GeoNet:
a project enabling Active Safety and IPv6 vehicular applications

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***Abstract*— Next generation vehicles are expected to exchange information with other non-LOS vehicles, the road infrastructure and databases in the Internet in order to increase road safety and traffic efficiency, or simply to entertain passengers.**

In this context, the mutual knowledge of positions and trajectories is necessary and is only meaningful to vehicles in a particular geographic area - potentially far away from the information source. It requires reliable and scalable communication capabilities which we refer to as geographic addressing and routing (geonetworking).

The TCP/IP protocol suite provides a unification layer between various physical communication technologies and various types of applications. A wide deployment of invehicle/onboard Internet access and services to millions of vehicles will only be possible with IPv6, the latest version of the Internet Protocol.

However, geonetworking and IPv6 need still to be combined efficiently, which corresponds to GeoNet project target, i.e. to have a single communication architecture, referred as "IPv6 geonetworking". It will allow for both IPv6 and non-IPv6 communications and will effectively provide a path to new and outstanding applications requiring data transmission to explicit geographical areas.

GeoNet aims at developing a reference specification of "IPv6 geonetworking", with active participation in standardization bodies such as ETSI TC ITS, ISO TC204 WG16 (CALM) and IETF.

I. Introduction

THE GeoNet project [1] started on 1st February 2008 and is an initiative launched by a group of industrial partners and research labs heavily involved in the design and deployment of vehicular communication and its application.

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To increase the road safety in Europe while traffic and driver's concentration demand also rises, the European Commission and the automotive industry have committed to halve the life loss by 2010. The GeoNet project will significantly contribute to this goal by implementing a reference specification of a geographic addressing and routing protocol with support for IPv6 to be used to deliver safety messages between cars but also between cars and the roadside infrastructure within a designated destination area.

While the Car-2-Car Communication Consortium (C2C-CC, [2]) has invested significant effort into the specification of a car-to-car communications mechanism suitable for safety applications, its mandate does not extend beyond defining a specification. At the same time, past projects like "Network on Wheels" (NoW, [3]) and ongoing projects like SafeSpot ([4]) would need an actual implementation to rely on whereas other such as CVIS [5] are developing a communication architecture relying on the maintenance of a constant access to the Internet over IPv6.

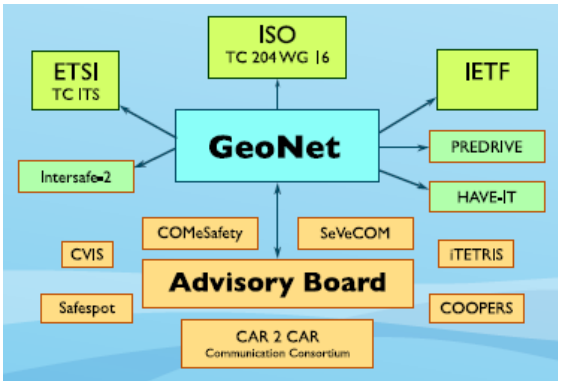
GeoNet (Geographic addressing and routing for vehicular communications) shall bring the basic results from the work of the C2C-CC to the next step, by further improving these specifications and creating a baseline software implementation interfacing with IPv6. The goal of GeoNet is thus to implement and formally test a networking mechanism as a standalone software module which can be incorporated into Cooperative Systems. This implementation shall enable transparent IP connectivity between a vehicle and the infrastructure, even in cases when delivery must be hopped over several vehicles or cached along the way. GeoNet not only benefits from previous work within these projects, but also will provide a support for the integration of its solution. This collaboration is sketched in support letters.

Once GeoNet fulfils the existing implementation gap of geo-addressed networking, ongoing and future projects for Cooperative Systems can maintain their focus on architecture design, application development and field trials.

II. GeoNet genesis

The genesis of GeoNet lies in the simple observation by technical partners of several consortia involved in both V2V and V2I vehicular communications (COMeSafety [6], SafeSpot, CVIS, COOPERS [7], SeVeCom [8], C2C-CC, ANEMONE [9], …) that there is a high risk of technological divergence in their respective implementations, coming from different objectives. Such common partners are HITACHI Europe, NEC Europe, INRIA (the Project Coordinator), EFKON, BroadBit, Lesswire, and Fundación IMDEA. The GeoNet consortium is a therefore a well-balanced European consortium with 7 partners from 6 different countries including one of the new member states of the EC, It also reflects a well balanced typology comprising, as it does, of 2 Research Institutes, 1 SME and 4 industrial partners.

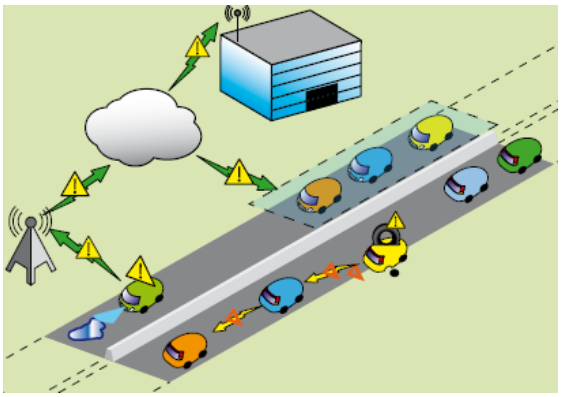
The GeoNet Partners decided to take the opportunity of a well suited European Commission FP7 ICT call to propose a solution to this potential divergence: the development, the standardization and the implementation of a geographic addressing and routing (geo-networking) IPv6 compliant module. GeoNet will keep close ties to other consortia and projects, interacting with the key European automotive players through an Advisory Board and the membership of some GeoNet partners in those entities.



Therefore, GeoNet is an opportunity to deliver a high quality, focused and very useful contribution to vehicular communications with a maximal impact.

III. GeoNet concepts

Originally, geographic addressing and routing algorithms have been considered for the delivery of safety messages between vehicles and between vehicles and the roadside infrastructure in a geographically bounded region.



Once combined with IPv6 the applicability of geo-networking is not limited to safety applications. It will also enable locally relevant dissemination of traffic control commands aimed at reduction of traffic congestion and locally relevant dissemination of multimedia services. The combination of geo-networking with IPv6 will also guarantee the interoperability of services and applications with dissemination means other than geo-networking. So, in addition to decreasing road fatality and injury in accidents, it will also reduce the number of traffic jams and create new business markets. Hence, the project will indirectly contribute to reduce the environmental pollution by reducing the ineffective waiting time in traffic jams. Moreover it will reduce the cost for road construction since electronic safety control systems can eventually increase the traffic density without decreasing the safety situation. As a side effect, this will strengthen the position of the European automotive industry.

GeoNet is thus committed to address this gap by combining geonetworking and IPv6 into a single communication architecture that we refer to as IPv6 geonetworking. The combination of geonetworking and IPv6 will allow for both IPv6 and non-IPv6 communications. This will, effectively, open the door for the development of new applications that require data to be transmitted to explicit geographical areas.

IV. GeoNet realization

The GeoNet concept will be realized via 3 main axes:

- **Knowledge**: GeoNet will elaborate, from existing knowledge, a unified geo-networking solution compliant with best practices in vehicular communications;
- **Standards**: GeoNet will produce a reference geo-networking specification and push it in standardization organizations (particularly IETF, ISO and ETSI);

- **Software**: GeoNet will produce two prototype implementations and will disseminate them to existing consortia and projects (particularly SafeSpot, CVIS, COOPERS, C2C-CC, HAVE-IT [10], PRE-DRIVE C2X, iTETRIS; the latter 2 started on 1st July 2008).

The reason is that these prototype implementations are needed by the industry, but must be standardized, modular, and providing the convergence of several state of the art communication means for automotive applications.

Standardization is a necessary step for wide dissemination of any technology, particularly at the network layer and in IPv6. Consequently, GeoNet aims to develop a reference specification of IPv6 geonetworking. This will be achieved through active participation in standardization bodies such as ETSI TC ITS, ISO TC204 WG16 (CALM) and IETF. Two independent Linux-based prototype implementations will be developed to ensure the completeness and unambiguity of the GeoNet reference specification. This will ensure greatly enhanced software quality and stability. Implementations will be platform-independent and will be easily incorporated into different cooperative architectures. It will enable subsequent large-scale field operational trials (FOT) and facilitate the future development of more complex functionalities.

The compliance of implementations with GeoNet specifications and their expected performance, scalability and efficiency will be assessed against well-known ETSI and ISO/IEC Standards. This will be done during conformance tests and field trial experiments conducted using actual vehicles. An emulation environment including emulated and real radio modules will be developed to validate implementations in scenarios traditionally too complex to be performed in field tests.

V. GeoNet Technical approach

"Geographic addressing and routing" is a networking mechanism distributing the information to nodes within a designated destination area. Routing protocols and algorithms are in charge of information dissemination over multiple hops until every vehicle has received this information within the destination area. Each vehicle evaluates whether re-transmission is required and executes it with proper timing if needed. In this concept, individual nodes' addresses are linked to their geographical position which is used by forwarding algorithms to transport data packets towards the destination node ("geographical unicast" or "geounicast"). Also, geographical positions are used to define a geographical region that can be linked to nodes, either to address all nodes in the region ("geographical broadcast" or "geocast") or to address anyone of the nodes in the region ("geographical anycast" or "geoanycast"). Key algorithms of the specified geo-networking layer have been verified through simulation tools and drive tests. The next step is therefore actual software implementation of network layer specifications. Though there are existing and proprietary implementations of geographic addressing and routing, there is no standardized specification. Existing implementations are therefore diverging.

The TCP/IP protocol suite provides a unifying layer between various physical communication technologies and various types of applications used in different contexts and environments. A wide deployment of in-vehicle onboard Internet access and services to millions of vehicles certainly will only be possible with IPv6, the latest version of the Internet Protocol. However, geonetworking is still lacking in IPv6.

GeoNet is seeing vehicles as a network made of several communication nodes. A typical in-vehicle network comprises:

- An on-board unit (OBU) functioning as a mobile router in charge of communications with other vehicles, road-side units (RSUs) and computers located in the Internet;
- A number of application units (AUs) such as a dedicated device for safety applications like hazard-warning, a navigation system with communication needs, a nomadic device such as a PDA that runs Internet applications, or infotainment devices.

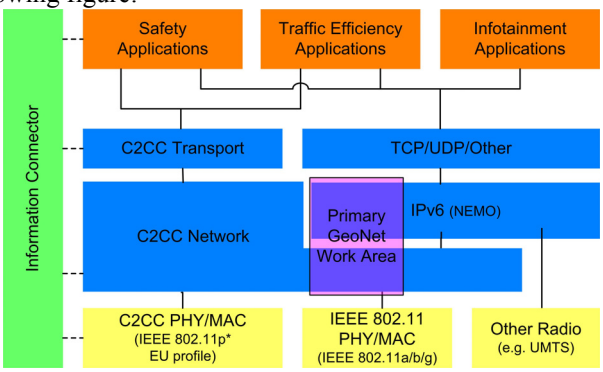
Several interfaces of various radio types will be available on the OBU. GeoNet will principally use IEEE 802.11p for its experiments but the communication architecture will not preclude any other communication media.

The OBU is in charge of maintaining Internet connectivity (using NEMO) and takes routing decisions, like maintaining routing paths with other vehicles (a georouting functionality efficient under fast changing topology without excessive amount of air interface signaling), deciding through which interface a particular flow should be transmitted (policy routing), etc.

GeoNet is structured in seven technical work packages, comprising all the usual design steps from architecture, specification, implementation, conformance testing,

emulation environment, porting to a target platform, and experimental validation.

The GeoNet protocol Architecture is depicted in the following figure:



GeoNet starts its work from the Car 2 Car Communication Consortium (C2C-CC) protocol stack which includes IEEE standards, IETF TCP/IP standards, and ITS-specific IP and non- IP protocol blocks (see picture above). The IPv6 protocol suite and past, unfruitful efforts on IPv6 geonetworking are then analyzed to identify the necessary protocol functionalities so that geonetworking is combined with IPv6. A thorough security threat analysis is conducted by investigating the impact of traditional attacks on vehicles operating IPv6 geonetworking.

The GeoNet reference specification will include:

- The geonetworking protocol with mandatory and compulsory functionalities.
- A transparent bridging adaptation layer between geonetworking and IPv6 networking protocols.

VI. Hitachi's Contributions to GeoNet

Hitachi Europe's Information and Communication Technologies Laboratory (ICTL), part of the European R&D Group (ERD) of Hitachi Europe Limited, is focusing in the following areas: Mobile Communications (automotive technologies included), Security of Communications and Next Generation Networks. ICTL has the ability in a truly international context to develop together with both governmental and industrial organizations cutting edge telecommunication technologies. ICTL is developing next generation network architectures targeting standardization and applications. The *Cooperative Systems Team* of ICTL actively contributes to standardization for vehicular communication, such as in C2C-CC and in ETSI where Hitachi Europe is Member.

Hitachi Europe is contributing to several work packages in GeoNet. The technical experience acquired during our activity within C2C-CC, where we actively contribute providing research solutions and ideas, and during other ITS-related activities in Europe and in Japan, is emerging once more during the GeoNet project. Hitachi will strongly contribute in the Implementation (WP3) and in the Emulation (WP5, Leadership) working packages, while supporting most of the other working packages, in particular for the GeoNet specifications.

ICTL is indeed working at different OSI layers, from the Applications down to the Medium Access Control (MAC) protocols. At the Physical and MAC layers we are supporting the IEEE 802.11p standard, which is an evolution of the 11a standard. 11p is still under development and is also called the Wireless Access in Vehicular Environments (WAVE). Event-driven safety messages are the result of an unsafe situation; therefore they should have higher priority than periodic preventive messages, which should themselves have higher priority than comfort messages. That is why the MAC layer for VANETs should implement some mechanisms for service differentiation and admission control [11]. C2C-CC's goal is to define a European standard for vehicular communication based on a slightly modified 802.11p covering European spectrum requirements.

At the Network OSI layer, ICTL conceived, developed and is optimizing and implementing two algorithms: MHVB ([12] - [14]) and MOPR ([15] - [18]), which are cooperating with other protocols and services like the Location or the Anycast Services.

At the Application layer, ICTL is developing prototypes of Advanced Navigation Systems which include communication capabilities and of Travel Time Management. As an overall topic, ICTL is also collaborating for the securization of vehicular communications [19].

Finally, ICTL is also developing an enhanced Network Simulator (NS2), which includes the 2 above algorithms for simulating and analyzing their performance with dedicated applications [20], and a test-bed running VANET technologies with vehicles and dedicated devices.

VII. Conclusion

GeoNet is a really focused project, concentrating many expectations – scientifically and technologically – but also very promising. The goal of this project is not to solve all challenges, but to define precisely the problem and bring a partial solution made of the specifications (that will be submitted to the relevant organizations for standardization),

two implementations that will be tested and experimented into vehicles. The Partners believe these implementations will be mature enough to be used in the numerous partners and ultimately industrialized and sold in the future communications devices that will equip future cars.

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