Enabling IP geomulticast services for vehicular networks

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***Abstract*— The main purpose of Vehicular networks is to improve safety and traffic efficiency. Geographic addressing and routing is currently the basic architecture solution adopted in most vehicular architectures and standards. However, it is also required that these vehicular architectures support the provision of additional IP based services and applications. One of these services is geo-enabled IP multicast, allowing to send traffic to some specific user groups within a geographic destination area; this is known as IP geomulticast. This paper presents a solution that allows the deployment of IP geomulticast services over the standardised architecture of the Car-to-Car Communication Consortium.**

***Keywords:* multicast, geographic addressing and routing, VANET, C2C-CC, IPv6**
***Submission area:* Naming/addressing, (IPv6 addressing scheme and mobility)**

I. Introduction

Vehicular networks have received a lot of attention in the last years, governments and automotive industries see them as the key to reduce the number of accidents and improve traffic efficiency. The idea is that vehicles and roadside equipment should collect and distribute information in order to improve safety, make possible an early response against complications, get better traffic efficiency and even improve the driving experience.

There are several standardisation efforts such as the Car to Car Communication Consortium (C2C-CC) [1], ISO CALM [2] and ETSI TC ITS which objective is to create and establish standards for communication systems based on wireless LAN which guarantee inter-vehicle operability. These standards are also expected to provide IPv6 support for non-safety and Internet-based applications. For safety applications, they provide geographic addressing and routing functionalities, however, these functionalities are also available for IP-based applications.

In order to provide these location-based functionalities for IP applications it is necessary that applications have some kind of location awareness and a mechanism which translates from IP addressing to geographic addressing. This paper presents a solution that allows the deployment of IP geomulticast services, i.e., aplications are able to send IP multicast traffic to some specific user groups within a geographic destination area.

The rest of the paper is organized as follows. Section II is devoted to the problem statement, describing the requirements of a solution which guarantees inter-vehicle operability. The proposed solution is described in Section III. Section IV provides a quantitative evaluation of the solution. The related work is presented in Section V. Finally, Section VI concludes the paper.

II. Problem Statement

According to the C2C-CC architecture, vehicles are equipped with an On Board Unit (OBU) and potentially multiple Application Units (AUs).

An OBU is a device that implements automotive communication protocols and is equipped with at least a short-range wireless network interface for external communications and with a wireless or wired network interface for connecting internal devices.

An AU is a device connected to the OBU that supports IPv6 standard protocol stack. An AU typically executes a set of applications and utilises communication capabilities of the OBU. It can be an in-vehicle embedded device or a portable device that connects to the OBU temporarily.

Road Side Units (RSU) are devices installed along roadsides that support the same protocols as OBUs. An RSU may be connected to a network infrastructure (i.e., Internet) and act as a gateway for nearby vehicles.

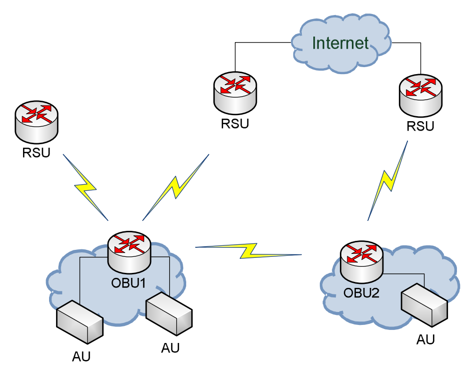

Fig. 1 - C2C-CC Reference Architecture

The reference architecture of C2C-CC is shown in Fig. 1.

OBUs and RSUs form a vehicular ad hoc network (VANET) which is a self-configured network with decentralised medium access control and dynamic network topology. OBUs and RSUs can communicate directly or, in case of no direct connectivity, indirectly using other OBUs or RSUs as relays. This communication is performed using geographic routing, i.e., using location information in order to find the optimal route between two nodes of the network. In the C2C-CC architecture, this geographic routing and addressing is provided by the C2C-CC Network layer.

IP-based applications are supported in this architecture by tunnelling the IPv6 packets over C2C-CC Network protocol packets. From the IPv6 layer perspective other OBUs and RSUs appear as directly connected to the same link, i.e., they are reachable within one single hop. The protocol architecture is shown in Fig. 2.

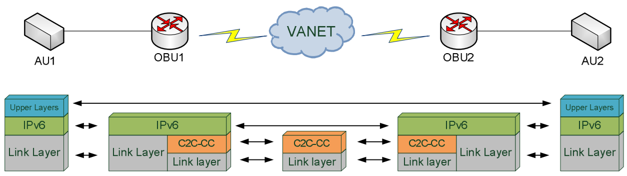

Fig. 2 - IP-based application communication

In this scenario, an IP-based application running in an AU that wants to send information to a geographical area needs to specify somehow the geographic destination to the OBU using the IP protocol stack. This is necessary in order to transfer this information from the AU to the OBU, which is the only device that can perform geographic routing (i.e., AUs do not implement C2C-CC protocol).

The proposed service would enable an AU to send IP traffic to a multicast group that is scoped by a geographic destination area. The usage of IP multicast and geographic routing limits the forwarding to the multicast group receivers within a geographic area, and this is why we call this service: *IP geomulticast*.

The challenges here are to support geomulticast and design a mechanism that allows AUs, which are devices only with IPv6 support (not involved in the geographic routing themselves), to address nodes within a certain geographic area.

A. Requirements

The proposed solution must satisfy these requirements:

• To be as IP standard as possible. In order to guarantee inter-vehicle operability, the solution should not require strong modifications to the IP stack of the involved components.

• To introduce minimum overhead in the radio interface. Due to the throughput constraints of the radio interface, the solution overhead should be reduced as much as possible.

• Not to require modifications in the AUs. AUs can be new in-vehicle embedded devices but also laptops or PDAs – which are IP standard legacy devices – temporarily connected to the OBU. The solution must allow these devices to communicate without performing any modifications in their protocol stack.

III. SOLUTION DESCRIPTION

In this section a description of the solution for providing IP geomulticast services for vehicular networks is given. First three alternatives for using this geographic addressing on IP are proposed. A binary encoding format, required by one of the approaches, is also introduced and explained.

A. Alternatives for encoding geographic information on IP packets

When the AU wants to send IPv6 multicast traffic to a geographic area, the geographic information needs to be encoded into the IPv6 packet until it reaches the source OBU. Three alternatives have been considered:

1) Encoding geographic information into the IPv6 Tunnel destination address (an IP multicast address)

The first alternative is to encode the geographic addressing information into the IPv6 destination field of an IPv6 multicast tunnel originated at the AU as seen in Figure 3.

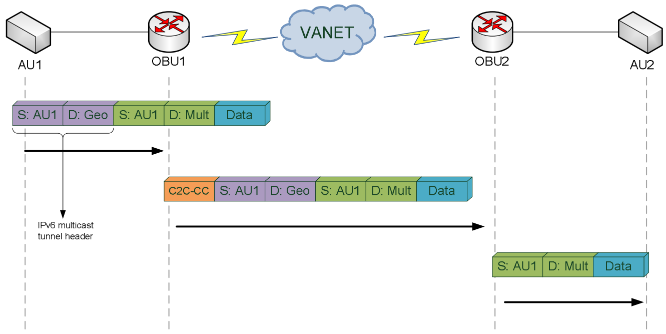

Fig. 3 – Approach A: Encoding geographic information into IPv6 Tunnel destination address (an IP multicast address)

The source AU (AU1) tunnels the IPv6 multicast packet, the one destined to a multicast application group (`Mult`), into an IPv6 multicast packet whose destination address contains (embedded) the destination geographic area (`Geo`). When the source AU's OBU (OBU1) receives the packet, it checks the IPv6 destination address field and recognises that the address corresponds to a geographic area. Therefore it translates this `Geo` information into the geographic information to be used when forwarding the packet at the C2C-CC layer.

Then the packet is forwarded at the C2C-CC layer until it reaches the destination geographic area. OBUs at this area (e.g., OBU2) process the packet and deliver it to the upper layer (the IPv6 layer) which checks if the IPv6 multicast address of the outer header corresponds to an IPv6 multicast group the OBU is subscribed to.

This solution requires the mapping between the geographic area and the IPv6 multicast address to be univocal, i.e., relative definition of a geographic area, e.g., 200 meters around the vehicle, is not allowed because although it works at the geographic routing layer, at the IP layer, destination nodes cannot be subscribed to a sender-relative address.

To cope with this issue, the geographic addressing at IPv6 layer has been limited to predefined squares of fixed length. In order to provide granularity, squares of different size have been defined. How to binary encode the geographic information and square identification is explained in Section III.B.

When a destination OBU receives the packet at the IPv6 layer, it extracts the IPv6 multicast packet from the tunnel and forwards it to the corresponding AUs subscribed to the IPv6 destination address of the inner packet.

Benefits

• At OBUs the IPv6 behaviour is the standard one, they forward packets at the lower layer according to upper layer destination address (as MAC multicast does with IP multicast), i.e., OBUs map IPv6 destination to the C2C-CC Network layer destination directly.

Drawbacks

• Destinations need to subscribe to IP multicast addresses which are location dependent addresses. Therefore relative definition of geographic areas is not allowed.

• Destination geographic areas are limited to a set of predefined squares of fixed length. Nevertheless, some granularity can be provided by defining squares of different size.

• Radio interface overhead. Geographic destination is transported two times, one at C2C-CC Network layer and one at the IPv6 tunnel.

2) Encoding geographic information into an IPv6 Extension Header

The second alternative is to encode the geographic addressing information in an IPv6 extension header field of the IPv6 multicast packet originated at the source AU as shown in Fig. 4.

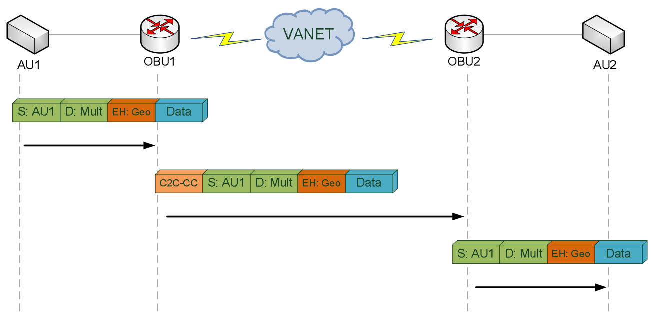

Fig. 4 – Approach B: Encoding geographic information into an IPv6 Extension Header

The source AU (AU1) introduces a Hop-by-Hop Option extension header with the geographic information in the IPv6 multicast packet. When the packet reaches the source AU's OBU (OBU1), the extension header is processed (the processing of Hop-by-Hop headers at every hop is mandatory in IPv6) and from it the OBU obtains the geographic information that needs to forward the packet to the destination.

The packet is then forwarded from the source OBU (OBU1) to the destination OBUs (e.g., OBU2) using geographic routing (i.e., C2C-CC network layer). When the packet reaches an OBU at the destination area, the C2C-CC Network protocol sends the packet to the IPv6 layer which, in case that there are AUs in its internal network that are subscribed to the IPv6 multicast group, forwards the IPv6 multicast packet to them..

Encoding the geographic information into an IPv6 extension header allows using relative geographic addressing because this relative information is only used at the source AU's OBU (which translates it into absolute position information at the C2C-CC Network layer). However, forwarding using an extension header instead of the destination address field is not the common behaviour of IPv6. This does not break IP behaviour because only introduces changes at the OBU forwarding process.

Benefits

• Allows relative geographic addresses (e.g., 200 meters around the vehicle).

Drawbacks

• Uses a Hop-by-Hop Option extension header, this header is processed at every node although its information is only necessary at the source AU's OBU.

• Uncommon behaviour at OBUs' IP layer. OBU uses an extension header to obtain the sub-IP layer destination address.

• Radio interface overhead. Geographic destination is transported two times, one at C2C-CC Network layer and one at the extension header.

3) Encoding geographic information into IPv6 Extension Headers of an IPv6 Tunnel from AU to OBU

The third alternative is to encode the geographic addressing information into an IPv6 extension header field of an IPv6 tunnel originated at the source AU with destination AU's OBU as shown in Fig. 5.

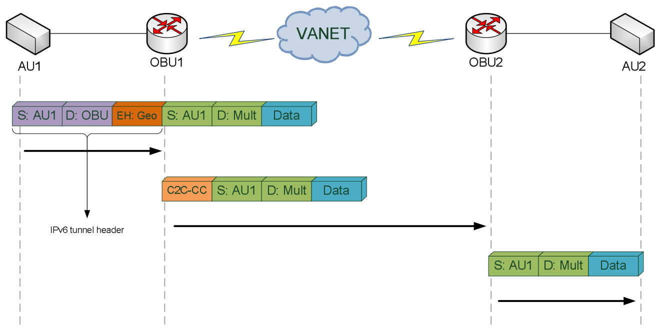

Fig. 5 – Approach C: Encoding geographic information into IPv6 Extension Headers of an IPv6 Tunnel from AU to OBU

The source AU (AU1) tunnels the IPv6 multicast packet, the one for a multicast application group, into an IPv6 packet which destination address is the source AU's OBU (OBU1) and introduces the destination geographic area as a Destination Option extension header of the outer packet. When the source

OBU receives the packet obtains the geographic information from the extension header and removes the tunnel, forwarding the IPv6 multicast packet over geographic routing (i.e., at C2C-CC network layer) without introducing any additional overhead.

As in the second solution, the source AU's OBU forwards the packet using an extension header instead of the destination address thus this solution also forces an uncommon IPv6 behaviour at the OBUs.

Benefits

- Allows relative geographic addresses.
- Does not introduce radio interface overhead. Geographic information at the IPv6 layer is only propagated in vehicle's internal network.
- Geographic information at the IPv6 layer is only processed once by using a Destination Option extension header in the source AU-OBU tunnel.

Drawbacks

- Uncommon behaviour at the source OBUs' IP layer. The OBU uses an extension header to obtain the sub-IP layer destination address.

B. Binary encoding geographic coordinates

In the second and third solutions, AUs specify geographic destinations using extension headers. This makes that the geographic information is not used for IP layer routing and therefore, the binary encoding of the geographic coordinates can be done as in C2C-CC Network protocol. When an IPv6 packet reaches a source AU's OBU, it checks if the packet has geographic coordinates in the correspondent extension header and copies the geographic address (transforming from relative to absolute position information if required) into the destination field of C2C-CC Network packet.

That is not the common forwarding mechanism. Forwarding is usually done according to the destination address field. In order to do that, the geographic coordinates would have to be mapped into the IPv6 destination address field, as it is done in the first proposed solution. This has some drawbacks because relative geographic addressing cannot be used at the IP layer, since destination OBU needs to recognise the incoming packet as destined to it. Therefore geographic addressing has to be absolute because relative geographic addressing cannot be routed at IP layer.

Regarding binary encoding geographic coordinates, Hain [3] proposes to divide the world in squares of different size in function of the divisor value used, i.e., the greater the divisor value the smaller the size of the squares. In our scenario addressing the whole world is not necessary, so the region to be addressed has been reduced to the European continent. Defining Europe latitude and longitude as 35ºN to 70ºN and 25ºW to 40ºE respectively, an "square" of 35 degrees of latitude and 65 of longitude is defined.

Table 1 shows the approximate length of the arc resulting of dividing 35 degrees of latitude by a factor; this factor is expressed in bits to measure its binary length. The eight resulting values are defined in order to provide eight different square sizes.

TABLE 1

Bits	Arc length (km)
9	7.610
10	3.805
11	1.902
12	0.951
13	0.476
14	0.238
15	0.119
16	0.059

TABLE 2

Bits	Arc length (km)		
	40º	50º	60º
9	9.084	10.826	12.239
10	4.542	5.413	6.119
11	2.271	2.706	3.060
12	1.135	1.353	1.530
13	0.568	0.677	0.765
14	0.284	0.338	0.382
15	0.142	0.169	0.191
16	0.071	0.085	0.096

Table 2 shows the approximate length of the arch resulting of dividing 65 degrees of longitude by a factor at three values of latitude, 40º (corresponding to Spain latitude) 50º (Germany) and 60º (Sweden). These additional values are presented to give a view of the reduction of longitude arc length when latitude is closer to the pole.

As seen in the tables, the more precise squares (the smaller ones) are obtained using the greater divisors, i.e., with a higher number of bits.

Therefore, to encode the geographic areas for the solution of Section 3.1.1, the total number of bits needed is 35 which correspond to 32 bits for identifying the lower left corner of the square (16 bits for latitude, 16 bits for longitude) and 3 bits for identifying the square size.

According to IPv6 Addressing Architecture [4], IPv6 multicast addresses have the following structure:

```
|   8    |  4 |  4 |       112 bits         |
+------ -+----+----+------------------------+
|11111111|flgs|scop|       group ID         |
+--------+----+----+------------------------+
```

Fig. 6 – IPv6 multicast address structure

`flgs` is a set of four flags which for the solution have the value 0001, i.e., non-permanently-assigned multicast addresses.

`scop` is a 4-bit multicast scope value used to limit the scope of the multicast group. Due to the fact that this multicast traffic will not be forwarded out of the VANET domain the value of this field is set to 2, Link-Local scope. As previously mentioned, from the IPv6 layer view all VANET nodes are as directly connected.

`group ID` identifies the multicast group, in the proposed solution this field identifies the geographic area according to the previously described codification; 3 bits to identify the square size, 32 for the lower left corner of the square and the rest with 0.

```
|      77 bits          | 3 |    32 bits      |
+-------------------------------------------+
|0000000000000000000000|siz|  square coords  |
+-------------------------------------------+
```

Fig. 7 – geographic area in group ID structure

`siz` is the square size. The values are as follows:

TABLE 3

000	Tables 1 and 2 values of arc length for factor value 9
001	Tables 1 and 2 values of arc length for factor value 10
010	Tables 1 and 2 values of arc length for factor value 11
011	Tables 1 and 2 values of arc length for factor value 12
100	Tables 1 and 2 values of arc length for factor value 13
101	Tables 1 and 2 values of arc length for factor value 14
110	Tables 1 and 2 values of arc length for factor value 15
111	Tables 1 and 2 values of arc length for factor value 16

`square coords` are the coordinates of the lower left corner of the square. The sequence for address formation given the coordinates of a point is:

1) Normalize the coordinates for origin of the allowed space (the European continent square 35N-70N and 25W-40E)
    a) For latitude subtract 35 from the value
    b) For west longitude subtract the value from 25
    c) For east longitude add 25 to the value
2) Divide resulting values by 35/2^factor for latitude and 65/2^factor for longitude.
3) Convert each of the integers to 16-digit binary
4) Prepend latitude to longitude into 32-bit result

IV. QUANTITATIVE EVALUATION

In this section a quantitative evaluation of the alternatives proposed is given.

A. Overhead

The overhead introduced by the different solutions is the following:

TABLE 4 - VEHICLE INTERNAL NETWORK OVERHEAD

Sol	Vehicle internal network overhead
A	40 bytes (IPv6 tunnel)
B	16 bytes (12 bytes C2C-CC Network destination position + 4 bytes Hop-by-Hop Option header)
C	56 bytes (40 bytes IPv6 tunnel + 12 bytes C2C-CC Network destination position + 4 bytes Destination Option header)

TABLE 5 - RADIO INTERFACE OVERHEAD

Sol	Radio interface overhead
A	40 bytes (IPv6 tunnel)
B	16 bytes (12 bytes C2C-CC Network destination position + 4 bytes Hop-by-Hop Option header)
C	None

As seen in Table 4 and 5, although solution C introduces the biggest overhead at vehicle's internal network, it does not introduce any overhead at radio interface. Therefore from overhead's point of view, alternative C is the best solution because minimising the overhead at the radio interface is a requirement of the solution and it is supposed that vehicles' internal network bandwidth should support the overhead of all proposed solutions.

B. Modifications to the IPv6 standard

As previously mentioned, solutions B and C impose a non-standard forwarding behaviour (or at least a non-common one) at the source OBU. OBUs forward the geographic IP traffic in function of the value of an extension header instead of using IPv6 destination address. This does not break IP because only introduces changes at the OBU forwarding process but is a debatable solution. Therefore, from standard accomplishment point of view solution A should be the preferred one.

At the AU, the three solutions impose the use of the Advanced Socket API [5] for managing tunnels and extension headers. This is a reasonable requirement since applications that make use of C2C-CC geographic routing are specifically designed for vehicular environments.

C. Flooding efficiency

Solutions B and C use the same geographic area definition as C2C-CC Network protocol so their flooding efficiency is the same and it depends on how precise the definition of the geographic area is.

However, solution A limits the allowed geographic areas to a set of predefined squares of fixed length. Due to that for a desired forwarding area the application must use the square or squares that contain that area, this makes that C2C-CC Network protocol forwards the traffic to an area greater that the optimal. Therefore its flooding efficiency depends on how close to the predefined squares is the desired forwarding area and logically, it is lower than the efficiencies of solutions B and C.

V. RELATED WORK

Most solutions in vehicular networks context only consider geocasting, i.e., delivering a packet from a source node to all other nodes within a specified geographical region called zone of Relevance (ZOR). The majority of geocast routing methods are based on flooding, or the use of unicast routing until the packet reaches the ZOR and then use flooding inside the ZOR [6]. In these solutions, the key is to minimise the number of rebroadcasts in the ZOR. The solution in [7] avoids the broadcast storm by a defer time algorithm; a node wait a defer time before taking a decision about rebroadcast and if during this time it has not received the same message from another node, it broadcasts the message. The solution in [8] uses a cache scheme and distance aware neighbourhood selection to improve the geocast delivery success ratio.

This paper is focused on enabling IP geomulticast services and, as previously said, geomulticast address a specific group of nodes within a geographical area. There are different ways of performing multicast routing inside the target area. In [9] they classify them in function of how the multicast group is defined. If the group is defined in the application layer, the routing layer performs broadcast inside the area and the application decides if the received packets are valid or not. If the group is defined in the network layer, the first node in the target area that received the packet sends a broadcast message to the area and the members of the multicast group answer with their IP address and position. With this information the node is able to send the data only to the members inside the area using unicast or building a multicast tree. In this paper we use the first approach; broadcast inside the area and every OBU decides to forward the messages if it has members of the multicast group inside its inner networks. This is due to the fact that C2C-CC Network does not support multicast groups and IPv6, which is where the multicast groups are defined, is transported over it.

The solution in [10] proposes a routing protocol for enabling geomulticast that uses a mobility-based clustering method which creates cluster-head based limited mesh structure within a guided region to reduce the overhead to the destinations. This provides efficiency in large-scale networks but at the cost of extra signalling to maintain the clusters.

VI. CONCLUSIONS

In this paper, three alternative solutions that allow the deployment of IP geomulticast services have been proposed. Our solutions do not define a new protocol, since we use the current specifications and propose how geomulticast can be achieved without any protocol modifications. All the alternatives require the use of an Advanced Socket API [5] because they use tunnels and extension headers to allow the source AU to send geographic information to its OBU but, as previously mentioned, applications that make use of C2C-CC geographic routing are specifically designed for vehicular environments and may take this into account. Solution A is the most IP standard alike solution, but it nevertheless introduces the greatest radio interface overhead and offers the less efficient geographic area definition, therefore making A the less suitable solution. Solutions B and C are similar; both use IPv6 Extension Headers to encode geographic information however C does not introduce any radio overhead. Minimising this overhead is one of the requirements of the solution and therefore solution C is our recommended approach.

Evaluation work using simulations, in order to analyse how the three proposed approaches perform, is the subject of our future work.

ACKNOWLEDGEMENT

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