ABSTRACT
In vehicular applications based on Vehicle to Vehicle (V2V) infrastructures, it is often desirable to address on location. Geonetworking could offer a great support to these vehicular applications by using location based addressing. Geonetworking can be split into two main parts, geographical addressing (geoaddressing) and geographical routing (georouting). Several geonetworking solutions are already available. However, in order to offer differentiated and reliable support, it is recommended that these solutions meet requirements regarding Quality of Service (QoS), reliability, scalability and standardisation. Using these requirements as criteria, a qualitative comparison is made between the main geonetworking solutions. The solution proposed by the European GeoNet project seems to be the best solution regarding these requirements, but in overall none of the solutions seems to be able to offer both differentiated and reliable support to vehicular applications in V2V communication infrastructures yet.

Keywords
V2V, Geonetworking, Georouting, Geoaddressing, VANET, Quality of Service

1. INTRODUCTION
To be able to make traffic safer, a possible solution is to make the vehicles communicate with each other. Today’s vehicles already collect various sorts of data, but they do not yet actively exchange the data with other vehicles or infrastructures that could be interested in this data [10]. Inter-vehicle communication systems (IVCs) are systems designed to make this possible. In this paper we will only consider Vehicle-to-Vehicle (V2V) communication, where packets are exchanged among vehicles without the need of an infrastructure [2]. Vehicles in V2V networks can communicate with each other through a Vehicle Ad Hoc Network (VANET) [6]. Figure 1 shows vehicle S communicating with vehicle D through the VANET.

In vehicular applications based on V2V infrastructures, it is often desirable to communicate with other vehicles at a specific location or inside a specific geographical area. For instance, if there is a traffic jam or chain collision, all vehicles heading towards this traffic jam should be warned. For the vehicles ahead that are moving away from this interruption, this information is not relevant anymore. This is where geonetworking could offer great support to these applications, where addressing is done using geographical locations. In this specific example, geobroadcasting can be used to transmit messages towards a certain geographical area, see [15].

Figure 1. Vehicle-to-Vehicle Communication, Sender S sends a packet to Destination D

Currently there are several geonetworking solutions available. However, there is no research done yet on which Quality of Service (QoS) and reliability requirements these geonetworking solutions should meet to be able to offer differentiated and reliable support to vehicular applications.

This paper presents those requirements for QoS and reliable support. Using these requirements, a qualitative comparison of the currently available geonetworking solutions will be done to conclude whether these solutions meet the requirements or not.

With the focus on geonetworking and the qualitative comparison, the main research question is:

‘Are geonetworking solutions able to provide a differentiated and reliable support to vehicular applications used in V2V communication infrastructures?’

In order to come to a structured and adequate answer to this main research question, the research has been built
upon some subquestions. These subquestions will be answered first and their results are used to come to an answer for the main research question:

1. What is geonetworking?
2. Which QoS and reliability requirements have to be supported by geonetworking solutions?
3. What is the current state of art on geonetworking?
4. How do the current geonetworking solutions meet the requirements?

To be able to answer these questions, a literature search and study has been done. Using the literature as base, a qualitative comparison is done to compare the geonetworking solutions. Most literature is found using IEEE Xplore. Other search engines used to find the literature are Google Scholar, Scopus and Web of Knowledge. Some of the many keywords used to find the literature are geonetworking, georouting, geocast, VAPR, and V2V.

The structure of this paper is based on the subquestions described above. Section 2 gives a description of geonetworking, answering the first question. In Section 3, this paper describes the state of art on geonetworking, describing the current available geonetworking solutions and answering the third question. After that, Section 4 describes the requirements for QoS and reliability for geonetworking solutions, answering the second question. Then in Section 5, these requirements are used as criteria to make a qualitative comparison for the earlier described geonetworking solutions, answering the fourth question. The conclusions section will fall back on the subquestions and answer the main research question. Then, future work for the described geonetworking solutions is presented.

2. GEONETWORKING

Typically, applications in networks use IP addresses to address a certain peer. When using geonetworking, peers are addressed using their geographical location instead of their IP address. In V2V applications, typical examples that might profit from geonetworking are safety related applications such as emergency warnings or transmission of traffic states [12].

The GeoNet project and ETSI [15, 8] give the following definition of geonetworking:

“*A network service that utilises geographical positions and provides ad hoc communication without the need for a coordination communication infrastructure.*”

When IPv6 is combined with geonetworking into a single protocol architecture, this new variation is called IPv6 geonetworking [15].

Looking in further detail to geonetworking, it can be split up into two essential parts, geographical addressing and geographical routing.

2.1 Geonetworking

In order to transmit messages to a target area, there should be geographical information available in the addressing mechanism. This is where geographical addressing, also geonetworking, comes into play. Imlinieski et al. [23] identify three approaches to integrate geographical location information into an addressing mechanism:

*Application layer solution* Databases with geographic information are added to DNS servers and new level domains are introduced in this approach. Every time nodes change their location, they register their location to the server. It is not yet clear how scalable this solution is in extremely mobile networks with big quantities of nodes moving at high speeds.

*GPS-Multicast* This approach makes use of smallest addressable units, called atoms, and partitions, containing multiple atoms and representing larger geographical areas. Every atom is mapped to a multicast address. For every atom that intersects a node’s range, it joins the multicast group. The sender determines the multicast address of the destination and sends a polygon for the target area along with the packet. This polygon is used to perform the exact match. The amount of areas and shapes in this approach is limited.

*Unicast IP routing extended to deal with GPS addresses* Geographical addresses are integrated into routing decisions in this approach. GeoRouters, GeoNodes and GeoHosts are considered as components. A GeoRouter transmits packets and communicates with other GeoRouters about their service area. GeoNodes store packets with geographical information and GeoHosts are daemons located on all hosts capable of receiving and sending a packet.

Besides the approaches above, several other solutions have been proposed for geonetworking, but are out of the scope of this paper.

2.2 Georouting

Routing using geographical information, also denoted as georouting, is another important part of geonetworking. The following definition for georouting is given by Franz et al. [12]:

“The problem of forwarding data packets over multiple hops by using the position of the destination node(s) and the positions of intermediate nodes for the routing decisions.”

Georouting can be further divided into addressing a single destination node, unicast routing, and addressing a group of nodes, where all the nodes inside a geographical area are addressed, which is referred to as geocast [10, 40]. Among geocast solutions we can distinguish abiding geocast, a time stable form of geocast. In abiding geocast, packets are addressed using a geographical area and a time window. All nodes inside the target area within the given period of time will receive the packets. Many services, such as position-based advertising and position-based publish-and-subscribe, will profit from abiding geocast [36].

A generic model for georouting, proposed in [12], splits the georouting process into two phases, line forwarding and area forwarding. Line forwarding forwards the data packet to the area in which the recipient is located. Area forwarding handles the routing inside of the target area. These two phases are shown in Figure 2.

2.2.1 Routing inside the target area

For routing in the target area, Franz et al. [12] proposed a taxonomy in which four methods are distinguished, unicast, multicast, broadcast and anycast.
Geobroadcast transmits a message to multiple peers and will flood the target area. Reliable geobroadcast and best-effort geobroadcast are distinguished here, depending on the sort of application and the reliability needed for the message to arrive at the recipient.

Geomulticast transmits a message to multiple peers with a certain characteristic. For example, all vehicles inside the target area of a certain brand.

Geoanycast transmits a message to one un-specified peer in the target area. For example, when a vehicle sends a request for the weather in a specific area, it does not matter which peer in that area responds, any peer will do.

3. GEONETWORKING SOLUTIONS

There are already several proposals and projects regarding geonetworking. This section describes the current state of art on geonetworking by describing several important geonetworking solutions. These geonetworking solutions will be compared in Section 5.

3.1 GPSR
Greedy Perimeter Stateless Routing, GPSR [26], combines the position of nodes and the packet destination to make forwarding decisions. Some enhancements of GPSR are proposed, like GPCR (Greedy Perimeter Coordinator Routing) and GprsJ+ [30].

GPSR consists of two methods for forwarding packets, greedy forwarding, shown in Figure 3, and perimeter forwarding. When a packet is in greedy mode, the node chooses the neighbour which is the closest to the destination to forward the packet to. This information of the neighbours is provided by a simple beaconing algorithm in which nodes periodically transmit a beacon with its location and position.

When there is no neighbour that is closer to the destination than the node itself, it marks the packet for perimeter forwarding and records the current location in the packet. The packet will now be forwarded using the line from the sender to the destination and the intersections of this line and the edges in the graph representing the network topology. GPSR forwards the packet along the face intersected by this line, forwarding the packet to the first edge counter-clockwise of the sender. Whenever the distance from the node to the destination is less than the distance from the node where the packet entered the perimeter mode to the destination, the packet goes back into greedy mode.

3.2 GeoTORA
GeoTORA [28] is a protocol derived from the Temporally-Ordered Routing Algorithm (TORA) [42]. This solution integrates TORA and flooding, complying to the generic model of line forwarding and area forwarding in section 2. TORA forwards a packet and flooding is used in the target area. Location awareness of the vehicles is managed by the assumption of the existence of a positioning device like Global Positioning System (GPS).

In TORA, a destination-oriented directed acyclic graph (DAG) is maintained for each possible destination in the ad hoc network. These DAGs are used for routing decisions by the nodes. In GeoTORA we distinguish a geocast group and a geocast region. A geocast region is a specified geographical region for which vehicles automatically become a member of if their location is inside this region. The group of nodes inside this region is named the geocast group. GeoTORA maintains a DAG for each geocast group. Whenever a link failure occurs, for example if a vehicle leaves a region and loses a link with another vehicle, procedures for maintaining routes and rebuilding the DAG are started. These procedures make use of link reversal algorithms that reverse links if a node no longer has any outgoing links, shown in Figure 4. For more information on DAGs, link reversal and TORA, see [13, 42].

When a node addresses a geocast group, it uses anycast to reach a member of the geocast group. It forwards the packet on any of its outgoing links. The receiving node does the same, until the receiving node is part of the geocast group. Once this occurs, the node will initiate local flooding to broadcast the packet to the rest of the group, where nodes inside the geocast group forward the packet to their neighbours and neighbours not in the geocast group discard the packet. Sequence numbers are attached to prevent that a node floods a packet more than once.

3.3 GeoGRID
GeoGRID [32] is a protocol based on GRID [33]. This solution uses grid areas and elects special hosts in each grid area to be responsible for communication. Location awareness of the vehicles is also managed by the assumption of existence of positioning devices.

The geographical area of the ad hoc network will be partitioned into 2D grids. Each grid is a square of size \( d \times d \) and is numbered with an \((x, y)\) coordinate. For every location, there should be a predefined mapping to its corresponding grid coordinate. The size of \( d \) is of great
influence on the performance. A smaller value for $d$ will lead to a higher connectivity, but too small would create too many grids and a higher overhead for delivering packets. A too large value could make the grids larger than the signal range of the vehicle, making it impossible to reach nearby grids.

In each grid, one node will be elected as leader, or gateway, for the grid. The gateway is responsible of propagating packets to neighboring grids. The node that is nearest to the physical center should be elected as gateway, for this host is more stable because it is likely to remain in the grid for a longer period of time. A gateway will remain the gateway until it moves out of the grid, avoiding a lot of traffic for the election procedure. The complete gateway election protocol is described in [32].

GeoGRID knows two approaches for routing the packets, flooding-based and ticket-based GeoGRID.

### 3.3.1 Flooding-Based GeoGRID

This approach determines a flooding region, which is the minimum rectangle that covers the grids of the source and the geocast region, shown in Figure 5. Every gateway within this flooding region helps forwarding the packets. If a gateway outside of this flooding region receives the packet, it will be discarded. Every gateway inside the flooding area will detect if it is a new packet and then rebroadcast it, otherwise it will discard the packet. When the gateways inside the geocast region receive the packet, they will forward it to the nodes in this region.

### 3.3.2 Ticket-Based GeoGRID

In this approach, the sender of a packet has a number of tickets, which it evenly distributes among its neighbours. Every ticket should now realise one forward of the packet. This approach avoids blind flooding and causes that not all gateways have to participate in the flooding process. The number of tickets should be proportional to the size of the geocast region.

Figure 5. Flooding-Based GeoGRID, based on [32]

### 3.4 MORA & MOPR

MORA [18], MOvement-based Routing Algorithm, does not only exploit the location of a vehicle, but also the direction and motion of the vehicle.

Regular protocols do not take into account that nodes can move into directions that can introduce unpredictable changes in the topology of the network. By taking the movement of a vehicle into account, a more optimal routing path can be found. MORA uses functions to assign values to nodes for picking the node to forward to. If a node is moving on the line from the source to the destination in the direction of the destination, it gets a high value. If it moves towards this line, it also receives a higher value and when a node moves away from the line this value becomes lower. MORA also introduces a weight function to obtain a fair distribution of the available resources. This weight function is based on parameters such as the congestion level of a node, available power resources, etc. With these values, MORA decides the optimal route through the network.

MOPR [38], MOvement Prediction-based Routing, is a concept that also takes driving speed into account for improving the performance of routing protocols. The MOPR concept can be applied to position-based routing algorithms like MORA and GPRS.

### 3.5 LAR

Location-Aided Routing, LAR [27], restricts the flooding zone to a request zone. The base for the request zone is the expected zone, in which the sender of the packet expects that the receiver will be. This estimation is based on the previous location of the destination and its average speed. Combining the expected zone with the zone between the sender and the expected zone forms the request zone. Only the nodes in the request zone forward packets instead of regular flooding. If the sender does not get a response within a suitable timeout period, the sender expands the request zone and tries again, which could lead to a request zone as large as the ad hoc network self. When the sender cannot make an estimation of the expected zone, it falls back to regular flooding.

### 3.6 Abiding Geocast

As stated in section 2, Abiding Geocast [46, 36] is a time stable version of geocast, where packets are delivered to a target area within a given time window. Three approaches of implementing Abiding Geocast are considered, each approach assumes there is an underlying geocast routing protocol.
and further routing is done using the available positions of a packet is sent, the location of the destination is requested is the closest to the final destination’s position. Whenever GPSR approach. Packets are given to the neighbour which FleetNet also makes use of greedy forwarding, based on the DaimlerChrysler AG.

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3.8 FleetNet

The FleetNet project [10, 11, 12, 19] is a project funded by the German Ministry of Education and Research, set up by six companies and three universities and is led by DaimlerChrysler AG.

FleetNet also makes use of greedy forwarding, based on the GPSR approach. Packets are given to the neighbour which is the closest to the final destination’s position. Whenever a packet is sent, the location of the destination is requested and further routing is done using the available positions of the neighbours, which is gained through periodic beacons sent by each node.

4. REQUIREMENTS FOR QoS AND RELIABILITY

In order to provide differentiated and reliable support to vehicular applications, the solutions of geonetworking described in Section 3 should have support for requirements regarding QoS and reliability. In Section 5, these requirements are used as criteria for a qualitative comparison of the geonetworking solutions presented in Section 3.

4.1 Support for Quality of Service

Due to the huge improvements in the physical layer bandwidth, QoS issues have been considered as uninteresting in Ethernet. However, due to the different nature of Wireless LANs, the IEEE 802.11e group developed the Medium Access Control (MAC) procedures to support LAN applications with QoS [14, 21].

Currently, all data is treated equally and the current MAC has no means of differentiating traffic streams or sources. Low priority data that generates a lot of traffic could interfere with more important data [14]. QoS is especially important for V2V applications. Different applications should have a corresponding priority level. For example, a safety service should always have a higher priority than a service for advertisements.

The geonetworking solutions should be able to support QoS, being able to guarantee different priority levels for different services and applications, introducing service differentiation. Besides in the MAC, there are several other ways to realise QoS, for example by using different wireless channels for different types of applications [3].

4.2 Support for reliability

Reliability is a very important aspect for V2V applications, especially for safety applications. Important messages for improving the safety of a vehicle should not get lost along the way, but should always be delivered. The geonetworking solutions should have a component or ability to maintain its functionality in a normal situation and under unexpected circumstances and therefore offer reliability.

Possible solutions to realise reliability for the geonetworking solutions are re-transmissions, include redundant information for forward error correction, additional communication paths for re-transmissions, and so on.

4.3 Support for scalability

Operability is very important and one of the main challenges in V2V systems. V2V applications should work in both very sparse and highly overloaded networks, making scalability a key feature for their operability [29]. A network is said to be scalable if it operates efficiently in a large population of participating nodes [4].

The geonetworking solutions should be able to increase the size of the network while maintaining the network performance. It should ensure the delivery of data to those nodes which are interested in it with e.g. a low latency. A possible solution for this scalability problem is the relevance-based approach, proposed by Kosch et al [29].

4.4 Standardised solution

Many different parties like businesses, customers and governments, benefit from standardisation. If products comply to standards, they meet requirements with wide international acceptance. This makes it possible to have
compatibility among products, introducing interoperability, which is of great importance in V2V applications [24]. Several standards bodies are already developing standards in the field of V2V applications. As stated in section 4.1, IEEE is currently developing the standard 802.11e for QoS in particular. A more general standard in development is IEEE 802.11p, which aims at adding wireless access in vehicular environments (WAVE) [22]. 802.11p uses the QoS differentiation solutions provided by 802.11e [21].

The GeoNet project [17] works on a solution for IPv6 geonetworking, which relies on the IPv6 standard and the geonetworking solution proposed by the Car-to-Car Communication Consortium (C2C-CC) [5]. A detailed specification of the results of the GeoNet project will be pushed to standardisation bodies like ETSI Intelligent Transport Systems (ITS) [8] and ISO Communications Access for Land Mobiles (CALM) [25] by the GeoNet Consortium [16].

So geonetworking solutions should make use of standardised solutions such as ISO CALM and ETSI ITS as named above.

5. COMPARISON OF GEONETWORKING SOLUTIONS

In this section we will compare the geonetworking solutions discussed in section 3, using the requirements from the previous section as criteria.

5.1 Support for Quality of Service

The geonetworking solutions should be able to support QoS, being able to guarantee different priority levels for different services and applications, introducing service differentiation.

Most of the solutions mentioned in section 3 mainly discuss the routing protocol and run simulations to check the performance of the protocol. However, Quality of Service is one of the aspects that most of the solutions do not consider or mention. Because QoS is an important aspect for VANETs, there are solutions available which introduce support for QoS and take one of the mentioned solutions as base.

The solutions MORA, MOPR, Fleetnet and Abiding Geocast do not mention QoS at all and there are also no solutions which take one of these protocols as base for a QoS supporting protocol. For GPSR, there is a QoS solution named QoS-GPSR [1]. INORA (INSIGNIA + TORA) is one of the solutions which takes TORA as base and uses INSIGNIA, a signalling system for releasing and releasing resources in the network to find routes that meet the QoS requirements [7]. There are actually no solutions purely based on GeoTORA. The same applies to GeoGRID, there is a solution called QoS-GRID [34] which uses GRID and not GeoGRID. Also for LAR there are extensions available which are tested for QoS [41].

GeoNet is a more complete geonetworking solution, but also GeoNet does not consider QoS. The GeoNet project focuses only on networking capabilities. They do mention that the proposed functional architecture will have to be extended with other functions like QoS. However, they rely on C2CNets [5] and assume that C2CNets is running over IEEE 802.11p [22][15]. This makes GeoNet able to support QoS differentiation, since the 802.11p uses the QoS differentiation solutions provided by IEEE 802.11e [21].

By using 802.11e or 802.11p, a geonetworking solution automatically has support for QoS differentiation. In 802.11e, two channel modes are used, Enhanced Distributed Channel Access (EDCA) and HCF Controlled Channel Access (HCCA). In EDCA, data is differentiated by classifying traffic into access categories (ACs) with different channel access parameters. By setting different values to for example the contention window, transmission opportunity limit and arbitrary interframe space number, priority differentiating is realised. In HCCA, a polling scheme is used to allocate guaranteed channel access to traffic flows, based on their QoS requirements. The AP polls a specific node for an amount of time, giving it a transmission opportunity, in which the node can transmit all the data that it has. By multiplexing between these two channel modes, QoS is achieved [43, 14].

5.2 Support for reliability

The geonetworking solutions should have a component or ability to maintain its functionality in a normal situation and under unexpected circumstances and therefore offer reliability.

Most solutions do not yet have reliability mechanisms and do not guarantee the delivery of a packet. Solutions like GeoGRID and GeoTORA do not provide guaranteed delivery at all, because this is usually a service provided by a higher level [35]. Typically, the transport layer is responsible for providing these end-to-end services, like reliability [45]. However, GeoTORA uses the link reversal algorithm to cope with link failures, increasing the reliability [28]. Abiding Geocast also does not discuss reliability mechanisms, the solutions for Abiding Geocast mentioned in section 3.6 do not try to achieve reliability [36].

As well as the other solutions, GPSR does not have a reliability mechanism. Although, when there is no neighbour that is closer to the destination and the greedy forwarding fails, it falls back on perimeter routing. This ability increases the reliability of GPSR and is used to avoid dropping of packets [37]. GPSR also has mechanisms to deal with out of date neighbour information. It has support for MAC-layer failure feedback, which keeps track of the number of retransmissions and notifies if it exceeds the maximum, on which that neighbour will be dropped, assuming a link failure [26].

MORA and MOPR do also not have a reliability mechanism. If there are any changes in the connectivity between neighbouring nodes resulting in a route failure, this can only be resolved in MORA by the generation of a new route discovery, initiated by the source node [18].

LAR is said to be suitable for use in situations where a small number of packets need to be transmitted very reliably. LAR is very robust against the failure of an individual node and position inaccuracy. This makes LAR an adequate solution for applications that require high reliability [37]. However, beside this natural reliability of the solution, it does not have a specific reliability mechanism.

Besides the reliability abilities for GPSR, on which GeoNet relies, GeoNet states reliability in its specification. The GeoNet architecture should provide reliable network layer communications with the highest reliability for safety messages [15]. The current specification of GeoNet can not yet give hard guarantees on reliable delivery of important messages. A future extension should provide an effective link management mechanism for achieving wireless congestion control [16].
FleetNet also relies on GPSR, having the same reliability increasing abilities. A reliability mechanism is not yet present in FleetNet and has been mentioned as future work [10].

5.3 Support for scalability

The geonetworking solutions should be able to increase the size of the network while maintaining the network performance. It should ensure the delivery of data to those nodes which are interested in it with e.g. a low latency.

Simulations have shown that GPSR has good performance [39]. It is not sensitive to the number of nodes in the network, and therefore a scalable solution [20]. This is achieved by the limited overhead in the routing process. Beacon messages are only sent periodically and the size of the tables with the locations of the neighbours is small.

GeoNet and FleetNet have the same degree of scalability, since they are both based upon GPSR.

Due to the link reversal process as reaction to topological changes in the network, GeoTORA localizes the management of this problem and increases the scalability. This makes the scalability primarily limited by the storage complexity, which grows linearly with the number of nodes in the network [42]. Simulations have shown that TORA is suitable for operating in large and highly dynamic mobile networks with a dense population of nodes [44]. This makes GeoTORA, which is mainly based upon TORA, a scalable solution.

GeoGRID is a scalable solution, but the degree of scalability in GeoGRID highly depends on the mobility of the nodes in the network [35]. When the mobility is high, the nodes will change their location in a high pace and often leave a grid and enter a new grid. This will cause a lot of gateway elections, which will have a negative impact on the scalability. The same problem will occur when the size of the grids is too small.

When there is no previous location known of the destination or when location information becomes obsolete in LAR, it reverts to basic flooding of the full area [20]. LAR also floods the whole network to obtain the location information. Due to these drawbacks, LAR does not seem suitable for large networks [31].

For MORA and MOPR there are no simulations done yet regarding the scalability of these solutions. Due to this lack of information it can not currently be derived whether MOPR and MORA are scalable.

For Abiding Geocast, they are currently working on simulations of the different approaches for this solution [36]. We could predict that the neighbour approach would be the most scalable solution, following the reasoning given above.

5.4 Standardisation

The geonetworking solutions should make use of standardised solutions by a standardisation body.

As mentioned above, most of the solutions mainly focus on the routing problem. Standardisation is also an aspect which is not considered by most solutions. GPSR mentions that it shall work on a mobile IEEE 802.11 network, but does not specify more than that [26]. Furthermore, GeoTORA, GeoGRID, MORA & MOPR, LAR and Abiding Geocast do not mention standards at all.

FleetNet and GeoNet are more complete solutions and due to this difference in nature they do address standards. GeoNet is a solution that clearly takes standards into consideration. As mentioned in section 4.4, a detailed specification of GeoNet will be pushed to standardisation bodies and GeoNet also continuously contributes to activities of ETSI ITS [8], who mainly focuses on standardisation of IPv6 in geonetworking. Besides these activities on standardisation, GeoNet also complies to ISO CALM [25] and as mentioned above, GeoNet assumes that C2CNet complies to the 802.11p standard.

FleetNet does also mention the importance of standards. They mention that FleetNet results will be open to other vehicle or equipment manufacturers to allow V2V systems to be installed in all sorts of vehicles. But instead of implementing current standards, they will only aim for standardising the technical solutions they found [11].

6. CONCLUSIONS & FUTURE WORK

In geonetworking, addressing is done on a geographical location instead of on IP address. This enables the ability to for example send a packet to all the vehicles behind the source vehicle that there is a congestion ahead. Geonetworking can be split into two essential parts, geocasting and georouting. Geoaddressing is the way of incorporating geographical data into the addressing mechanism. Georouting is the problem of forwarding data packets by using the position of the destination node(s) and the position of intermediate nodes for routing decisions [12]. Addressing a group of nodes inside a target area is called geocast.

6.1 Conclusions

GPSR is the most important geonetworking solution. It uses greedy routing decisions based on the locations of its neighbours. GeoNet and FleetNet are more concrete projects and are currently built upon GPSR. LAR and GeoGRID both use restricted flooding, where GeoGRID divides the ad hoc network into small grids with one node per grid responsible for communication. GeoTORA uses destination-oriented graphs for taking its routing decisions. MORA and MOPR are solutions that also take the direction and motion of the vehicle into account and even driving speed in MOPR to take more efficient routing decisions. The last solution, Abiding Geocast, accepts a time window in which the message should stand inside the geocast region. All of the solutions assume that the vehicles have a positioning device like GPS for location awareness.

In order to offer differentiated and reliable support to vehicular applications, the geonetworking solutions should meet certain requirements regarding QoS and reliability. The solutions should be able to support QoS for service differentiation. Reliability should be supported so the solution is able to maintain its functionality under unexpected circumstances. The solutions should also keep working when a large amount of nodes join the network, making support for scalability another requirement. Last, the solutions should make use of standardised solutions to guarantee compatibility and interoperability.

For GPSR, TORA and GRID (not for GeoTORA and GeoGRID), there are solutions available that introduce support for QoS using the solution as base, respectively QoS-GPSR, INORA and QoS-GRID. The GeoNet project assumes that C2CNet, on which it relies, implements 802.11p, making GeoNet able to support QoS. Other solutions do not mention QoS.

To increase the reliability, GPSR uses perimeter routing
and GeoTORA uses the link reversal algorithm. LAR is a reliable solution which is suitable for applications requiring high reliability. However, none of the named solutions support a realistic reliability mechanism. GeoNet and FleetNet do mention it as future work.

GPSR, GeoNet, FleetNet, GeoTORA and GeoGRID are all scalable. However, the scalability of GeoGRID highly depends on the mobility of the nodes, since a high mobility will cause a lot of gateway elections. LAR does not seem suitable for large networks due to its extended usage of flooding. MORA and MOPR have not yet been analysed and evaluated from the point of view of scalability. GeoNet complies to ISO CALM and assumes that C2CNet implements IEEE 802.11p. GeoNet also continually contributes to ETSI ITS activities and will push a detailed specification towards standardisation bodies. FleetNet does also aim on standardising their technical solutions, but they do not implement existing standards. The other solutions do not even mention standards.

Considering the results above, it can be said that the current geonetworking solutions are not yet able to provide differentiated and reliable support to vehicular applications. For scalability there are good solutions. Also taking standards into account, GeoNet seems to be the best solution and is also quite active in the field of standardisation. However, considering reliability and QoS, even GeoNet falls short, having no reliability or QoS support yet, mentioning it as future work. The other solutions do not seem to qualify to offer differentiated and reliable support at all yet, leaving it as future work to meet the requirements regarding QoS, reliability, scalability and standardisation.

6.2 Future work

GeoNet seems to be the only solution that can support QoS. Other solutions like GPSR, TORA and GRID have solutions available that use them as base and support QoS, but the rest of the solutions do not mention QoS at all. A way to meet this requirement is by implementing either the IEEE 802.11e or IEEE 802.11p, which uses the QoS differentiation solutions provided by IEEE 802.11e standard. This enables the solution to support QoS differentiation.

Realistic reliability mechanisms are not yet available in the geonetworking solutions, although some solutions already mention it as future work. So for all the solutions this is future work.

Most of the current geonetworking solutions are already tested for scalability. For MORA and MOPR there are no test results available yet and there are no speculations done yet. For these solutions it is future work to run simulations regarding scalability.

There are several standards available regarding vehicular applications. However, the only solution that actually complies to standards and also serves as input for ISO CALM and ETSI ITS is GeoNet. All the other solutions do not mention standards or do not implement them, leaving it as future work to comply to the available standards.

7. REFERENCES


