*Journal of Universal Computer Science, vol. 17, no. 8 (2011), 1202-1218*
*submitted: 15/9/10, accepted: 1/3/11, appeared: 28/4/11 © J.UCS*

# Cooperation as a Service in VANETs

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**Abstract:** Vehicular Networks, including Vehicular Adhoc Networks (VANETs) and Vehicular Sensor Networks (VSNs), stimulate a brand new variety of services, ranging from driver safety services, traffic information and warnings regarding traffic jams and accidents, to providing weather or road condition, parking availability, and advertisement. 3G networks and sophisticated Intelligent Transportation Systems (ITS), including deploying costly roadside base stations, can indeed be used to offer such services, but these come with a cost, both at network and hardware levels. In this paper we introduce Cooperation as a service (CaaS): A novel architecture that will allow providing a set of services for free and without any additional infrastructure, by taking advantage of Vehicle-to-Vehicle communications. CaaS uses a hybrid publish/subscribe mechanism where the driver (or subscriber) expresses his interests regarding a service (or a set of services) and where cars having subscribed to the same service will cooperate to provide the subscriber with the necessary information regarding the service he subscribed to, by publishing this information in the network. CaaS structures the network into clusters, and uses Content Based Routing (CBR) for intra-cluster communications and geographic routing for inter-cluster communications.

**Keywords:** VANETs, service, publish/subscribe, cluster, CBR, geographic routing
**Categories:** C.2.1, C.2.2

## 1 Introduction

Wireless Sensor Networks are widely deployed nowadays because they effectively enhance our ability to monitor and control the physical environment. Environmental monitoring, battlefield and harsh areas surveillance, healthcare and agriculture applications are only few applications of Wireless sensor networks. Recently, academia and automobile industry have been developing a growing interest in equipping regular vehicles with a large number of onboard sensors, thus technically creating a mobile, vehicular-based sensor network (VSN) [Manvi, 2009] [Spaho, 2010]. Unlike a traditional wireless sensor network, vehicles in a vehicular sensor network are typically not affected by limitations in power, computational capacities or memory. In fact, vehicles can be easily equipped with powerful processing and storage units, multiple wireless interfaces (e.g. Wifi, Bluetooth and 2G/3G), Event Data Recorders (EDRs) [Gabauer, 2008], and sensing devices of some complexity (e.g. GPS receivers, cameras, vibration sensors and acoustic sensors). This stimulates a brand new variety of attractive services for vehicles ranging, from safe navigation services, traffic information and warnings regarding traffic jams and accidents, to providing weather or road condition, parking availability, and advertisement [Xuan, 2008] [Xuan, 2011] [Zhao, 2011]. Other interesting vehicular-based services can be found in [Gerla, 2010] [Qadri, 2010]. 3G networks and sophisticated Intelligent Transportation Systems (ITS) [Crainic, 2009], including deploying costly roadside infostations, can indeed be used to offer such services, but these come with a cost, both at network and hardware levels [Thill, 2004].

Under the present-day practices, vehicles act only as spectators that witness traffic-related events while they have the potential to cooperate between them to achieve better performances, offer more services or solve problems that usually take a considerable amount of time to solve like traffic jams. Hence, research communities have been investigating a novel paradigm for Vehicular Networks called Vehicular Clouds (VC) [Olariu, 2011] which adapts the conventional concept of cloud computing [Goscinski, 2010] to vehicles. Cloud computing aims at reducing the IT's services costs by making the computing resources (from data storage to complete configurations of distributed systems) available through the Internet as on-demand services. Typically, clouds services fall into three major categories: a) Software as a Service (SaaS), in which applications are run on the cloud, suppressing the need to install and run the applications on the client computer, b) Platform as a Service (PaaS) which allows the development of applications without having to deal with buying and managing the underlying hardware and software layers and c) Infrastructure as a Service (IaaS), whereby storage and compute capabilities are offered as a service. Readers can find in [Buyya, 2009] many fully detailed examples on cloud computing services. In fact, Vehicular Clouds extend "conventional" clouds by offering at least two other novel types of services: a) Network as a Service (Naas) where vehicles on the road may share their connection to the Internet with other vehicles while on the move and b) Storage as a Service (SaaS) where vehicles may offer their extra storage capabilities to the vehicles which need them, for a certain period of time.

In this paper, we enlarge these two novel types of Vehicular Clouds' services by introducing what we will call "Cooperation as a Service" or CaaS: Our architecture aims at providing some sets of services for free, and without any additional infrastructure, for vehicles/drivers that are willing to cooperate by taking advantage of Vehicle-to-Vehicle (V2V) communications. It is important to point that V2V communications are made possible via the DSRC/WAVE (Wireless Access in a Vehicular environment) standard [Jiang, 2006] which is a short to medium range communication technology operating in the 5.9 Ghz. DSRC technology allows also Vehicle-to-Infrastructure (V2I) communications where vehicles can directly communicate with road base stations, e.g. infostations [Frenkiel, 2002] that can be connected with each other or, depending on the deployment scenarios, can also be connected to the Internet. It is not the scope of this paper to study V2I communications since our framework is mainly based on V2V communications, but readers can find a detailed overview of the DSRC standards in [Jiang, 2006]. CaaS uses a hybrid publish/subscribe mechanism where the driver (or subscriber) expresses his interests regarding a service (or a set of services) and where vehicles/drivers having subscribed to the same service will cooperate to provide the subscriber with the necessary information regarding the service he has subscribed to, by publishing this information in the network.

Our main objective is to provide drivers with a set of VANET-based services for free, despite the limited network capacity, the intermittent connectivity and the existence of competing cellular network technologies. We are going to show how vehicles' collaboration can be used to overcome such problems.

The remainder of this paper will be organized as follows: Section 2 presents some motivational scenarios related to Vehicular Clouds services. Section 3 overviews some related work and highlights our contribution. In section 4, we present the "Cooperation as a Service" architecture in details. Section 5 concludes our paper.

## 2 Motivational scenarios

While the past decade has witnessed a proliferation of mainly vehicular safety applications, many other innovative applications can be realized by combining high accuracy positioning, inter-vehicular communication technologies and a vehicle's sensor suite.

In this section, we will be presenting three classes of motivational scenarios that nurture the feasibility of our framework. The first one is related to vehicular safety, the second is related to infotainment while the third is mainly comfort-related.

### 2.1 Cooperative vehicular safety scenarios

Safety is the most important concern for drivers. The non-line-of-sight advantage of VANETs makes possible preventing rear-ending accidents. In the Electronic Brake Warning (EBW) application, a vehicle broadcasts an event-based message when it brakes sharply, alerting the surrounding cars of the braking maneuvers. The application is particularly useful when the view of brake lights is blocked by other vehicles. In [Fig. 1], vehicle *B* undergoes severe braking. Vehicle *D* is unable to see the brake lights of vehicle *B* because the view is blocked by vehicle *C*. Without EBW warnings, vehicle *D* has no time to react to the delayed braking of vehicle *C*. But with EBW warnings, vehicle *D* is informed about the braking before the driver of vehicle *C* has even begun braking, keeping longer braking distance between his vehicle and vehicle *C*.

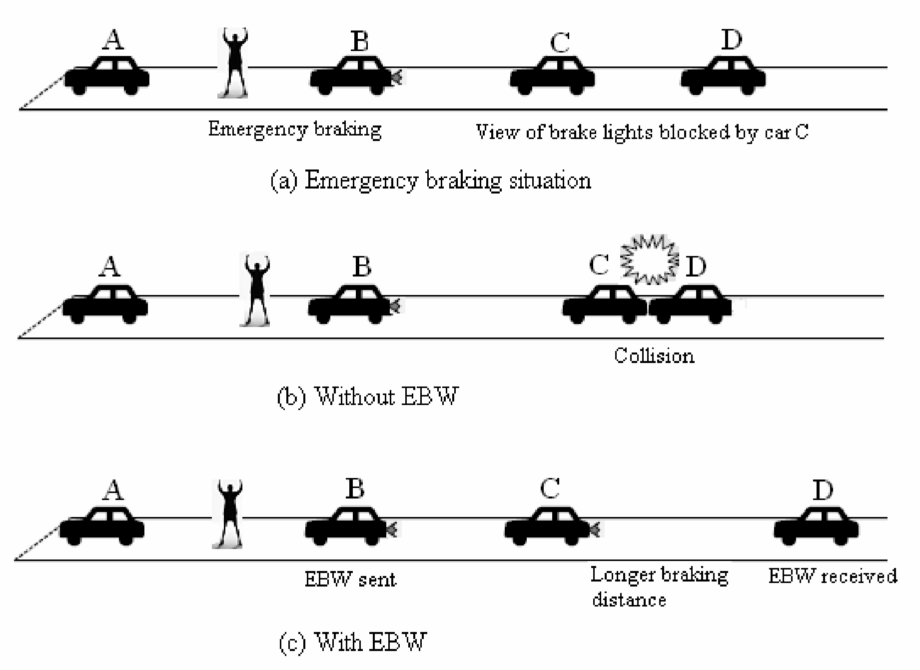


*Figure 1: Electronic Brake Warning scenario*

Another cooperative vehicular safety application is the Vehicle Stability Warning (VSW) application. In VSW, preceding remote vehicles alert following host vehicles of upcoming potential hazardous driving conditions, e.g. icy or oily patch of road.

Vehicle Stability Warning messages are similar to Electronic Brake Warning messages in such a way that they are both event-based, thus, requiring reliable communications between vehicles during all times. If the sent emergency messages were not received, these applications would be ineffective and the traffic situation would revert to the default behavior of drivers relying only on the view of preceding vehicles. Readers may find other interesting cooperative vehicular safety applications such as On-coming Traffic Warning (OTW) and Lane Change Warning (LCW) in [Hartenstein, 2010].

### 2.2 Infotainment-related scenarios

Vehicle infotainment system (VIS) [Hsu, 2005] has gained much attention recently due to its promising usage in a wide range of Internet-based services, ranging from location-aware services such those in [Dikaiakos, 2007], on-demand traveling information and traffic conditions, to rich media news and video distribution [Gehlen, 2005]. Since our aim is to mainly study VANET-based scenarios, we will dwell on applications that are built on top of direct communication between cars.

Let us consider the example of a VANET-based traffic information system where vehicles act like mobile sensors monitoring parameters such as road and weather conditions, parking lots availability (like in [Caliskan, 2006]) or traffic density (like in

[Dornbush, 2007] and [Nadeem, 2004]). Such information can be shared among vehicles in order to perform route optimization or adaptations of driving behavior. To illustrate this, let us consider the example of one-way roads (Road 1 and Road 2 in [Fig. 2]). If a collision occurs between car B and car C, car D has no choice but to be blocked in the traffic jam caused by the accident. But if the information is disseminated throughout the road network, car E and car F might still have the opportunity to avoid the traffic jam by taking Road 2 because they are in the Domain of Interest.

The Domain of Interest (DoI) is defined as the set of roads, where the information about a traffic jam influences the route choice of the driver. However, if the driver enters the zone of no return, there is no possibility to avoid the traffic jam.

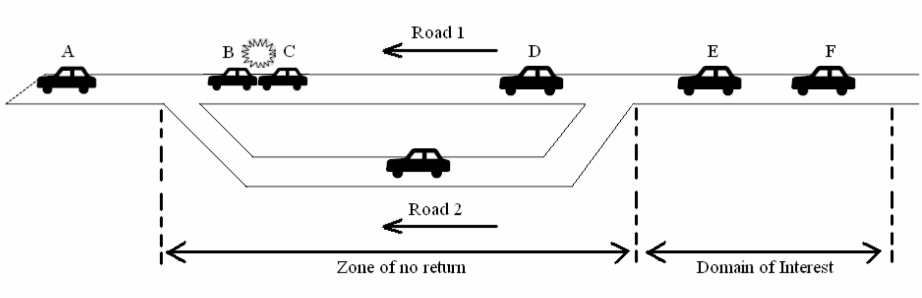


*Figure 2: Traffic jam scenario*

We may also consider a traffic scenario where a critical traffic/safety situation occurred on a highway, e.g., a natural or manmade disaster or even a hostile attack. Participants in the network (e.g., Police officers) would want to stay “visually” informed of the problem. In such cases multimedia content (e.g., video) could be streamed from vehicles in the vicinity of the incident to the vehicles following several kilometers behind. Network Coding techniques ([Gkantsidis, 2005] and [Lee, 2006]) could be used to enhance the video stream reliability [Park, 2006] and solve intermittent connectivity issues.

### 2.3 Comfort-related and entertainment-related scenarios

Internet access was one of the earliest applications proposed for VANETs. Two deployment scenarios to provide cars with access to the internet are viable: 1) The deployment of more wireless connectivity such as roadside WiFi Access Points (APs) like in CarTel [Hull, 2006] or 2) allow drivers, who are willing to and who have persistent connectivity to internet through cellular networks, to share their underutilized network resource with other drivers who may need to access the Internet while on the move. This is possible for two reasons: Firstly, not all drivers will be searching or downloading from the internet while driving, which will lead to under-utilized network resources, and secondly, many applications (pushed-base email access for instance) require only intermittent internet access.

Free internet access can also be combined with some form of advertisement distribution like in [Lee, 2007], where cars carry and distribute advertisement using mainly single-hop inter-vehicle communication. The same idea is found in [Nandan, 2006], where authors propose AdTorrent; an extension of the physical billboards that allows drivers to download advertisements of interest using a location-sensitive distributed mechanism.

Other applications such as RoadSpeak [Smaldone, 2008] which allows drivers to communicate on the road via voice chat messages, and interactive online games [Palazzi, 2007], might not be a driving force for VANETs in the immediate future.

## 3 Related Work

Before a VANET-based application can start to process and propagate data, local measurements need to be made. These local observations are application-dependant and are usually obtained through the car integrated sensors. Reading information from these sensors alone can indeed provide important information. As an example, reading the speedometer of a vehicle may allow conclusions to be drawn about the traffic conditions. But, integrating and combining information from different sources will make such conclusions even more accurate. Authors in [Ozbay, 2007] examine a system that aims at integrating measurements from multiple sources through sensor fusion techniques in order to provide useful information about the current road condition.

After obtaining local measurements, information has to be disseminated to interested parties. Nevertheless, due to the capacity constraints [Gupta, 2000] in VANETs, it is technically unfeasible to deliver detailed and regularly updated information to all participants in the network. The key idea is to combine information from a cooperative VANETs using measurement summarizing and aggregation mechanisms which aim at reducing the generated amount of data. Further details about data fusion techniques can be found in [Nakamura, 2007].

Depending on the application, information needs also to be shared among vehicles that are interested in it. These vehicles might need to adapt their behavior based on the received information. One way of distributing this information inside the network is to use flooding which simply consists of rebroadcasting the information by each node which receives it [Waluyo, 2003] [Waluyo, 2004]. Since this naïve approach may lead to severe congestions in the network, many approaches have been proposed to deal with this problem and mainly aim at influencing the forwarding behavior of vehicles by either adapting the time to forward, the geographic area where to forward [Maihofer, 2004] or by simply placing rules on whether a vehicle should forward or not. Readers can find details on the use of these flooding techniques in [Tonguz, 2007] and [Saito, 2007].

Despite the use of these flooding techniques and due to wireless signal dynamics, node mobility and vehicular networks density, especially in big cities, poor performance of flooding-based routing protocols has been noticed [Wong, 2003]. Actually, geographic routing has been chosen as the most suitable technique in most routing algorithms used for VANETs. Geographic-based routing protocols exploit both local information and information about the surrounding road topology to route packets. In some scenarios, information about speed, direction or route plan can also be used. Details about the most used geographic-based routing protocols in VANETs can be found in [Lochert, 2005], [Zhao, 2006] and [Leontiadis, 2007].

In many application scenarios, geographic routing is replaced with another class of routing paradigms known as Content-Based Routing (CBR) to achieve better performances. In CBR, the sender simply injects the message in the network, which then determines how to route it according to the nodes' interests (or subscriptions). CBR is proposed as an efficient publish/subscribe approach in many Service-Oriented Architectures (SOAs) [Cugola, 2008].

To the best of our knowledge, our work is one of the few attempts that focus on providing the driver with services for free, by taking advantage of vehicle-to-vehicle communications, rather than with commercial services. We aim at integrating as many VANET-based services as possible (like those described in [section 2]) and allowing the driver to select the one or ones he is interested in. Cooperation among vehicles is the key point in our framework. This collaboration is illustrated through the novel publish/subscribe mechanism we propose for VANETs; participants can act as publishers who generate information (either local or collaborative measurements) and subscribers are drivers who express their interests in a set of services and who are willing to cooperate to provide other subscribers with the information they are interested in.

Our work deals with three major challenges in VANETs: 1°) we suppose completely infrastructure-less scenarios (like in [Olariu, 2009]) 2°) not all vehicles would be interested in collaborating, so they should not be affected. 3°) we deal with network fragmentation and the resultant lack of continuous end-to-end connectivity at any given instant.

## 4 Cooperation as a Service (CaaS)

As stated earlier, our framework deploys a publish/subscribe interaction scheme. With publish/subscribe models; participants can act as subscribers who express their interest in an event, or a pattern of events, and publishers who submit information regarding those events to the system. Readers can find a detailed survey on this communication paradigm in [Eugster, 2003]. Such a scheme is well adapted to the loosely coupled nature of distributed interaction in large-scale networks, VANETs for instance, mainly because of its decoupling properties. In Fact, publish/subscribe-based schemes achieve at least two dimensions of decoupling: 1°) Space decoupling: subscribers are interested in getting the information they want regardless of who published or how this information is published in the network and 2°) Time decoupling: publishers and subscribers do not need to interact at the same time. Our designed publish/subscribe mechanism for VANETs insures both of them.

We make our work more challenging by making two environmental assumptions. First, we suppose completely infrastructure-less scenarios so no central dedicated servers or roadside base-stations are present because our target is pure VANETs. Second, publishers have no prior knowledge neither about brokers nor subscribers. A node may become a subscriber or publisher at any time.

In this section, we will be discussing our proposed publish/subscribe interaction scheme from the algorithmic, the functional, and the architectural perspectives. But before doing so, we will start first by arguing our choices regarding the underlying routing protocols we use in our approach.

### 4.1 Discussion

A “traditional” publish/subscribe system model relies on an event notification service (or broker) that stores and manages subscriptions, thus, acting as a mediator between publishers and subscribers. In VANETs, we can not expect any dedicated server (or service) that will play such a role. Nodes themselves should act as mediators as well as publishers and subscribers. This makes designing a scalable publish/subscribe scheme well suited to VANET environments extremely challenging.

Two main approaches have been proposed to support the publish/subscribe paradigm in MANETs in general and in VANETs in particular: a structured-based approach (like [Yoo, 2009]) and a gossip-based approach (i.e BubbleStorm [Terpstra, 2007]). The former requires the nodes to be organized into a sort of overlay structure and builds the publish/subscribe methods on top of it. The latter uses gossiping for information exchange which supposes that a query or publication will sufficiently populate a large portion of the network so that their paths intersect at some rendezvous nodes with high probability. Although, the first approach suffers from the disadvantage of introducing an additional overhead for structure construction and maintenance, it achieves better efficiency in comparison to the second which introduces additional computation and storage costs due to the intermittent connectivity issues in VANETs. Since we want to guarantee a high level of service delivery to the participants in the network without affecting non-interested parties, we favor the structure-based approach over the gossip-based one.

In most structure-based approaches proposed for VANETs, Content based data dissemination, where information is routed based on the content rather than the destination address, is proposed as an efficient publish/subscribe scheme. But again Content Based Routing (CBR) requires a one-tree structure network topology [Mottola, 2008], almost impossible to maintain when the size of the network increases. The high dynamicity of nodes in the network may make this tree maintenance issue even worse since a tree may become partitioned into a number of trees leading to serious issues finding a connectable path to merge those trees.

To take advantage of the benefits of CBR and reduce its disadvantages, we decide to allow more than one tree structure in the network. Each tree will represent a cluster whose size and depth are appropriately chosen to allow a proper maintenance of the trees. In our structure, we use CBR for intra-cluster communications; subscriptions of all members of the cluster are forwarded to a clusterhead and updated regularly to deal with the continuous movement of the nodes. This will be done using the protocol we will be describing in the next section.

For inter-cluster communication, two options can be considered. The first is to use a flooding-based approach (i.e Document flooding (DF) [Yoo, 2009]) to exchange subscription summarizations and publications among clusterheads in the network. The second is to take advantage of the performance efficiency achieved by deploying geographic routing to disseminate subscriptions and publications between clusters. In our structure, we decide to use geographic routing for inter-cluster communication for two main reasons: in most VANET-based services (i.e. traffic warning services), content need to be first routed into specific *geographic areas* (Domains of Interest) where vehicles need to receive it, before delivering it to interested vehicles in those areas. The second is that we can easily consider that some vehicles in the network are equipped with a navigation system (NS), available on more and more vehicles nowadays, which will provide valuable information about how to route content to specific geographic locations instead of sending it to all clusters in the network.

As a summary, our approach suggests a hybrid publish/subscribe scheme for VANETs where content based routing (CBR) is used for intra-cluster communication and geographic routing for inter-cluster communication. [Fig. 3] summarizes our proposed network structure.

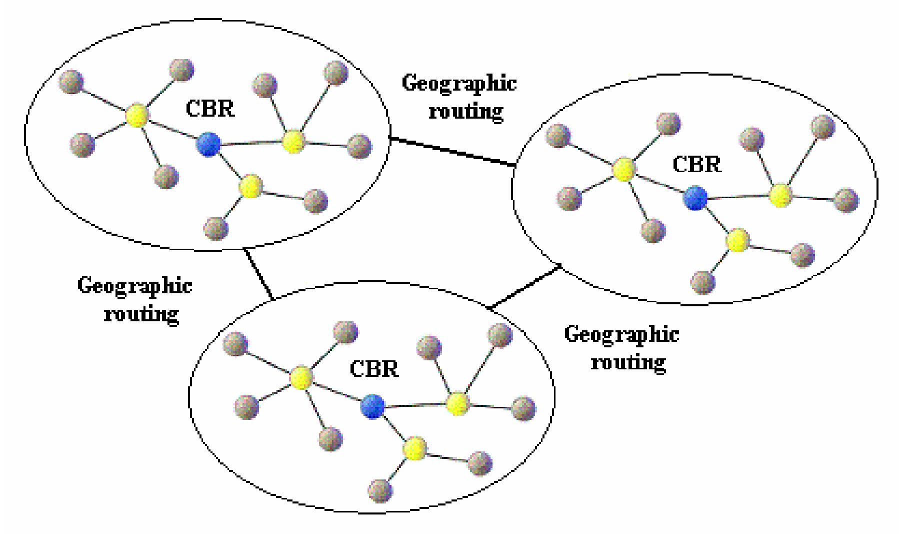


*Figure 3: Our proposed network structure*

### 4.2 Intra-cluster structure

As we mentioned earlier, we allow more than one tree structure to exist in the network. Each tree represents a cluster where the root of the tree (i.e clusterhead) should maintain an up-to-date subscription summary of all members in its cluster. The clusterhead should also be able to route publications to interested vehicles using CBR. Since a node might join or leave the cluster at any time, the tree should also be able to maintain itself and, depending on the proximity of nodes, merge itself with another tree. Our intra-cluster structure considers the following roles to set up a routing infrastructure:

- Clusterhead: node responsible for summarizing subscriptions of the cluster members and forwarding them to other clusters. It is also responsible for delivering publications to interested nodes inside the cluster.
- Broker: node acting mainly as a relay. Each broker holds a subscription table used to determine how to disseminate subscriptions/publications along the tree.
- Subscriber: a node which expresses its interest in a service (or a set of services).
- Publisher: any entity in the network that publishes information about services in which vehicles might be interested.

So let us first introduce our algorithm for tree construction and then explain how subscriptions and publications are disseminated along those trees.

### 4.2.1 Tree construction

To form a cluster, each node needs to know its neighbors' interests (i.e subscriptions). Like other routing protocols for VANETs, we consider that each node broadcasts a Hello message each Hello_Interval seconds to announce its existence to neighboring nodes. When a node is no longer receiving those messages from a neighbor, it means that this neighbor disappeared or moved out of the transmission range of the current node. Hello messages will also serve to update cluster members and nodes' subscriptions. To achieve this, each Hello message should contain some necessary information to maintain the tree such as the node Id, the cluster Id, the height of the tree, the level of the node and the subscription table (or a part of it, in case a change in the nodes' subscriptions occurs) as described in [Tab. 1]. However, depending on whether the node is already a member of a cluster or not, the format of these messages might vary.

| | |
|---|---|
| $NodeID_i$ | A unique identifier of node i, it could be a MAC address |
| $ClusterID_i$ | The id of the root node of the tree to which node i belongs |
| $Height_i$ | The maximum number of nodes separating a leaf from the root in the tree to which node i belongs. This value is the same for all members of a cluster, but could vary in time if a node joins or leaves the cluster |
| Max_Height | The maximum height allowed for a tree. This value is fixed to allow a proper maintenance of the trees |
| $Level_i$ | The number of nodes separating node i from the root. The immediate neighbors of the root are on the first level |
| $ParentID_i$ | The identifier of the neighbor parent of node i |
| $Child\_list_i$ | Identifiers of the neighboring childs of node i |
| $CH\_Flag_i$ | A flag indicating whether node i is a clusterhead or not. |
| Subscription Table | A list of pairs (NodeID, subscription list) maintained by each node |

*Table 1: Acronyms and meanings*

Initially, when a node enters the system, it tries to join an existing cluster by listening to the broadcasted Hello messages sent by neighbors and by considering as a parent the node whose signal is the strongest and whose level is strictly smaller than the maximum height allowed for the tree. A child can not have two parents because the tree should not contain any cycles. If no such node exists, the node considers itself to be a clusterhead.

Each node broadcasts a hello message with the information listed above along with its interests if there are any. Upon receiving a hello message, a neighboring node will update its local information (ClusterID, level, Child_list.. etc.). Moreover, each node should maintain heartbeats of its neighboring nodes (i.e parent and children):

After receiving a Hello message from a neighbor, a timer is set to a certain value. If this timer expires without receiving any hello messages from this neighbor, this neighbor will be considered unreachable and is removed from the list of neighbors maintained by the node. Particularly, if a node loses its parent, it should initialize its local parameters to the default ones ([Fig. 4], initialization section) to either join another cluster or build its own tree. To avoid cycles, we also consider that only roots of the trees can issue the merging process. [Fig. 4] shows our proposed algorithm for processing hello messages.

**Input:** The Hello message received, it should contain at least the following fields: $NodeID_{sender}$, $ClusterID_{sender}$, $level_{sender}$, $Height_{sender}$, $ParentID_{sender}$, $Child\_list_{sender}$
**Initialization:**
//initialize local information
$ClusterID=NodeID_{current}$ //Initially, a node considers itself as the root of a tree
Level=0
Height=0
$ParentID=NodeID_{current}$ //Initially, a node is a parent of itself
Child_list=none //Initially, no children
CH_Flag=1 //Initially, a node considers itself a clusterhead
**Output:**
1:**IF** $ClusterID_{sender}$ is different from the current ClusterID **THEN**
2: **IF** (CH_Flag=1) && ($Height_{sender}+Height < Max\_Height$) **THEN**
3: //Node should join the cluster of the sender (trees merging) and local information need to be updated
4: $ClusterID=ClusterID_{sender}$
5: $ParentID=NodeID_{sender}$
6: $Level= level_{sender}+1$
7: $Height=Height+Height_{sender}$
8: CH_Flag=0 //Current node is no longer a clusterhead since it joined a tree
9: **END-IF**
10: **ELSE** //Sender belongs to the same cluster as that of the current node
11: **IF** ($ParentID_{sender}= NodeID_{current}$) //The sender is a child of the current node **THEN**
12: //Update child list
13: $Child\_list=Child\_list+\{NodeID_{sender}\}$
14: **END-IF**
14: **IF** ($NodeID_{sender}=ParentID$) //The sender is the parent of the current node **THEN**
15: execute instructions 4 , 6, and 7 // Local information update
16: **END-IF**
17: **END-IF**

*Figure 4: Hello messages processing algorithm*

#### 4.2.2 Subscriptions and publications dissemination

Now that the trees are constructed and properly maintained thanks to the merging and dissociation processes explained earlier, subscriptions and publications can now be forwarded along the constructed links of the tree. Our idea is to exploit hello messages to communicate the node subscriptions to other nodes in the cluster and especially to the clusterhead which will be in charge of forwarding those subscriptions to other clusterheads using geographic routing. Each node (broker) will maintain a subscription table containing its interests, if any, along with the neighboring nodes' interests. Each node will send its subscription table only once; unless a change in this subscription table occurs (a node inserted a new interest or changed a subscription for example). If so, only the affected lines in the table will be sent in the following hello message.

Publications will be routed along the path set up by subscriptions to the interested subscribers only. This is the same approach as CBR. Moreover, each clusterhead will have to forward publications to other clusters. But because in most VANET-based services, publications need only to be routed into specific Domains of Interest (DOI), not all clusters in the network will need to receive them even if they have "automatically" subscribed to receiving them. That is why we chose to deploy geographic routing for inter-cluster structure.

### 4.3 Inter-cluster structure

Most geographic routing protocols use the destination's position and the position of the forwarding node's neighbors to make routing decisions hop-by-hop in a per-packet basis. The most important assumption that almost every geographic routing protocol makes is that nodes are capable of determining their own position. This can be done either by equipping vehicles with GPS devices; a navigation system available on more and more vehicles nowadays can provide location information, or by deploying virtual coordinates, such as in [Carus, 2005], which consists in assigning some elected nodes in the network coordinates and letting the rest of the nodes obtain their virtual coordinates either through triangulation techniques or by averaging the coordinates of their neighbors. Efficient routing decisions can be taken if the knowledge of the street map of the area where nodes are deployed is used.

Since our main objective is to provide all vehicles with services they subscribed to, regardless of whether they are equipped with a navigator device or not, it would be unfair to consider that all vehicles in the network need to be equipped with such devices to benefit from a certain service, although it would be the ideal case. For this reason, we suggest a compromise between the two extreme options listed above and consider an infrastructure where only some nodes (i.e. base points) are equipped with a navigation system (which is a fair assumption in the VANET context) while the others obtain the information they might need about area topology using the trees constructed earlier. Three scenarios are possible (as depicted in [Fig. 5]): optimistic, relatively optimistic, and pessimistic. In the first, we consider that all clusterheads are equipped with a navigator device, so they can easily decide to which geographic areas (i.e other clusterheads in the network) the content should be delivered and using which routes. This can be achieved using many existing techniques such as by determining the trajectory the message must follow applying Dijkstra's algorithm over the street map like in [Lochert, 2003] and [Seet, 2004], or deploying other solutions such as GPCR [Lochert, 2005] and VADD [Zhao, 2006] as an alternative to Dijkstra's algorithm. The content will be then disseminated using CBR inside the concerned clusters as explained in the previous section. In the second scenario, we consider that there is at least one vehicle in each cluster that is equipped with a navigation system. In this case, this vehicle should regularly communicate information about area topology to the clusterhead which will then operate as in the first scenario. The last scenario is the pessimistic one, where none of the vehicles is equipped with a navigation system. In this case, a flooding-based approach is the best option.

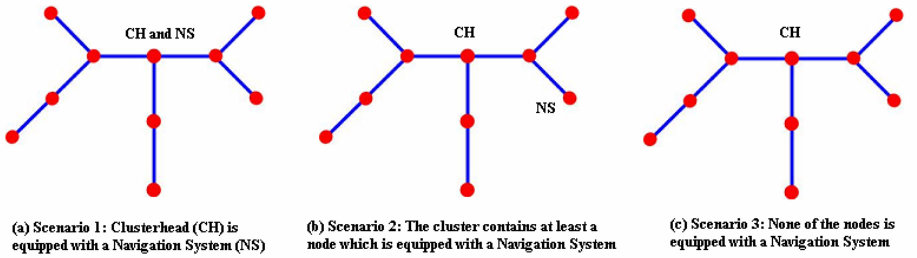


*Figure 5: Possible infrastructure scenarios*

In all scenarios, content is expected to be disseminated to interested vehicles in the network. However, the overall network traffic overhead, the end-to-end delay and the number of hops will probably vary from one scenario to another. Future work will consist in evaluating the overall performance of our proposed publish/subscribe mechanism in all those scenarios. But as a first step towards conducting simulations, we will be simply considering the first one.

## 5 Conclusions and future work

In this paper, we introduced Cooperation as a Service; a new architecture that extends the two novel types of Vehicular Clouds' services: Network as a Service (NaaS) and Storage as a Service (SaaS). Our architecture aims at providing vehicles with a set of services for free, and without any additional roadside infrastructure, by integrating as many VANET-based services as possible and allowing the driver to select the one or ones he is interested in. This is achieved through the novel and hybrid publish/subscribe mechanism we propose for VANETs.

To tackle the infrastructure-less nature of these networks, we decided to organize our network into clusters that can be properly maintained and to use content based routing (CBR) for intra-cluster communications and geographic routing for inter-cluster ones.

Future work will mainly consist in conducting exhaustive simulations in order to evaluate the performance of our proposed architecture.

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