for communications taking place over the Internet or between vehicles using IP-based applications while acting as communication endpoints. In this communication architecture, the involved communication system components include the vehicle sub-system, the roadside sub-system, the central sub-system (in charge of providing application and network services and other functions to vehicles and the roadside) and the personal sub-system (third parties located in the Internet communicating with ITS-dedicated components and typically belonging to the users, possibly portable and themselves brought into vehicles).

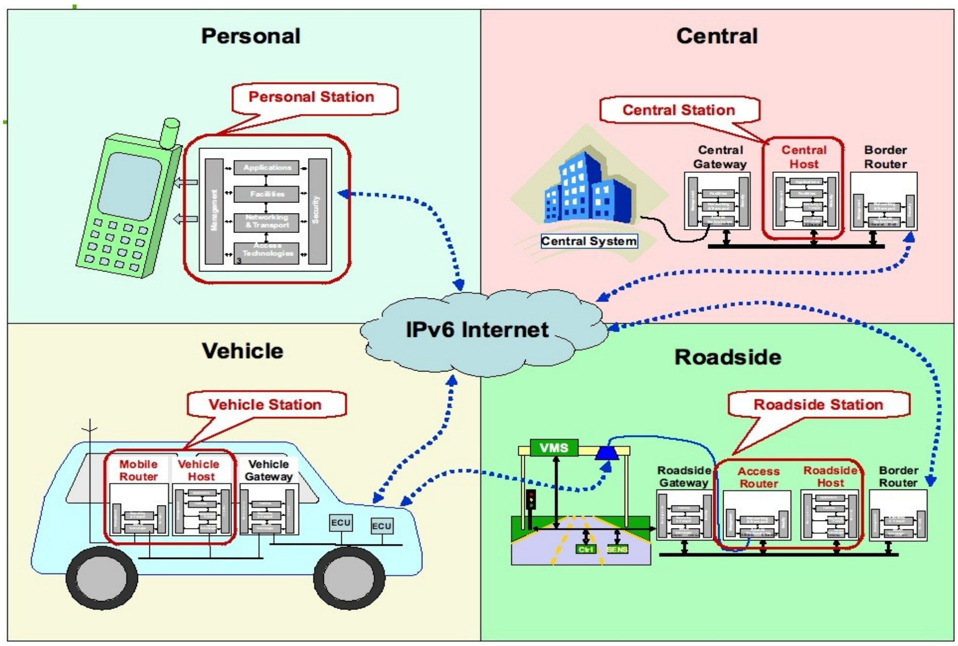

Figure 2: COMeSafety: European ITS Communication Architecture – IPv6

In GeoNet, this model is simplified as the entities involved are IPv6 nodes located in any of these sub-systems or anywhere in the Internet and communicating end-to-end using on one hand IPv6 and on the other hand GeoNetworking (C2CNet over the GeoNet domain) capabilities. The IPv6 entities involved in GeoNet communications are thus as follows:

- **IPv6 nodes located in the vehicle sub-system**: the IPv6 Mobile Router (MR) and its attached IPv6 nodes (respectively, the On-Board Unit (OBU) and Application Units (AUs));

- **IPv6 nodes located in the roadside sub-system**: the IPv6 Access Router (AR) and its attached IPv6 nodes (respectively the Roadside Unit (RSU) and AUs);

- **IPv6 nodes located in the Internet**: IPv6 nodes located in the central or personal sub-systems or anywhere in the Internet and corresponding with vehicles and the roadside. These typically include ITS-dedicated servers, the Home Agent, nodes hosting other networking functions (e.g. DNS) and other third parties.

The GeoNet architecture supports safety, non safety and infotainment types of applications and considers communications involving nodes located in the vehicle sub-system:

- **Infrastructure-less communications**: between vehicles alone without infrastructure support;

- **Infrastructure-based communications**: between vehicles and roadside peers or Internet peers.

The mode of communication could be either point-to-point (unicast or anycast), or point-to-multipoint (multicast). For both modes, GeoNet introduces a geographic range of communication (respectively GeoUnicast, GeoAnycast and GeoBroadcast).

The GeoNetworking features are only implemented into the mobile routers and access routers which are respectively referred to as GeoNet OBUs and GeoNet RSUs. From an IP point of view all of these system components are independent IPv6 networks linked over the Internet. GeoNet OBUs and GeoNet RSUs form a vehicular ad-hoc network (VANET) cloud which we refer to as the GeoNet domain where routing is performed using GeoNetworking addressing and routing.

Among several options, it was concluded that IPv6's multicast capabilities would best fit the objective of combining IPv6 and GeoNetworking into a single communication architecture. IP multicast is used to efficiently propagate data packets to a set of recipients. The principle of IP multicast is that only one copy of a given packet is transmitted on any given link, and only to the condition that there is are known destinations reachable through this link.

The document "Final GeoNet Architecture Design" [GeoNetD2.1] describes the final version of the communication architecture as it is implemented under the framework of the GeoNet project. For details, the interested readers can access to the other deliverables available from the GeoNet web page.

4. Reference Specification

The purpose of GeoNet Specification is to describe unambiguously the required system implementation for software engineers, to allow multiple interoperable implementations, and to allow the conformance testing of produced implementations with respect to a common specification document.

From the perspective of GeoNet users, the relevance of GeoNet specification is to identify interoperable system interfaces, to understand the type of communication scenarios which are supported by this specification, and to have a reference for trouble-shooting. These aspects are explained in the following sections.

4.1 Specified interoperable interfaces

Referring to the overview figure of GeoNet modules in the Architecture overview chapter, the following figure highlights those Service Access Points (SAPs), whose specification is crucial for achieving system interoperability:

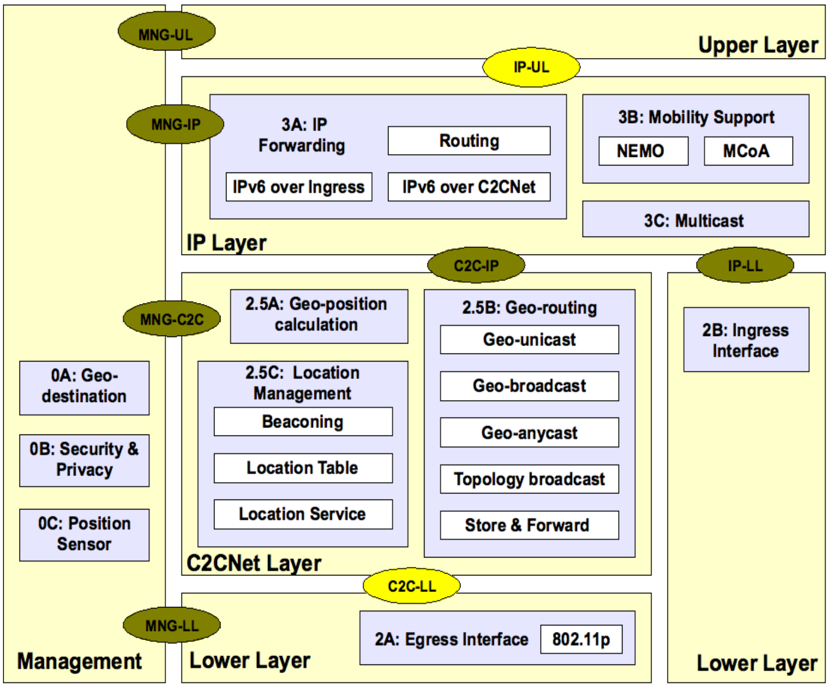

Figure 3: Overview of GeoNet modules and SAPs

The crucial SAPs are the SAP between IP Layer and Upper Layer (IP-UL) and the SAP between C2CNet Layer and Lower Layer (C2C-LL). According to the IP-UL SAP, applications using the GeoNet system may communicate with their counter-parts by generating standardised IPv6 packets. The specified C2C-LL SAP describes the SAP services that must be provided by the underlying radio implementation to the installed GeoNet system. Once system implementers provide the adaptation of the underlying radio link layer to the C2C-LL SAP, they may utilise any GeoNet implementation that conforms to the GeoNet specification. End-to-end interoperability of course also requires interoperability of the underlying radio channels and link-layer packet formats.

In the future the SAP between Management Layer and Upper Layers (MNG-UL) and SAP MNG-LL between Management Layer and Lower Layers (MNG-LL) may also impact the interoperability between systems that use GeoNet implementation. The current GeoNet implementation does not utilise these SAPs, whose details shall be specified in the future.

4.2 Supported GeoNet communication scenarios

4.2.1 Vehicle-to-Vehicle scenarios

GeoNet specification facilitates the following messaging scenario types, including the transition between described delivery phases:

- Unicast messaging between two application units, when the destination IP address is known ahead of the transaction. The IPv6 NEMO mechanism ensures global message delivery within the GeoNet domain, or even if there is an infrastructure transport segment within the messaging route.

- Unicast messaging between two nearby application units, even when the destination IP address is not known ahead of the transaction. The application may rely on the underlying network prefix provisioning procedure to discover the correct communication counter-parties for its transaction.

- Multicast messaging among application units, which is delivered within a designated radius around the source vehicle. Future versions of the GeoNet specification may facilitate more elaborate GeoDestination designation.

4.2.2 Vehicle-to-infrastructure scenarios

GeoNet specification facilitates all the messaging services that are available to the nodes, which are part of the IPv6 internet. Application units may rely on vehicle-to-infrastructure messaging even in the absence of direct physical link to an Access Router; its messages will be delivered to the serving roadside Access Router through multiple hops. This allows the use of GeoNet system even under sparse roadside infrastructure deployment.

4.2.3 Infrastructure-to-vehicle scenarios

GeoNet specification facilitates the following messaging scenario types, including the transition between described delivery phases:

- Unicast messaging between two application units, when the destination IP address is known ahead of the transaction. The IPv6 NEMO mechanism ensures global message delivery into the vehicular domain. IPv6 NEMO mechanism routes the message to the closest roadside Access Router the first phase of the message delivery, and the C2CNet protocol layer delivers the message to its final destination within the vehicular domain.
- Multicast messaging among application units, which is delivered within a designated radius around a specified geographic location. During the first phase of such message delivery IPv6 routing forwards the message to the closest roadside access router, then the C2CNet protocol forwards it to the designated destination area, and finally the message is delivered to all application units that are subscribed to this multicast type within the designated destination area. This mechanism requires the implementation of roadside Access Routers compliant to the GeoNet specification, and the use of advised IP tunnelling mechanism at the initiating application.
- Unicast messaging between two nearby application units, even when the destination IP address is not known ahead of the transaction. Through the combination of the above transaction types, the infrastructure application may first use multicasting to learn the IP addresses of vehicles around the geographic location of interest, and then initiate unicast transactions with the selected counter-parties of interest.

4.3 Reference for trouble-shooting

GeoNet users may use the specification as a guidance for performing troubleshooting, if the need for such procedure arises. As required for the analysis of generated data or for the building of test scenarios, the specification document specifies both the expected system behaviour and the data encoding over the bounding SAPs.

The users should note that effective troubleshooting requires advanced testing tools, such as the tools developed in the course of the GeoNet 'Conformance Testing' work package.

4.4 Future versions of the GeoNet specification

The final GeoNet specification document has been contributed to the ETSI ITS standardisation committee. Therefore future versions of this specification will be the standards releases that are published the by WG3 (Networking working group) of ETSI ITS, and are produced within the scope of its ongoing 'GeoNetworking' and 'IP over GeoNetworking' standardisation work items.

5. IPv6 GeoNetworking Scenarios

IPv6 GeoNetworking scenarios can be illustrated through an application known as Enhanced Driver Awareness (EDA) within the CVIS community. This type of application, which targets road safety, is one of the most able to benefit from the combination of IPv6 and GeoNetworking and thus is the very appropriate to demonstrate the usefulness of IPv6 GeoNetworking which is not limited to infotainment types of applications. Such example clearly shows that some applications ranged into the category “road safety” need IPv6 support in order to extend the range of dissemination.

5.1.1 Example: Traffic hazard report

Figure 4 shows a scenario where road traffic hazard information (black ice) is transmitted to all the vehicles located in a target geographic area (GeoDestination). Transmission is performed immediately to the set of nearby vehicles and repetitively to all the vehicles that are heading to the hazard area but are too far to get the notification directly.

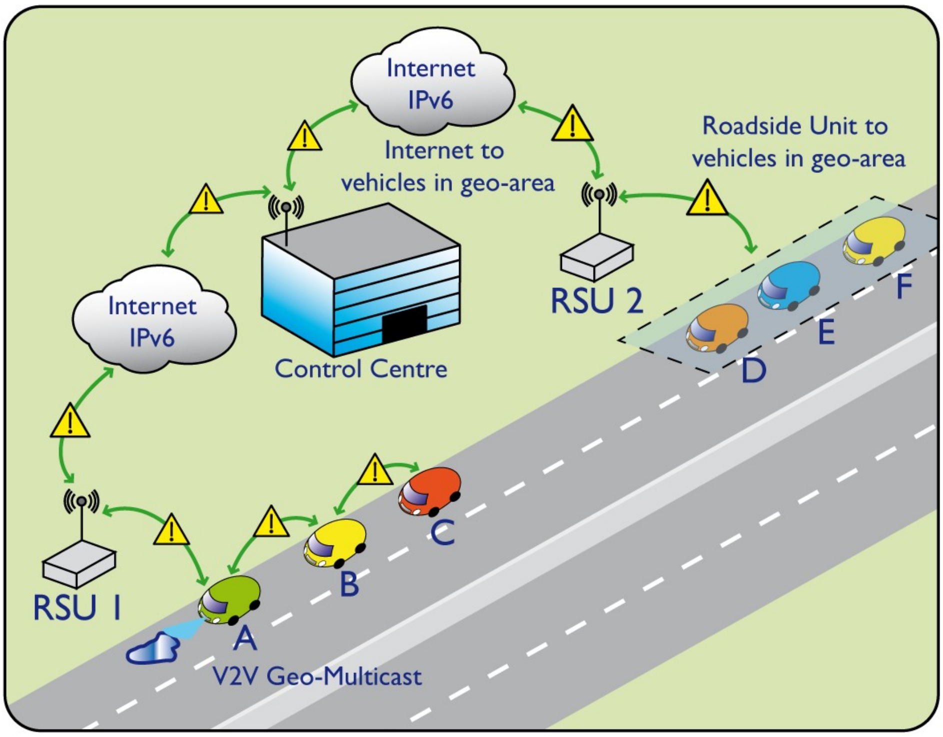

Figure 4: Scenario demonstrated at GeoNet final workshop: Traffic hazard

The information is transmitted in three steps:

- Step 1: Car A detects a Black Ice area ahead. It sends the warning message to all vehicles in a specified surrounding target geographic area. The message is received by car B. Car B forwards in turn the warning to car C, and so on, until themessage reaches the boundary of the specified target geographic area or there is no vehicle able to forward it further.
- Step 2: At the same time, car A sends the same warning message to a traffic hazard control centre. The message is forwarded by RSU1 and reaches the control center through the Internet.
- Step 3: The control centre periodically dispatches the warning to RSUs serving the target geographic area (here only RSU2). RSU2 transmits the warning to all the cars located in the target geographic area (cars D, E, F).

The figure is indeed an illustration combing three different end-to-end communication scenarios:

1. Information sent by a vehicle to all vehicles in an immediate geographic area around the vehicle (GeoBroadcast).
2. Information sent by a vehicle to a server in the Internet (IPv6 unicast / GeoUnicast).
3. Information sent by a server in the Internet to all vehicles in a given geographic area (IPv6 multicast / GeoBroadcast).

Other end-to-end communication scenarios are not illustrated, for example:

- Information sent to any vehicle located in a target area (IPv6 anycast / GeoAnycast);
- Information sent to one vehicle located in a given target area (IPv6 unicast / GeoUnicast)

In all of these scenarios, the sender and the receiver(s) could either be a vehicle, a roadside unit, or any node in the Internet, and the target area could be local (immediately surrounding the sender) or remote (reachable via other vehicles, roadside, or the Internet).

GeoNet organised its final workshop on the 29th January 2010 – the day of official project completion – at INRIA Rocquencourt, France where this scenario was demonstrated live using three vehicles (see the GeoNet website and [GeoNetD7.1] for more details).

Three types of hazard messages were reported: an accident, emergency vehicle, and congestion. The former two are directly reported by a moving vehicle (Green) to the road traffic centre while the latter is sent on demand by the traffic centre operator (in a real situation, the report would be sent based on fusion of information received at the traffic centre). There were no sensing capabilities in the reporting vehicle, so these reports were sent automatically as soon as the vehicle reached a pre-defined location on the INRIA campus based on GPS position.

The traffic hazards were sent periodically during a certain period of time from the road traffic centre to a target geographic area (GeoDestination). IPv6 multicast packets were

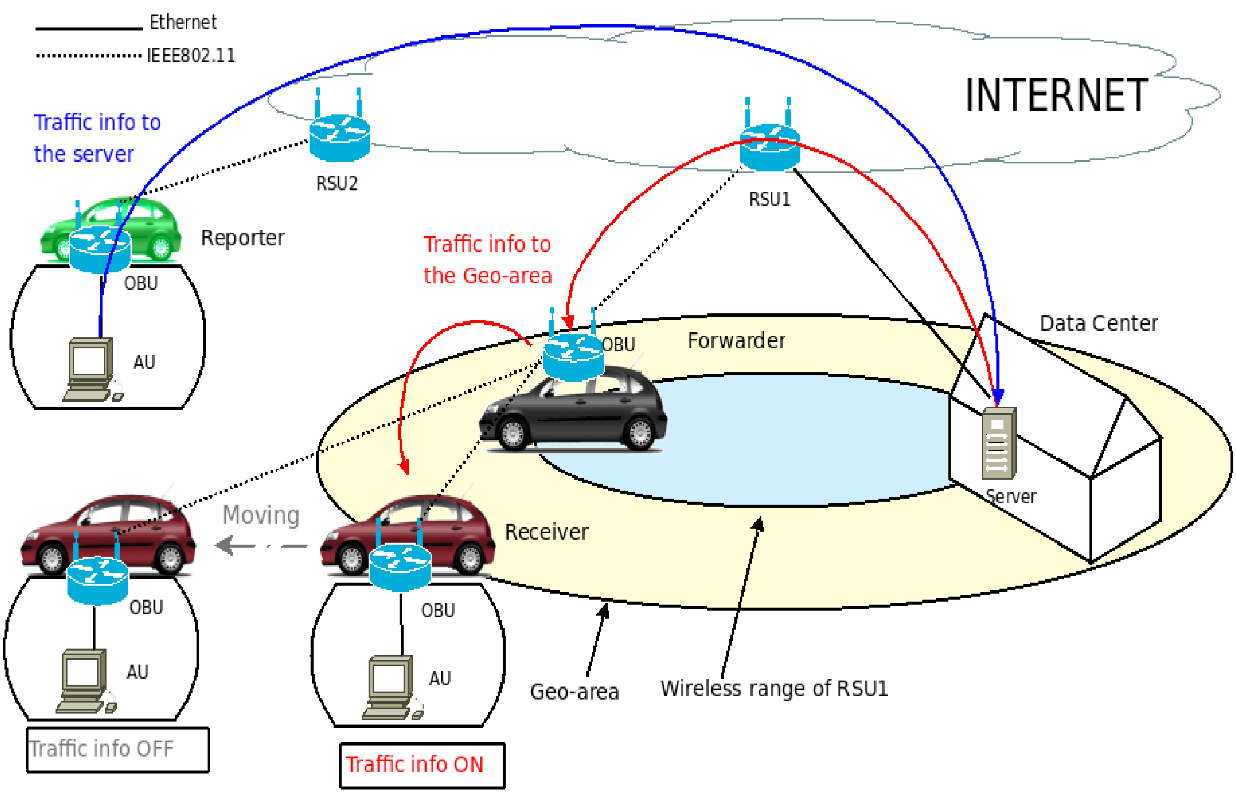

Figure 5: Scenario demonstrated at GeoNet final workshop: Network topology

sent from the road traffic centre to a RSU serving the GeoDestination where packets were GeoBroadcast at the C2CNet layer. The size of the GeoDestination was about two times the radio range of the RSU. A static vehicle (Black) which was within the radio range of the RSU received the packets and continued to GeoBroadcast them at the C2CNet layer. A third vehicle (Red) outside of the radio range of the RSU was moving in and out of the GeoDestination. Traffic hazards were received and displayed when the vehicle is located in the GeoDestination.

Workshop attendees were allowed to participate in the live demonstration as passengers into the green vehicle (reporting hazard) and the red vehicle (displaying hazard). Passengers in the red vehicle could directly observe that traffic hazard were effectively displayed as long as the hazard reports are received when the vehicle is in the target GeoDestination area. The demonstration ran for an hour and a half until the closure of the workshop.

6. Prototype Implementations

This section presents the development results of implementation work carried out within GeoNet.

6.1 Development environment

This section highlights the development environment and programming languages.

6.1.1 Hardware platform

It was decided in GeoNet to use commercial off-the-shelf PCs, such as normal desktops and laptops, with processor based on X86 architecture for software development. This frees developers from dealing with hardware-specific details from a specific target system, thus reduces the development efforts for WP3 as well as for future developments.

The developed software is hardware-platform independent, i.e. it does not contain any features or configurations related to a specific hardware and specific software running on the hardware. Consequently, for use on target hardware platforms it will be ported. This task is part of the integration and porting within WP6.

6.1.2 Software platform

The operating system for development was chosen to be Linux. However, partners used different kernel versions varying from 2.6.19 to 2.6.24 or later. Considering the fact that the kernel version will also evolve during the development process, no requirement is made on the kernel version, but each partner was asked to use kernel version equal or higher 2.6.19 and not to include any specific features of a certain version of kernel.

The programming language C/C++ was chosen for all software modules. No specific and only standard C/C++ libraries were identified for the implementation. All software modules are user-space programs, and are not kernel modules. This eases the whole implementation process and does not limit the deployment of modules.

The management of source code and binary releases was carried-out using the tool SVN on a dedicated GeoNet server. Developers collaborated using the tool TRAC that was set up on GeoNet server with ticket-based task management.

6.2 Software architecture

Figure 6 illustrates the software modules and their interfaces with each other. The central part of GeoNet implementation is the C2CNet module. It implements the geographical addressing and routing functionalities and has interfaces with a number of other software modules. Two independent implementations of C2CNet were developed with exactly the same functionalities. The Lower layer implementation works as the access layer for the C2CNet and hides all hardware-specific details from the C2CNet. It communicates with C2CNet bi-directionally. The module NEMO, IPv6 over C2CNet implements the interface between IPv6 and the C2CNet and NEMO related functionalities and also communicates with C2CNet bi-directionally. As an advanced IPv6 feature, MNPP implements a mechanism that enables two OBUs to communicate directly. The software module "position sensor" sends local position read from a GPS receiver to the C2CNet. The location privacy module manages the list of the available C2C-IDs and communicates with the C2CNet and NEMO, IPv6 over C2CNet module.

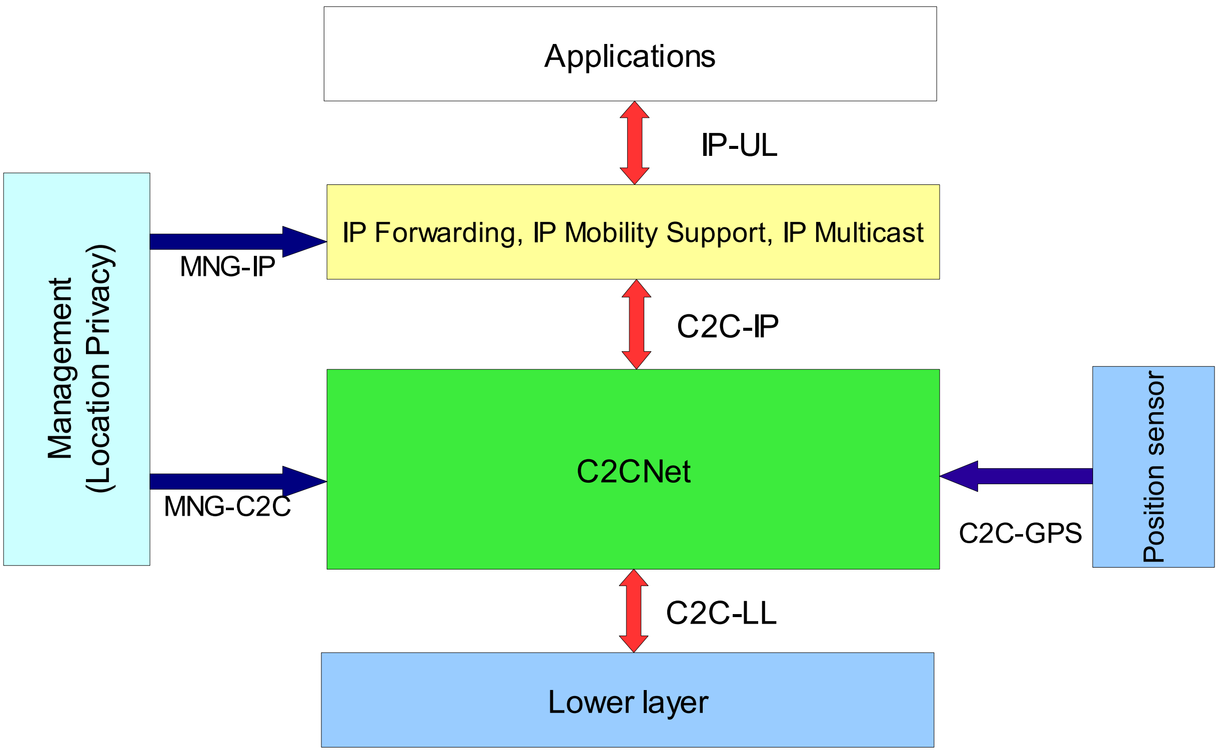

Figure 6: Software modules and interfaces

6.3 Software module description

6.3.1 C2CNet

GeoNet provides two implementations of the C2CNet layer, one done by NEC and another one done by Hitachi. Both implementations are compliant to the GeoNet specification as described in D2.2. In the rest of this section we refer to both implementations as “C2CNet daemon“.

The C2CNet daemon is a C/C++ user space program which runs under Linux. It has already been tested with different Linux kernel versions (from v.2.6.19 to v.2.6.28), and it should work with any newer kernel version since it does not include any kernel specific feature or library.

C2CNet daemon supports four georouting schemes: GeoBroadcast, GeoUnicast, GeoAnycast, and also TopoBroadcast.

6.3.2 IPv6 over C2CNet

In Linux system, IPv6 packet forwarding is processed in the kernel space. However the packet has to be brought to the user land from kernel, because the C2CNet is implemented in user land. Then the packet is encapsulated with C2C NET header and tsent back to the kernel again. We decided to use TUN[1] virtual interface to bring the packet to the user land.

The actual implementation is divided into two parts, which are 1) shell script for the configuration of IPv6 and TUN interface and 2) C/C++ program to send the necessary information from IPv6 to C2CNet. The shell script sets up configurations with the help of Linux typical commands (iwconfig, ip, tunctl, ifconfig, sysctl, ip6tables and radvd). The C/C++ program implements the following functions:

- Receive the packet from tun0
- Parse the source and destination of the packet from tun0
- Look up routing table by destination to find the IP next hop by using netlink
- Find C2C-ID from the IP next hop

1 http://www.kernel.org/pub/linux/kernel/people/marcelo/linux-2.4/Documentation/networking/tuntap.txt

6.3.3 Mobile Network Prefix Provisioning

Mobile Network Prefix Provisioning (MNPP) is used to announce a Mobile Network Prefix (MNP) assigned to an OBU to neighbouring OBUs and RSUs. By utilizing MNPP, OBUs and RSUs can recognize MNP and C2C-ID information of neighbour OBUs so that the direct communication between them can be achieved.

MNPP is designed to operate as an upper level user space daemon at IPv6 over C2CNet. In order to provide compatibility with the previous well-known Router Advertisement (RA) daemon called *radvd*, the implementation of MNPP is provided as an extension (patch) of *radvd* so that the MNPP patched *radvd* provides its original functionalities as well as the functionalities of MNPP. From the perspective of implementation, MNPP consists of two parts: receiver part and sender part.

6.3.4 Lower layer implementation

The Lower Layer module – also called adaptation layer module – is the interface between C2CNet (GeoNet internal modules) and the PHY/MAC Layer. This module is not a core part of GeoNet protocol stack but is needed to support the platform independence of GeoNet.

The GeoNet modules use SAP C2C-LL to communicate with Lower Layer module. This module runs in its own process, which allows GeoNet to support different platforms with different network-interfaces without holding platform specific parameters within the C2CNet modules. The Lower Layer module can also be used on common PCs or laptops when no 802.11p hardware is present (e.g. for development it can also be tested with 802.11a).

The C2C-LL is implemented by local UDP connections. One UDP port is used for sending requests to the lower layer module (direction C2CNet to Lower Layer). Another UDP port is used for informing C2CNet about PHY/MAC configuration or received messages (direction Lower Layer to C2CNet). There is no other interface for configuration or transmitting messages. The UDP connections may be used from both the Management modules and the C2CNet modules.

6.3.5 Position sensor

The idea of the position sensor module is to create a stable interface for acquiring geographic data by the C2CNet modules (GeoNet routing modules). It is implemented as a stand-alone program connected to a positioning service available for a particular platform. It sends the position information over a UDP socket to C2CNet modules.

In the current GeoNet implementation an adaptation for gpsd was done. “gpsd” is an open source tool for getting formatted positioning data from a connected NMEA device. In order to use another or extend the currently used positioning system, the module must be adapted.

Every time new position data is known, a message is sent to C2CNet modules via a UDP socket (event driven). Therefore it depends on the service used for gathering position information how often a new position is published, but not on the position sensor module itself.

6.3.6 Location privacy

The privacy module is a single process, user space daemon. It is implemented in C++ and needs a configuration file where to read the list of the available C2C-IDs in the host.

It provides the C2CNet, MNPP and the NEMO, IPv6 over C2CNet modules with the current C2C-ID to be used. The mechanism used to change the current C2C-ID to be used is chosen among different available algorithms. The round robin algorithm is taken as default. Algorithm behaviour can be customized by specifying parameters. In the case of Round Robin, the time between changes can be specified as input parameter.

The privacy module is composed by the user space daemon and the configuration file where to place the list of available C2C-ID.

An in-depth description of module and interface implementation of GeoNet protocol stack is provided in deliverable “D3.1.Development Results”, see [GeoNetD3.1]. Note that [GeoNetD3.1] is not publicly available. However, after reaching a non-disclosure agreement (NDA) GeoNet will deliver [GeoNetD3.1] to requesting third parties.

7. User Guide

7.1 Software installation

7.1.1 Reference hardware configuration

In a reference configuration of hardware, there are two computers, the AU and the OBU. On the AU, applications are running, and it is connected to the OBU via an Ethernet interface. On the OBU, GeoNet software modules are running. In addition to Ethernet interface, it also has the interface ath, which is the wireless interface, and a USB interface that is connected to a GPS receiver. This reference configuration may be applied to a vehicle as well as a RSU.

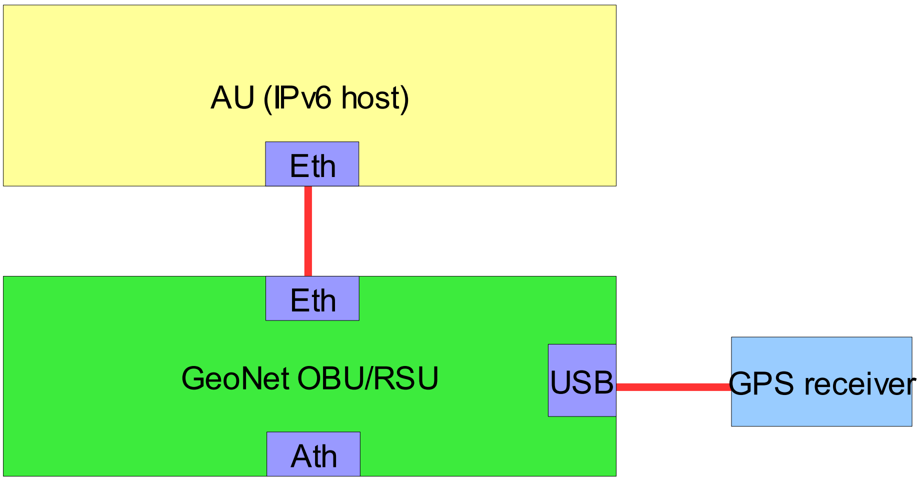

Figure 7: Reference hardware configuration

7.1.2 Required software

The OBU is assumed to have Linux with kernel fresher than 2.6.19 installed. The following software is required in order to run GeoNet software modules:

IP, NEMO, TUN related software:

- The *tunctl* tool to allow users to configure tun/tap devices
- The *radvd* software to advertise Router Advertisements on the Home Link (ingress link). If MNPP is used, *radvd* does not need because MNPP provides the original *radvd* functionalities as well as the MNPP functionalities.

- The NEMO *patch* (version 20090624)

Position sensor related software:

- The *gpsd* tool to get access to a GPS device

Lower layer related software:

- The *linux wireless* tools (http://linuxwireless.org/) to configure the wireless interfaces in Linux

7.1.3 Installation

The detailed installation procedures for each software module can be found in the GeoNet software release.

8. Integration and Porting Guidelines

The purpose of this section is to guide interested users into porting the GeoNet protocol stack to their target system since one of the GeoNet main goals is to make the project results available to other EU and national ITS projects. More detailed information is available in public deliverable [GeoNetD6.1].

8.1 GeoNet as part of European ITS architecture

The European ITS architecture is provided in Figure 8. In layer “Networking & Transport” a GeoRouting module is foreseen.

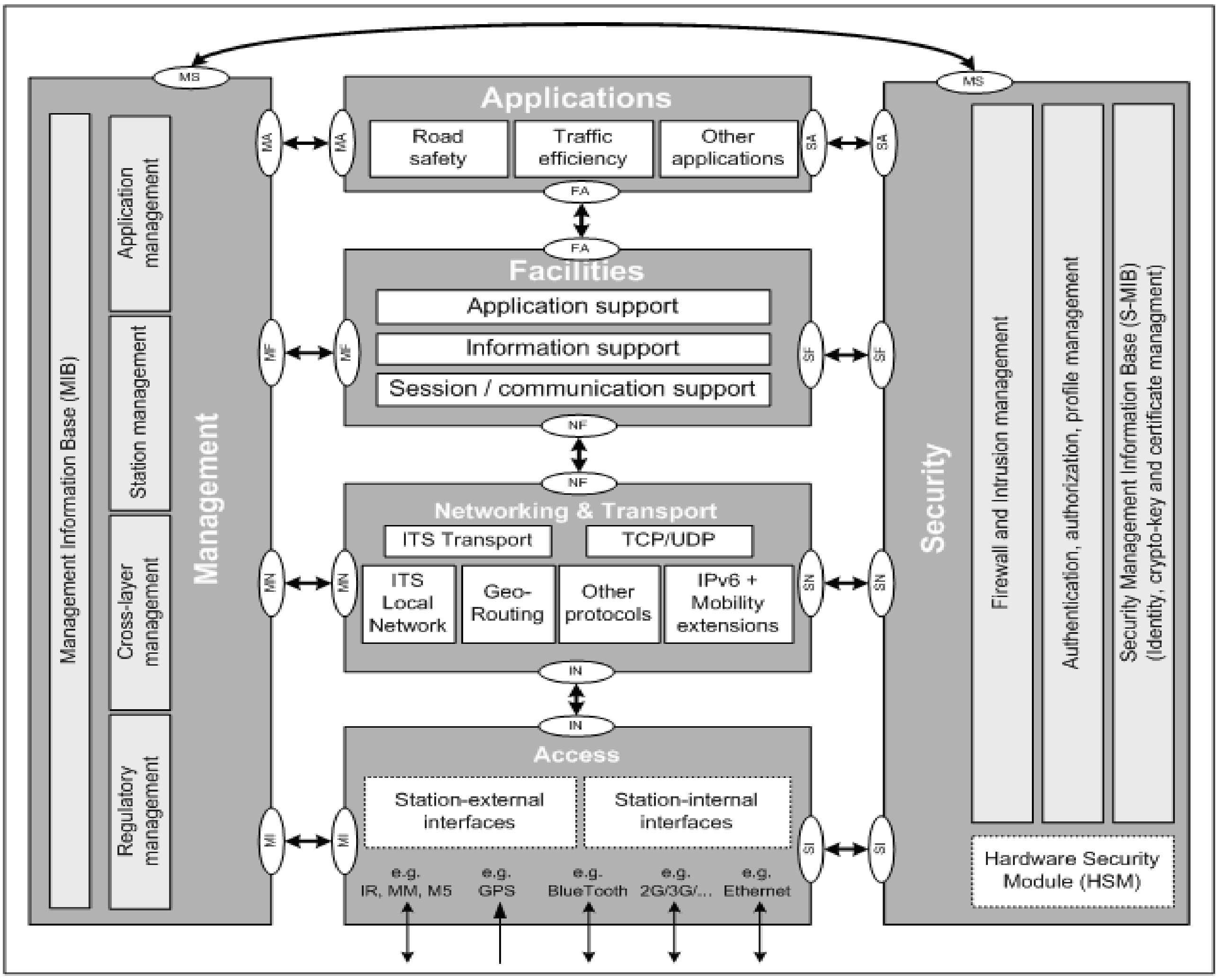

Figure 8: European ITS architecture [ETSI-TS-102-665]

Figure 9 depicts the “Networking & Transport” layer in more detail. Figure 9 shows that the GeoNet architecture is fully compliant to the European ITS architecture. [GeoNetD6.1] provides a mapping of GeoNet SAPs to the SAPs of European ITS architecture according to [ETSI-TS-102-665] that is not repeated here.

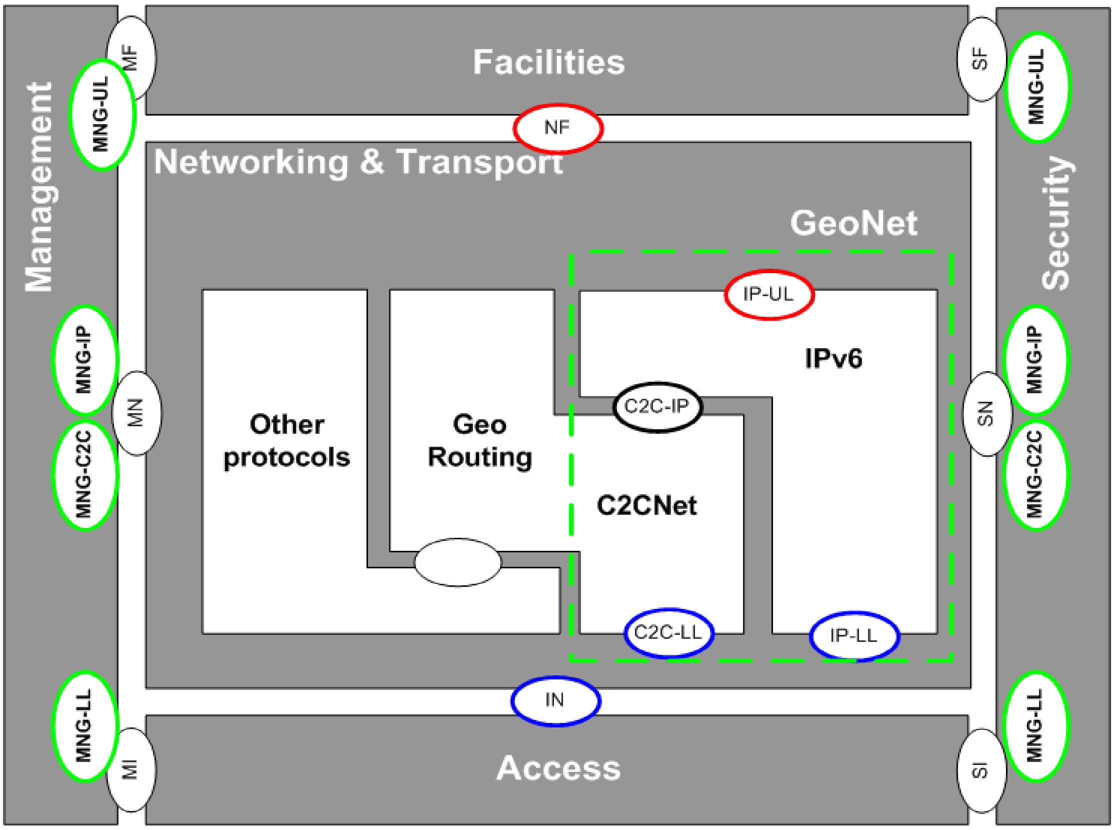

Figure 8: Integration of GeoNet into ITS Networking & Transport layer of European ITS station architecture, see [GeoNet-Integration]. Note that ITS Transport and ITS TCP/UDP are not shown in this figure.

The proposed integration of the GeoNet into the ITS station reference architecture will be intensively discussed in SDOs (Standard Developing Organisations) by GeoNet project partners.

8.2 Porting and integration goals

The main goal which has led GeoNet partners to create a porting and integration guideline is to support the easy use of project results within other EU and national ITS projects. The porting and integration goals are as follows:

1. Check proper functioning on other platforms.
2. Prove platform independence of GeoNet specifications and implementation.
3. Provide required information to potential users.

8.3 Porting and integration

8.3.1 Typical target system requirements

A typical hardware platform consists of following components:

- **CPU:** Typically performance > 750 MIPS (e.g. XScale/ARM11 core / 64bits MIPS@ 266MHz)
- **Flash**: 128MB NAND-Flash and 128MB SDRAM
- **Position sensor** (e.g. GPS device with update rate of 4Hz), gyrometer, odometer to provide more accurate position information or update position information when GPS is not available
- **Egress interface**: One or two ETSI ITS-G5A or IEEE802.11p compatible NIC, antenna diversity
- **Ingress interface**: Ethernet NIC @ 10/100Mbps

Normally such a device is equipped by an interface to a vehicle bus like CAN, MOST, or similar. However, such an interface is not required for proper function of GeoNet protocol stack. Other ITS related functions may be implemented and run in parallel on such a target platform. In principle there are no major differences between the deployment of the GeoNet stack in OBUs or RSUs.

8.3.2 Software and tool requirements

Deliverable D6.1 enumerates the software and tool requirements:

- **Operating system:** Multi-tasking operating system with IPv6, NEMO (network mobility), MCoA (Multiple Care-of Address Registration) and multicast support. Typically this can be a Linux system with kernel higher than 2.6.XX. Software runs in user-space, but kernel implementation may be more efficiently.
- **Libraries and programming language:** The programming language C/C++ was chosen for all software modules. Only standard C/C++ libraries were used for implementation. Since C language is well standardised, highly portable and available on almost all embedded platforms, this should ease the porting and integration to 3rd party platforms. Note that 3rd party using specific libraries at the application layer must make sure about their compatibility for use in an IPv6 environment.

- **Tool chain:** Since GNU tool chain is of great importance for Linux and embedded systems, GeoNet relies on GNU Open Source tools. This tool chain is available for most embedded platforms and supports porting in a perfect way.

- **Platform dependent:** Modules 2A: Egress Interface and Module 0C: Position Sensor. These modules must be adapted to the target platform

8.3.3 Development Platform

State-of-the-art x86 systems - laptops and PCs - were used by GeoNet partners as development platforms. This should also be a good choice for embedded target platforms using the GNU cross-compiling options.

8.4 Platform independence of GeoNet stack

GeoNet subdivides software modules by functionality. Each software module runs in its own process, all processes are running in user space. Processes exchange information by using socket connections. Thus the concurrent access to resources is handled by operating system. The endianness problem is solved by the use of network order library functions. On the operating system and software library side the access is limited to standard POSIX C/C++ library routines only.

All operations that require hardware access are moved to modules outside the core of GeoNet stack. These operations are performed by typical platform drivers. This is of course platform dependent and a matter of porting. Deliverable [GeoNetD6.1] provides the Position Sensor as a characteristic example. Each software interface is discussed in D6.1 in more detail.

Therefore the requirements to hardware target platform integration are reduced to the minimum of three hardware / operating system dependent driver interfaces:

- Egress interface to access ETSI ITS-G5 or IEEE 802.11p compliant NICs;
- Position information interface to update position information;
- Ingress interface to communicate to IPv6 hosts attached to GeoNet OBU or GeoNet RSU (e.g. IPv6-based Application Units) – Note, nothing is to be implemented here for GeoNet stack porting.

8.5 CVIS Porting example

A guideline and the experience of porting and integration to CVIS platform is delivered. Two options are discussed: A lightweight and a full integration of GeoNet into CVIS.

8.5.1 Lightweight integration

The lightweight integration is based on CVIS OSGi architecture. The GeoNet OBU (Mobile Router) runs on a separated controller that is connected by Ethernet to the CVIS Host. As a future work this GeoNet OSGi module could be enhanced in such a way that it exposes both the IP-UL and the MNG-UL SAPs. The advantage of this approach is the simplicity of integration. The disadvantage is the need for separate GeoNet Box (MR) what may be accepted only for research purposes. Therefore the preferred approach is the full integration.

8.5.2 Full integration

The second approach performs a full integration into CVIS architecture. In full integration GeoNet will run directly on the CVIS MR Box as an additional software module and provide all GeoRouting functionality to CVIS applications. CVIS applications may use IPv6 GeoNetworking in the same way as any other protocol supported by CVIS. GeoNet protocol stack will access IEEE802.11p or ETSI ITS-G5 compatible hardware without disturbing the parallel use of these interfaces by other protocols.

Only the Lower Layer module is ported, since the other modules can work on this platform without change. The Lower Layer interacts with the CALM device driver framework in kernel space over netlink sockets.

The disadvantage of current implementation is that not all benefits of a full integration are available. In current implementation no special VCI for GeoNet is created, instead the available default CVIS VCIs are used. This causes performance losses. Further there is no kernel integration of GeoNet from CVIS site. This integration step lies outside of the scope of GeoNet and can only be performed with support of CVIS project.

Unfortunately there was no porting and integration support of CVIS project available. Under these circumstances the first integration step this is done to show that GeoNet runs on CVIS platform. The GeoNet stack gains access to the wireless medium by using the M5 devices. The proper functioning of GeoNet routing mechanisms are not restricted by this unilateral porting.

8.5.3 Porting and integration results

It was shown, how to port GeoNet to CVIS platform in a first preliminary implementation. The first step of integrating GeoNet to CVIS platform is done. The complete functionality of GeoNet is available. However, there are further enhancements necessary to make CVIS applications and M5 drivers GeoNet aware.

As mentioned before GeoNet provides a unilateral porting. The adaptation of CVIS M5 driver will probably improve performance. In this case GeoNet packet's priority and transmit power settings will be used by the driver on a per-packet base to increase the performance of GeoNet on CVIS platform. There are further possibilities to improve the GeoNet integration.

9. Software Licensing Aspects

Intellectual Property Rights (IPR) are regulated by GeoNet consortium agreement and depicted in Description of Work (DoW) in sub-clause “B.3.2.3 Management of Intellectual Property”, see [GeoNetDoW]. Figure 9 is copied from the DoW and provides an overview:

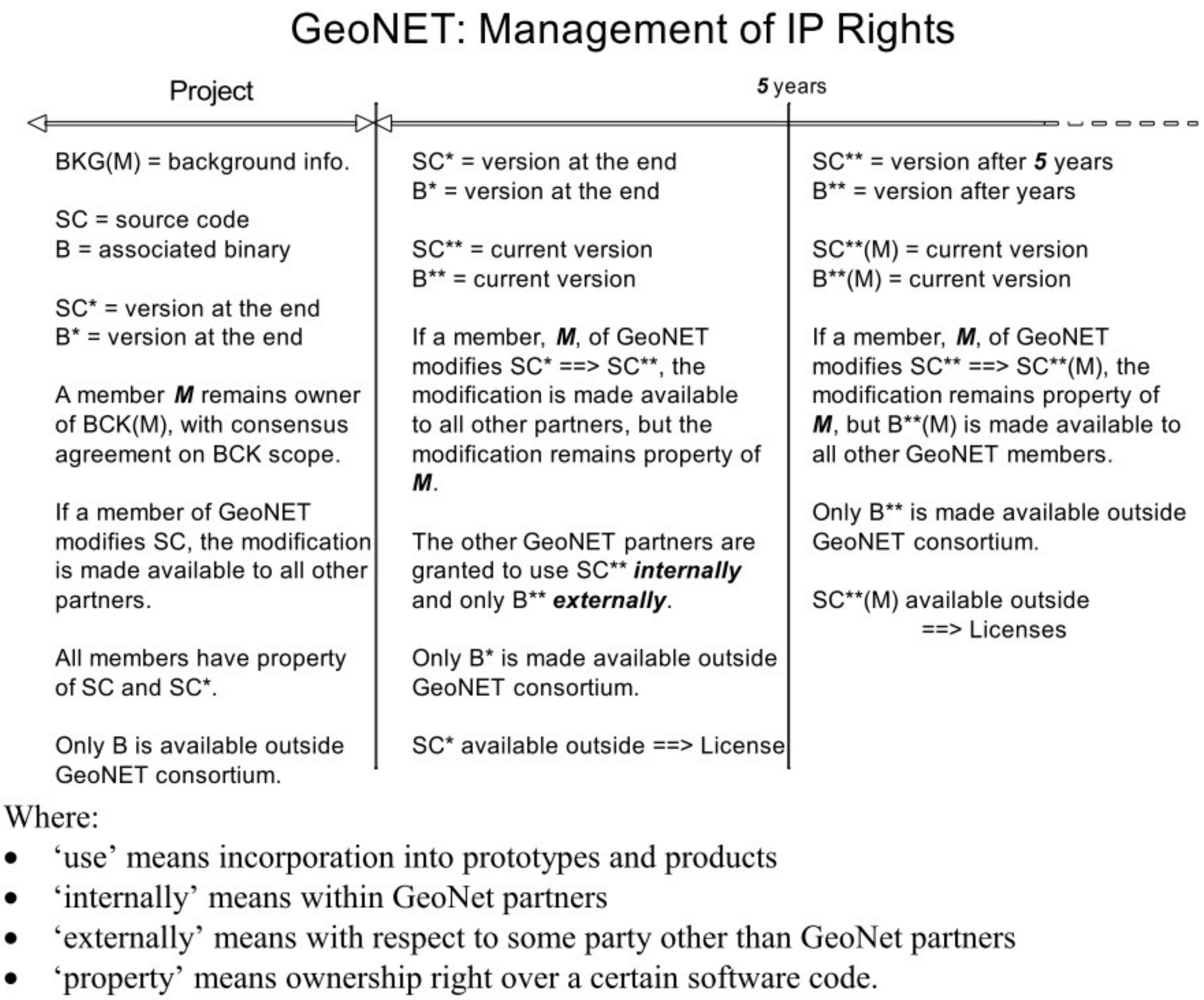

Figure 9: GeoNet management of IPR [GeoNetDoW], chart on p.62

According to the IPR, only binary code is made available outside the consortium, except for cases where license agreements are closed after the end of project. At the end of project all GeoNet members have the ownership right of their source code they developed. Within 5 years after project's end all source code is made available to all partners within the GeoNet project for internal use.

It is explicitly stated, that both the interface and the functional specifications created within GeoNet project are published, with the objective of promoting their standardization, see [GeoNetD1.2] and [GeoNetD2.2]. All binary software and major parts of source code created within GeoNet project will be made available to external parties on fair and non-discriminatory basis.

Figure 11 provides an overview of partner contribution. and the related IPR model for GeoNet protocol stack, see also [GeoNetD3.1], sub-clause “2.1.2 Partner contributions” (Partners in alphabetic order):

- **BroadBit**: Developed SAP TTCN-3 implementation and test routines for conformance testing. Maintained the SVN / TRAC system and developer SDK environment.

  License model: Provide software and support on request and on base of individual license agreement.

- **Hitachi**: Developed independent C2CNet software module, utility software and corresponding documentation.

  License model: Provide binary code on request and on base of individual license agreement.

- **IMDEA**: Integrated IPv6 related functionalities on security and mobility.

  License model: Provide binary code on request and on base of individual license agreement

- **INRIA**: Integrated the code with IPv6 specific functionalities and implemented advanced IPv6 features; performed performance evaluation of IPv6 GeoNetworking.

  License mode: Provide source code on request according to GPL2 (http://www.gnu.org/licenses/gpl-2.0.txt)

- **Lesswire**: Implemented Egress interface module with SAP C2C-LL prototype and position sensor software.

  License mode: Provide source code on request according to GPL2 (http://www.gnu.org/licenses/gpl-2.0.txt)

- **NEC**: Developed independent C2CNet software module, utility software and corresponding documentation.

  License model: Provide binary code on request and on base of individual license agreement.

Note: All GeoNet modules are Linux user space implementations and therefore not affected by Linux kernel copyright and IPR restrictions.

The GeoNet partners Hitachi and NEC brought into the GeoNet project a strong background and expertise of earlier developments in the area of GeoNetworking. These partners developed two independent prototype implementations. This is useful for standardization, but also for exploitation since their characteristics can be compared and a quality competition of implementations is initiated. In turn, these implementations are not public available on source code level. However, these partners are willing to provide binaries, as regulated by consortium agreement, to 3rd parties on fair and non-discriminatory basis.

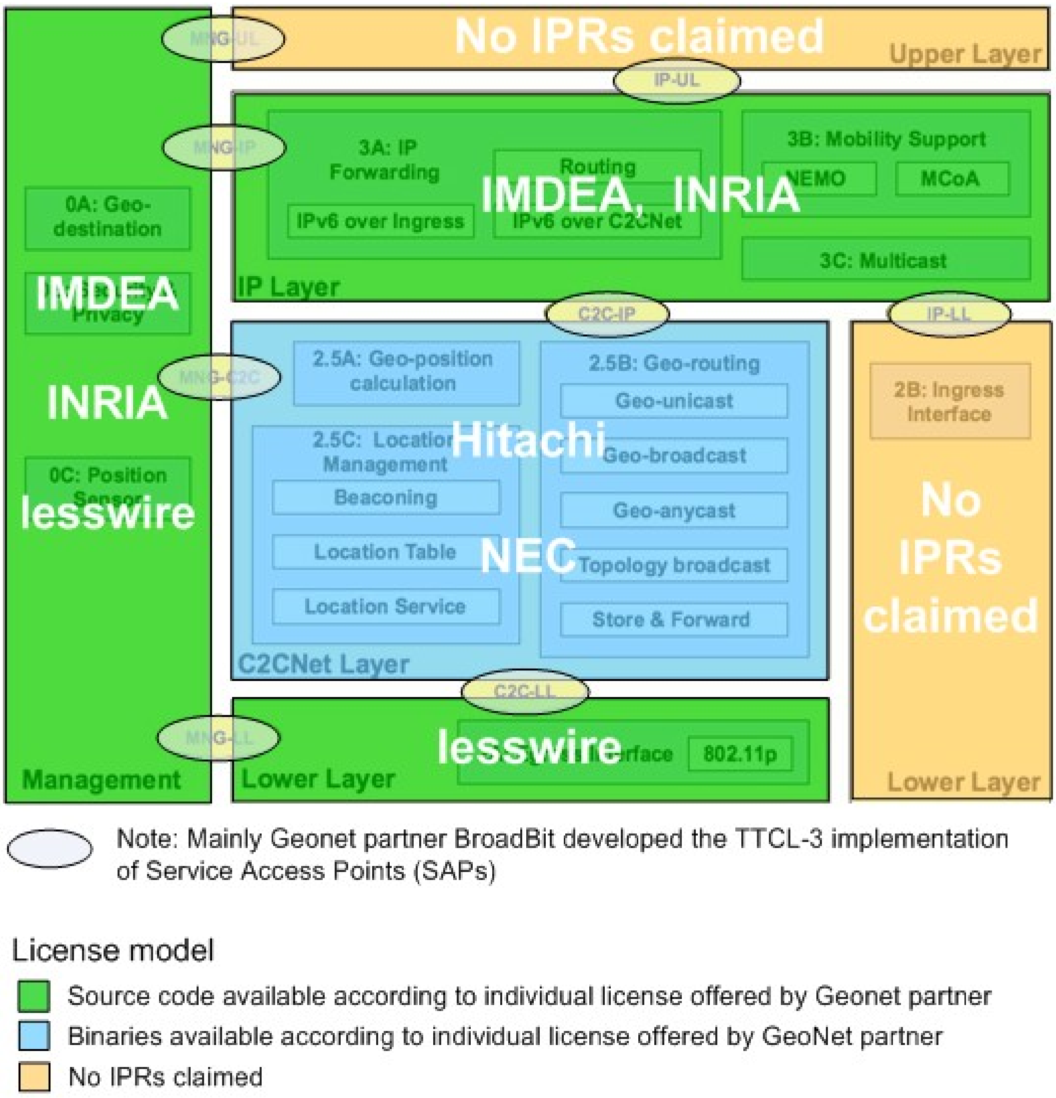

Figure 10: Contribution of GeoNet partner

10. GeoNet Contributions to Standardisation Work

This sections describes GeoNet contributions to standard organisations (SDOs) and other fora at both the European and international level. GeoNet has both influenced and has been influenced by the standardisation effort.

10.1 ETSI TC ITS

ETSI Technical Committee ITS (ETSI TC ITS) is a newly established Technical Committee within Europe's ETSI standardisation body which aims at harmonising existing communication architectures in a single one or ensuring their interoperability. It is taking over initial work conducted by the Car-to-Car Communication Consortium, COMeSafety, and the GeoNet and Pre-Drive FP7 projects.

GeoNet contribution: Thierry Ernst (INRIA) and Hamid Menouar (Hitachi) are acting as GeoNet liaison officers for GeoNet-ETSI matters. The final GeoNet architecture [GeoNetD1.2] and specification [GeoNetD2.2] were presented at length at the 9th ETSI TC ITS WG3 meeting (January 27th 2009). GeoNet partners have actively contributed to the standardisation activities at ETSI TC ITS. There is a number of Work Items (WI) that are closely related to GeoNet, and GeoNet partners have made different levels of contributions.

- In ETSI TS ITS WG3 Transport and Network, GeoNet partners have made major contributions on two work items: Requirements for GeoNetworking [ETSI-TS-102-636-1] and Scenarios for GeoNetworking [ETSI-TS-102-636-2]. These two documents deal with GeoNetworking requirements and scenarios in general, and work as a basis for GeoNet architecture and specification. NEC is the rapporteur of these two work items. GeoNet partners including NEC, Hitachi, Efkon and INRIA have actively joined discussions and meetings and prepared the two documents.

- The work item Transmission of IPv6 Packets over GeoNetworking Protocols [ETSI-TS-102-636-1] deals with the same problem as investigated within GeoNet, but less globally than GeoNet. GeoNet partners NEC, INRIA, IMDEA and Hitachi have actively contributed to it and its technical specification is fully compliant with the GeoNet approach.

- Other related work items include Vehicular Communications Architecture [ETSI-TS-102-665] in WG2, Network Architecture [ETSI-TS-102-636-3] in WG3, European profile standard on the physical and medium access layer of 5 GHz ITS [ETSI-ES-202-663] in WG4. GeoNet partners have contributed to them and made the GeoNet architecture and specification compliant with them.

- It is envisioned to include GeoNet input in two other work items in coming days: “Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Subpart 1: Media independent functionalities” [ETSI-TS-102-636-4-1] and “Subpart 2: Media dependent functionalities for 5 GHz media (5,9 GHz)” [ETSI-TS-102-636-4-2]. GeoNet plans to bring its specification to them. However, at the beginning of 2010, they are still at the drafting phase without major technical input. GeoNet partners, NEC and Hitachi serving as editors of these two work items will continue to bring GeoNet results to these two work items.

10.2 ISO TC204 WG16

ISO's Technical Committee 204 Working Group 16 is specifying a protocol architecture (known as **CALM**, for “Communication Access for Land Mobiles”) [ISO-21217] which enables the use of various access media technologies transparently to the upper layers. The objective is to provide universal access through any available media. The architecture is spanning from the physical layer (e.g. the CALM media) up to the application layer (e.g. probe vehicles) whereas the networking layer specification is largely based on existing IETF IPv6 standards (**NEMO, Mobile IPv6**, etc.) [ISO-21210]. The architecture allows both IP (Vehicle-Internet and non time critical V2X) and non-IP (time critical V2X) communications. ISO's work represents the state of the art of such universal access applied to the automotive needs. EC-funded **CVIS** (see Section 5.1) can be considered as the European proof of concept of CALM. INRIA is contributing to this standard effort, particularly on the overall architecture [ISO-21217] and the specifications related to IPv6 [ISO-21210], under the umbrella of the CVIS project.

GeoNet contribution: GeoNetworking is a capability listed in the CALM architecture [ISO-21217] on which CVIS bases its work though there is currently not such a specification in the CALM set of standards. INRIA has thus participated to ISO TC204 WG16 meetings and introduce the GeoNet architecture and key GeoNet concepts to the ISO group. According to EC mandate on ITS, GeoNetworking within CALM may indeed be contributed by ETSI, in coordination with ISO. GeoNet has thus investigated how IPv6 GeoNetworking as specified by GeoNet could fit in the CALM set of standards [GeoNetD6.1]. INRIA has conducted the investigation on parts related to the CALM Manager, IPv6 networking and SAPs involving modules defined in the GeoNet architecture. As presented in Figure 8 a proposal is worked out together with CVIS and ISO TC204 WG16 how to present the GeoNet protocol stack within the ITS station reference architecture

10.3 CEN TC278 WG16

Working Group 16 “Co-Operative Systems” has recently been established within CEN TC 278 “Road Transport and Traffic Telematics” (RTTT).

GeoNet contribution: INRIA participated to the first meeting (joint meeting with ISO TC204 WG16) and pointed out the need to differentiate between roadside-based communications and Internet-based communications, which is key to understand why combination of IPv6 and GeoNetworking is needed. Once understood, requirements on co-operative systems could better be defined and will ensure proper tuning of ITS communication architectures. Information about GeoNet was provided to meeting attendees.

10.4 IETF

The **Internet Engineering Task Force** (IETF) is an international standard organisation championing the standardisation of the Internet-based protocols, particularly basic IPv6 protocols and IPv6 mobility support (NEMO and security) as far as vehicular mobility is concerned. The IETF is not targeting any particular use case and is not doing architectural work. It only specifies independent protocols blocks that other organisation can use in their architectures.

GeoNet contribution: GeoNet partners have been particularly active in the **MeXT** (Mobility EXTensions for IPv6), **Autoconf** (Ad-Hoc Network Auto-Configuration) and **IntArea** (IntArea) Working Groups which are the working groups handling topics related to GeoNet. **INRIA** worked on NEMO Routing Optimisation (RO) issues in ITS architectures and co-authored an internet-draft submitted to the MeXT WG to provide the IETF with automotive requirements on NEMO RO [Baldessari2009] which is a Working Group item within MeXT. In the context of the GeoNet architecture, INRIA specified a solution for IP-based V2V communications (MNPP: Mobile Network Prefix Provisioning) which was submitted to the IETF in the form of an Internet-Draft [Lee2009] and presented in the MeXT WG at the IETF in November 2009. **IMDEA Networks** has also kept on contributing to IETF MEXT WG, specially in the topic of NEMO Route Optimisation for the automotive industry. IMDEA Networks has been working on the requirements for traffic safety applications. This work was sent as an Internet-draft [Karagiannis2009] and was presented to the IETF Intarea WG at the IETF 76 hold in November 2009. The mentioned document describes a number of communication performance requirements that are imposed by traffic safety applications on a network layer. These traffic safety applications and requirements have been derived by the USA VSC (Vehicular Safety Communications) and VSC-A (VSC-Applications) projects and by the European Car to Car Communication Consortium (C2C-CC) and the ETSI TC ITS standardisation body. The goal of this document is to stimulate the discussion on judging whether these performance requirements could or could not be supported (currently and in the future) by IP-based network solutions.

10.5 COMeSafety

COMeSafety (COMmunications for eSafety) is a Specific Support Action funded by the European Commission within FP6 and supports the eSafety Forum with respect to all issues related to vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications as the basis for co-operative intelligent road transport systems.

COMeSafety provides a platform for both the exchange of information and the presentation of results (newsletters, publications and press events). COMeSafety established a Common Communication Architecture Task Force to enable and facilitate the development and deployment of safety applications based on an harmonized architectural framework. COMeSafety is indeed co-ordinating the integration of Coopers, CVIS, SafeSpot contributions on architecture into the European ITS Framework Architecture.

GeoNet contribution: The technical work carried out in GeoNet is closely related to COMeSafety in that GeoNet architecture and specification will support co-operative intelligent transport systems, and GeoNet implementations may be used by research and field operational tests in this area. GeoNet architecture can be considered as the sub-part of overall COMeSafety system architecture, which deals specifically with IPv6 GeoNetworking. NEC has contributed to COMeSafety newsletter issue with an article introducing the GeoNet project [Zhang2009a]. INRIA participated to the design of the COMeSafety architecture version 2.0 [COMeSafety2008] and version 3.0 [COMeSafety2010] where GeoNet is described and mentioned in a few locations throughout the document. INRIA also participated to the 5th International Workshop on Vehicular Communication co-located with the 16th ITS World Congress in Stockholm (2009).

10.6 C2C-CC

The **Car-to-Car Communication Consortium** (**C2C-CC**) is a European industry consortium of car manufacturers and equipment vendors aiming at the development and release of an open European standard for co-operative Intelligent Transport Systems and associated validation process on V2V and V2I communications systems. C2C-CC has made technical specification on V2V and V2I communications, mainly limited to single-hop communication, which is the basis of GeoNet specification. GeoNet uses the common network header defined by C2C-CC and further extends it with specifications for multi-hop communications.

GeoNet contribution: GeoNet partners are very active in C2C-CC, where they keep on promoting GeoNet output. The GeoNet specification is considered in C2C-CC as complementary of their basic specification. GeoNet partners who are very active in C2C-CC keep referring to GeoNet whenever the opportunity is given. NEC has contributed an article “Vehicular ad hoc networks research and standardisation in Europe” in AHSNTC Newsletter in 2008 [Festag2008]. INRIA has provided input on how the sub-IP GeoNetworking layer (i.e. C2CNet) could be integrated in the ISO CALM architecture [ISO-21217] and gave an overview talk about GeoNet at the C2C-CC Forum 2009. IMDEA Networks has been working on the requirements of traffic safety applications in the context of the IETF. This work was presented to the C2C-CC COM WG.

Annex A: Acknowledgements

The following people have contributed to this GeoNet document, by alphabetical order:

- Carlos J. Bernardos – IMDEA Networks
- Maria Calderon – IMDEA Networks
- Thierry Ernst – INRIA
- Maria Goleva - NEC
- Andras Kovacs - Broadbit
- Massimiliano Lenardi – Hitachi Europe
- Wilfried Lohmann - Lesswire
- Hamid Menouar – Hitachi Europe
- Carsten Schulze - Lesswire
- Wenhui Zhang - NEC

Annex C: Terminology & Acronyms

The terminology used in this document is divided into three main families: GeoNet newly defined terms, IPv6 terms and generic networking terms.

C.1 GeoNet terms

- **Application Unit (AU):** An in-vehicle or road-side entity and runs applications that can utilise the OBU's or RSU's communication capabilities, respectively. Examples of AUs are i) a dedicated device for safety applications like hazard-warning, ii) a navigation system with communication capabilities, iii) a nomadic device such as a PDA that runs Internet applications.

- **GeoNet domain:** an ad-hoc domain, also referred to as Vehicular Ad hoc Network (VANET), which is composed of GeoNet nodes (i.e. GeoNet OBUs, GeoNet RSUs) and C2C nodes (i.e. C2CNet OBUs and C2CNet RSUs) and their attached nodes.

- **GeoNet nodes**: nodes implementing GeoNet extensions, i.e. nodes implementing the C2CNet layer or the Management layer or both.

- **GeoNet OBU (On-Board Unit):** A C2CNet OBU which implements IPv6 basic operations and C2CNet layer capabilities. It is an IPv6 router with at least an egress interface (GeoNet interface) and an ingress interface serving other IPv6 nodes. A GeoNet OBU is likely equipped with other network devices in order to allow communications with an infrastructure network. A GeoNet OBU acts as an IPv6 Mobile Router or a VANET IP router.

- **GeoNet RSU (Road-Side Unit)**: A C2CNet RSU which implements IPv6 basic operations and C2CNet layer capabilities. It is an IPv6 router with at least one egress interface (C2CNet interface) and one ingress interface serving other IPv6 nodes. A GeoNet RSU is likely equipped with other network devices in order to allow communications with an infrastructure network. A GeoNet RSU can act as an IPv6 Access Router or a VANET IP router.

- **GeoDestination**: a destination corresponding to a specific geographic area e.g. “all vehicles in 1km range” or “all vehicles located in an area defined by latitude and longitude”.

- **IPv6 GeoNetworking**: the combination of C2C-CC's GeoNetworking together with IPv6 into a single protocol architecture.

- **C2C-CC**: CAR 2 CAR Communication Consortium is a non-profit organisation initiated by European vehicle manufacturers, which is open for suppliers, research organisations and other partners. The CAR 2 CAR Communication Consortium is dedicated to the objective of further increasing road traffic safety and efficiency by means of inter-vehicle communications. [1]

- **C2CNet nodes:** nodes implementing C2CNet layer functions, i.e. C2CNet OBUs and C2CNet RSUs.
- **C2CNet OBU (On-Board Unit)**: a physical device located in a vehicle and responsible for Vehicle-to-Vehicle and Vehicle-to-Infrastructure communications. It also provides communication services to AUs and forwards data on behalf of other OBUs in the GeoNet domain. A C2CNet OBU must implement C2CNet layer capabilities and is equipped with at least a network device for short range wireless communications based on IEEE 802.11p* radio technology. The C2CNet OBU acts as a VANET non-IP router.
- **C2CNet RSU (Road-Side Unit)**: a physical device located at fixed positions along roads and highways, or at dedicated locations such as gas station, parking places, and restaurants. A C2CNet RSU must implement C2CNet layer capabilities and is equipped with at least a network device for short range wireless communications based on IEEE 802.11p* radio technology. A C2CNet RSU is likely equipped with other network devices in order to allow communications with an infrastructure network. The C2CNet RSU acts as a VANET non-IP router.
- **C2CNet layer**: Maintains the information about communication peers by using location-based routing, beaconing and location service. The layer is seen as a link layer from the point of view of IPv6.
- **C2CNet link:** a virtual link with multi-hop GeoNetworking capabilities on which all GeoNet OBUs and GeoNet RSUs in a GeoNet domain are able to communicate at the IPv6 layer.
- **C2CNet neighbours**: Nodes which can communicate directly with one another over the wireless link, i.e. IEEE 802.11p.
- **C2CNet packet**: A specific packet format used by C2CNet layer. Forwarded by using position based routing with the information in C2CNet header.

C.2 IPv6 networking terms

- **Legacy IPv6 node**: An IPv6 node that conforms to RFC 4294 (IPv6 Node Requirements) and functions without additional IPv6 networking capabilities. In IPv6 GeoNetworking, legacy IPv6 nodes must continue to function and interact with GeoNet nodes.

- **IPv6 mobile network**: An IPv6 subnetwork - or an entire set of IPv6 subnetworks moving as a unit - which dynamically changes its IPv6 point of attachment to the Internet and thus its reachability in the topology.

- **IPv6 Access Router**: An IPv6 router residing on the edge of an Access Network and connected to one or more Access Points. The Access Points may be of different technology. An Access Router offers IP connectivity to Mobile Nodes, acting as a default router to the Mobile Nodes it is currently serving. The Access Router may include intelligence beyond a simple forwarding service offered by ordinary IP routers.

C.3 Generic networking terms

- **Ad hoc network:** Communication network which is set up by the communication nodes (peer-to-peer) without any pre-installed fixed infrastructure.

- **V2V (Vehicle-to-Vehicle) communication**: Communication between two vehicles.

- **V2I (Vehicle-to-Infrastructure) communication**: Communication between a vehicle and the infrastructure.

- **I2V (Vehicle-to-Infrastructure) communication**: Communication between the infrastructure and a vehicle.

- **Unicast**: A means of transmitting a message from one source to one specific destination.

- **Multicast**: A means of transmitting a message from one source to several destinations.

- **Anycast**: A means of transmitting a message from one source to one un-specified destination.

- **Broadcast**: A means of transmitting a message to all nodes connected to a network. Normally, a special address, the broadcast address, is reserved to enable all the devices to determine that the message is a broadcast message.

- **GeoNetworking**: Network service that utilises geographical positions and provides ad hoc communication without the need for a coordinating communication infrastructure (definition taken frol [ETSI-TS-102-636-3])

- **Geocast**: A means of transmitting a message to a designated geographical area. GeoBroadcast and GeoAnycast are geocast communication means.

- **GeoBroadcast**: A means of transmitting a message from one source to all nodes located within a certain geographical area. The area is defined by the sender and transmitted with the data packet control information.

- **GeoAnycast**: A means of transmitting a message from one source to one un-specified destination located within a certain geographical area. The area is defined by the sender and transmitted with the data packet control information.

- **GeoUnicast**: A means of transmitting a message from one source to one specific destination located within a certain geographical area.

- **TopoBroadcast**: Refers to the routing protocol which, based on network topology information, routes data from a source node to all nodes located at a specific distance, in terms of hops.

- **1-Hop Broadcast**: To send a data packet to all direct neighbours of a node. No further forwarding of that data packet is applied.

- **Geo-routing**: Geographic position and movement information of vehicles are used to route data.

- **SAP**: Service Access Point (SAP) is an identifying label for network endpoints used in OSI networking.

- **Location**: Position of a node and time at which this position was taken.

- **IEEE 802.11p**: Is a draft amendment to the IEEE 802.11 standard to add wireless access in the vehicular environment (WAVE). It defines enhancements to 802.11 required to support Intelligent Transportation Systems (ITS) applications. This includes data exchange between high-speed vehicles and between the vehicles and the roadside infrastructure in the licensed ITS band of 5.9 GHz (5.85-5.925 GHz). IEEE 1609 is a higher layer standard on which IEEE 802.11p is based.

- **ITS-G5:** Is the functionality of an ITS Station as defined in [ETSI-ES-202-663] for physical layer, medium access control sub-layer and extensions to handle parameters of these layers, including the related management. ITS-G5 distinguishes several frequency ranges in European ITS frequency band.

- **ITS-G5A:** Is the operation of ITS-G5 in European ITS frequency bands dedicated to ITS for safety related applications in the frequency range 5,875 GHz to 5,905 GHz as defined by [ETSI-ES-202-663]

- **ITS-G5B:** Is the operation of ITS-G5 in European ITS frequency bands dedicated to ITS non- safety applications in the frequency range 5,855 GHz to 5,875 GHz as described by [ETSI-ES-202-663]

Annex D: References

[COMeSafety2008] European ITS Communication Architecture - Overall Framework - Proof of Concept Implementation. Draft Version 2.0, COMeSafety Specific Support Action, October 2008.

[ETSI-TS-102-636-1] ETSI. “Intelligent Transportation Systems (ITS); Transport & Network: Vehicular Communications; GeoNetworking and Data Transport; Part 2: Requirements for GeoNetworking”. ETSI, V0.3.1 Work in Progress, September 2009.

[ETSI-TS-102-636-2] ETSI. “Intelligent Transportation Systems (ITS); Transport & Network: Vehicular Communications; GeoNetworking and Data Transport; Part 2: Scenarios for GeoNetworking”. ETSI, V0.3.1 Work in Progress, September 2009.

[ETSI-TS-102-636-3] ETSI. “Intelligent Transportation Systems (ITS); Vehicular Communications; GeoNetworking and Data Transport; Part 3: Network Architecture”. ETSI, V0.5.9 Work in Progress, September 2009.

[ETSI-TS-102-636-4-1] ETSI. “Intelligent Transportation Systems (ITS); Transport & Network: Vehicular Communications; GeoNetworking and Data Transport; Part 4: “Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Subpart 1: Media independent functionalities.

[ETSI-TS-102-636-4-2] ETSI. “Intelligent Transportation Systems (ITS); Transport & Network: Vehicular Communications; GeoNetworking and Data Transport; Part 4: “Geographical addressing and forwarding for point-to-point and point-to-multipoint communications; Subpart 2: Media dependent functionalities for 5 GHz media (5,9 Ghz)”

[ETSI-ES-202-663] ETSI “Intelligent Transport Systems; European profile standard on the physical and medium access layer of 5 GHz ITS” ETSI ES 202 663 V<0.0.6> Draft for member approval, October 2009.

[ETSI-TS-102-665] ETSI. “Intelligent Transport Systems (ITS); Vehicular Communications; Architecture”. ETSI, Work in Progress, December 2009.

[GeoNetD1.2] GeoNet. “Final GeoNet Architecture Design”. GeoNet Deliverable D1.2, January 2010.

[GeoNetD2.2] GeoNet. “Final GeoNet Specification”. GeoNet Deliverable D2.2, January 2010.

[GeoNetD3.1] GeoNet. “GeoNet Development Results”. GeoNet Deliverable D3.1, January 2010

[GeoNetD4.1] GeoNet. “GeoNet Conformance Test Plan and Results”. GeoNet Deliverable D4.1, January 2010.

[GeoNetD5.1] GeoNet. “GeoNet Emulation Environment Results” GeoNet Deliverable D5.1, January 2010.

[GeoNetD6.1] GeoNet. “GeoNet Porting and Integration Guideline” GeoNet Deliverable D6.1, January 2010.

[GeoNetD7.1] GeoNet. “GeoNet Experimentation Results” GeoNet Deliverable D7.1, January 2010.

[GeoNetD8.2] GeoNet. “GeoNet Dissemination and Use Plan” GeoNet Deliverable D8.2, February 2010.

[GeoNetD8.3] GeoNet. “GeoNet Handbook” GeoNet Deliverable D8.3, February 2010.

[GeoNetDoW] GeoNet. Grant agreement no.: 216269. Grant agreement for small or medium-scale focused research project - STREP - CP-FP-INFSO. Annex I - “Description of Work”, Date of approval of Annex I by European Commission: November 10, 2007.

[GeoNet-Integration] A. Edelmayer, H-J. Fischer, W. Lohmann, A. Simon “Meeting Minutes – How to integrate GeoNet in ITS architecture”. Document version 1.1, 21 January 2010. GeoNet internal document.

[IEEE802.11p] IEEE “Draft 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; Amendment 7: Wireless Access in Vehicular Environments”. IEEE P802.11pTM/D9.0

[ISO-21210] ISO TC204 WG16. “Intelligent Transport Systems – Communication for Land Mobiles (CALM) – IPv6 Networking”. ISO FDIS specification 21210, ISO, October 2009. Work in progress.

[ISO-21215] ISO DIS 21215:2009, “Intelligent Transport Systems – Communications access for land mobiles (CALM) – M5”. ISO FDIS specification 21215, ISO, October 2009. Work in progress.

[ISO-21217] ISO TC204 WG16. “Intelligent Transport Systems – Communication access for land mobiles (CALM) – Architecture”. ISO FDIS specification 21217, ISO, October 2009. Work in progress.

[Karagiannis2009] G. Karagiannis, R. Wakikawa, J.Kenney and C. J. Bernardos “Traffic safety applications requirements”, IETF Internet-draft, draft-karagiannis-traffic-safety-requirements-01, October, 2009.

[Lee2009] J.-H. Lee, M. Tsukada, T. Ernst “Mobile Network Prefix Provisioning”, IETF Internet-Draft, draft-jhlee-mext-mnpp-00.txt, October 2009. Work in progress. Presented at the IETF in November 2009 (http://tools.ietf.org/agenda/76/slides/mext-6.pdf)

[Zhang2009a] W. Zhang, “GeoNet: Geographic addressing and routing for vehicular communications”, COMeSafety Newsletter Issue 6. January 2009.