1. INTRODUCTION

In the upcoming years, the transportation industry will witness a fascinating period of major changes and evolution thanks to the implementation of Intelligent Transport Systems (ITS). Probably, one of the most interesting characteristics of ITS is the exchange of information between vehicles in order to increase the traffic awareness of drivers, and even of vehicles in case of highly autonomous driving. In this context, the so-called Road Hazard Warning (RHW) messages can be transmitted upon detection of a hazardous event. Although these messages were primarily thought to be locally distributed, in many cases, distant vehicles can benefit from receiving remotely generated RHW messages, e.g., several kilometers away, so that the driver and the vehicle itself can act accordingly and even modify the route to avoid the hazardous situation. Examples of such cases are notifications of traffic jams on a highway or vehicles driving in the wrong direction.

The European Telecommunications Standards Institute (ETSI) has released a set of standards for addressing Cooperative ITS (C-ITS). One of these standards is referred to as ITS-G5, which corresponds to the lowest protocol stack layer identified in. This technology, which is based on the IEEE 802.11-2012 specification, was designed for Vehicle to Vehicle (V2V) communications in a Vehicular Ad-hoc Network (VANET).

In VANETs, messages can be broadcasted to distant receivers using multiple transmission hops, which may produce broadcast storms, i.e., extreme amounts of broadcast traffic. Moreover, multihop transmissions may not be able to forward the message to all vehicles in areas with a low density of ITS stations, i.e., a vehicle or infrastructure element capable of receiving and transmitting ITS messages. Although some mechanisms have been proposed to alleviate these problems, they do not completely solve them, as concluded, and require significant message reception delays. Indeed, another means to reach distant vehicles and spread the RHW messages to as many ITS stations as possible is the use of certain infrastructure. For instance, interconnected Road Side Units (RSUs) could be used as access points of a supporting infrastructure, as proposed by the so called CAN DELIVER approach However, this approach might suffer from coverage problems since RSUs are not deployed for coverage maximization but for their primary functionality related with traffic management. Another example of supporting infrastructure is a cellular network, which might be seen as a better option due to its coverage centric deployment. In this case, an ITS server, located for instance in the internet, redistributes the RHW messages, i.e., it collects and routes the messages from and to other ITS stations. Moreover, the RHW messages can be distributed using the VANET and the cellular infrastructure interoperating in three different configurations: Cellular Unicast Configuration (CUC), Cellular Broadcast Configuration (CBC), and Hybrid Cellular-VANET Configuration (HCVC). Figure 1 depicts an example of RHW message distribution among vehicles in two perpendicular streets with the three configurations. The distribution procedure comprises four or five steps, depending on the configuration of the VANET and cellular infrastructure interoperation. These steps are the following: an accident happens, the neighboring ITS stations detect a road hazard, the road hazard is signaled

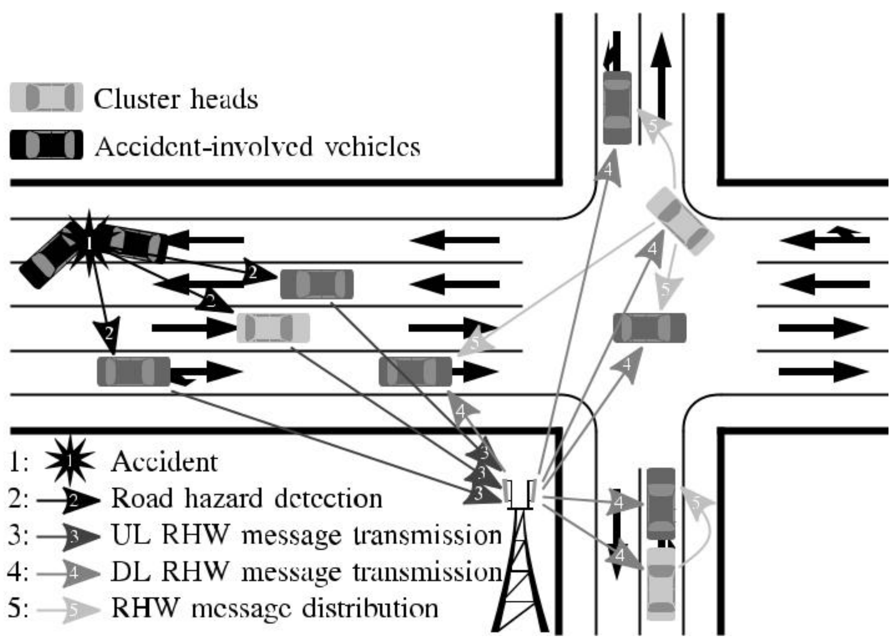

Fig. 1. Distribution of an accident related RHW message in the three VANET and cellular infrastructure interoperation configurations. Solid arrows represent transmissions that occur in the three configurations. Striped arrows refer to only

HCVC transmissions and dotted arrows to only CUC and/or CBC transmissions (UL in only the CUC, DL in the CUC and CBC).

Table 1.1: Characteristics of the Vanet And cellular Infrastructure Interoperation Configurations

	CUC	CBC	HCVC
Allows UL transmissions	yes	no	yes
Need of cellular broadcasting features	no	yes	no
UL load	high	—	low
DL load	high	very low	low
Size of a user profile database	large	—	small

to the network, the network transmits a RHW message, and a subset of ITS stations distribute the RHW message. The main characteristics of the three configurations are summarized in Table 1.1.

A CUC can be used for both Uplink (UL) and Downlink (DL) transmissions. In this case, all the ITS stations that detect the road hazard send a RHW message to the infrastructure (dotted and solid arrows in dark gray in Figure 1), which filters the different messages about the same event and retransmits only one of them to potentially interested ITS stations (dotted and solid arrows in medium gray in Figure 1). All these transmissions are point-to-point (ptp). The main drawback of this configuration is the large amount of cellular resources that is required to deliver the RHW messages, which, besides, might produce undesirable delays in congested scenarios or with high path losses. In addition to this, the ITS server has to be aware of the existence of all ITS stations to be able to route the messages to them. Therefore, the server has to manage a user profile data base with all the necessary information. In the case of the CBC, all the ITS stations belonging to a broadcast area, defined as any set of cells specified by the cellular operator, are addressed collectively, rather than individually. This implies that keeping a complete user profile in the server is not necessary. Thus, scalability and privacy are less critical and less signaling is foreseen. Although the CBC is more efficient, it exhibits two main drawbacks: (i) cellular operators do not usually activate the broadcasting features of their networks, and (ii) it cannot be used in the UL.

In the case of the HCVC, a subset of ITS stations act as gateways between the infrastructure and the rest of the ITS stations (vehicles in light gray in Figure 1). In particular, in the UL, they capture RHW messages generated by neighboring ITS stations and transmit them to the infrastructure with ptp transmissions (solid arrow in dark gray in Figure 1), which reduces the connection attempts and the amount of traffic transmitted to the network. In the DL, the gateways receive the RHW messages from the infrastructure with ptp transmissions (solid arrows in medium gray in Figure 1) and retransmit them to their neighboring ITS stations by means of direct communication and broadcast transmissions (stripped arrows in light gray in Figure 1). These gateways can be seen as cluster heads of certain ITS station clusters. The use of direct vehicle-to-vehicle communication together with broadcast dissemination improves the efficiency and timeliness of ITS information compared to traditional cellular ptp communication in scenarios with a congested cellular network or with high path losses. Another difference of the HCVC as compared with the CUC and CBC is the potential need for additional signaling between the ITS stations and the cellular network or the ITS server. This signaling is used to e.g. indicate which ITS stations are acting as cluster heads at any moment. The higher the number of cluster head reconfigurations, the higher the signaling.

Clustering and cluster head selection in Mobile Ad-hoc Networks (MANETs) have been widely studied in the literature, although most approaches consider only ptp communications without infrastructure, and the clustering procedures focus on improving some performance indicators of the message routing between a transmitter and a receiver through the MANET. The goal of the envisioned HCVC for RHW messages distribution is completely different. In particular, messages do not have to be delivered to a single receiver, but need to be distributed to all ITS stations in a certain area. First, a new class of cluster head selection techniques in which ITS stations become cluster heads with a certain precomputed probability. Second, the performance of the three configurations is analyzed by means of simulations in two scenarios with high and low path losses, respectively. The results show the gain that can be achieved by an HCVC with respect to traditional CUC and CBC scenarios in a cellular network with high path losses.

2. LITERATURE SURVEY

[1] Intelligent Transport Systems (ITS); Access Layer Specification for Intelligent Transport Systems Operating in the 5 GHz Frequency Band, document ETSI EN 302 663 V1.2.1, Jul. 2013

Wireless communication is a cornerstone of future Intelligent Transport Systems (ITS). Many ITS applications require the dissemination of information with a rapid and direct communication, which can be achieved by ad hoc networking. GeoNetworking is a network-layer protocol for mobile ad hoc communication based on wireless technology, such as ITS-G5. It provides communication in mobile environments without the need for a coordinating infrastructure. GeoNetworking utilizes geographical positions for dissemination of information and transport of data packets. It offers communication over multiple wireless hops, where nodes in the network forward data packets on behalf of each other to extend the communication range. Originally proposed for general mobile ad hoc networks, variants of GeoNetworking have been proposed for other network types, such as vehicular ad hoc networks (VANETs), mesh networks and wireless sensor networks. Therefore, GeoNetworking can also be regarded as a family of network protocols based on the usage of geographical positions for addressing and transport of data packets in different types of networks. In VANETs, GeoNetworking provides wireless communication among vehicles and among vehicles and fixed stations along the roads. GeoNetworking works connectionless and fully distributed based on ad hoc network concepts, with intermittent or even without infrastructure access. The principles of GeoNetworking meet the specific requirements of vehicular environments: It is well suited for highly mobile network nodes and frequent changes in the network topology. Moreover, GeoNetworking flexibly supports heterogeneous application requirements, including applications for road safety, traffic efficiency and infotainment. More specifically, it enables periodic transmission of safety status messages at high rate, rapid multi-hop dissemination of packets in geographical regions for emergency warnings, and unicast packet transport for Internet applications. GeoNetworking basically provides two, strongly coupled functions: geographical addressing and geographical forwarding. Unlike addressing in conventional networks, in which a node has a communication name linked to its identity (e.g. a node's IP address), GeoNetworking can send data packets to a node by its position or to multiple nodes in a geographical region. For forwarding, GeoNetworking assumes that every node has a partial view of the network topology in its vicinity and that every packet carries a geographical address, such as the geographical position or geographical area as the destination. When a node receives a data packet, it compares the geo-address in the data packet and the node's view on the network topology, and makes an autonomous forwarding decision. As a results, packets are forwarded "on the fly", without need for setup and maintenance of routing tables in the nodes. The most innovative method for distribution of information enabled by geographical routing is to target messages to certain geographical areas. In practise, a vehicle can select and specify a well-delimited geographic area to which messages should be delivered. Intermediate vehicles serve as message relays and only the vehicles located within the target area process the message and further send it to corresponding applications. In this way, only vehicles that are actually affected by a dangerous situation or a traffic notification are notified, whereas vehicles unaffected by the event are not targeted. Basically, geographical routing comprises the following forwarding schemes: • GeoUnicast: figure 2.1 shows a possible method of packet delivery between two nodes via multiple wireless hops. When a node wishes to send a unicast packet, it first determines the destination's position and then forwards the data packet to a node towards the destination, which in turn re-forwards the packet along the path until the packet reaches the destination.

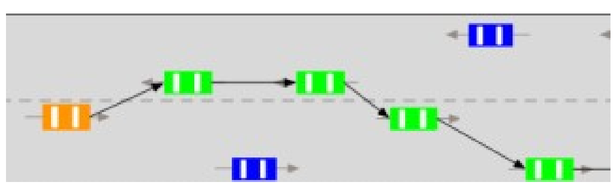

Fig 2.1: Geo UniCast

GeoBroadcast: figure 2.2 shows a possible method of geographical broadcast. A packet is forwarded hop-by-hop until it reaches the destination area determined by the packet, and nodes rebroadcast the packet if they are located inside the destination area. GeoAnycast is different from geographical broadcast in that a node within the destination area will not rebroad cast any received packets.

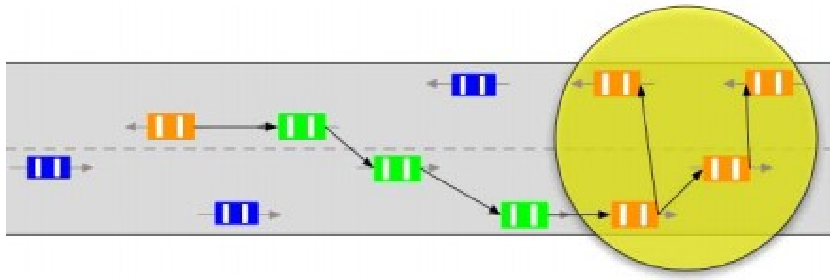

Fig 2.2: Geo BroadCast

Topologically-scoped broadcast: figure 2.3 shows rebroadcasting of a data packet from a source to all nodes in the n-hop neighbourhood. Single-hop broadcast is a specific case of topologically-scoped broadcast, which is used to send packets only to one-hop neighbourhood.

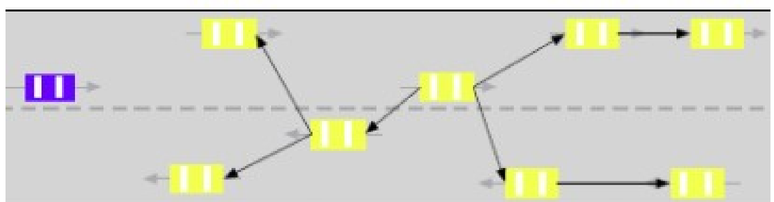

Fig 2.3: Topologically-scoped Broad Cast

[2]. J. Y. Yu and P. H. J. Chong, "A survey of clustering schemes for mobile ad hoc networks," IEEE Commun. Surveys Tuts., vol. 7, no. 1, pp. 32–48, 1st Quart., 2005.

Clustering is an important research topic for mobile ad hoc networks (MANETs) because clustering makes it possible to guarantee basic levels of system performance, such as throughput and delay, in the presence of both mobility and a large number of mobile terminals. A large variety of approaches for ad hoc clustering have been presented, whereby different approaches typically focus on different performance metrics. This article presents a comprehensive survey of recently proposed clustering algorithms, which we classify based on their objectives. This survey provides descriptions of the mechanisms, evaluations of their performance and cost, and discussions of advantages and disadvantages of each clustering scheme. with the proliferation in personal computing devices and the development in wireless communication technologies, ad hoc wireless networks have gained worldwide attention in recent years. The great popularity of Internet services makes more people enjoy and depend on the networking applications. However, the Internet is not always available and reliable, and hence it cannot satisfy people's demand for networking communication at anytime and anywhere. MANETs, without any fixed infrastructures, allow mobile terminals to set up a temporary network for instant communication. Hence, MANETs bear great application potential in these scenarios, including disaster and emergency relief, mobile conferencing, sensor dust, battle field communication, and so on. Dynamic routing is almost the most important issue in MANETs. However, it has been proved that a flat structure exclusively based on proactive or reactive routing schemes cannot perform well in a large dynamic MANET. In other words, a flat structure encounters scalability problems with increased network size, especially in the face of node mobility at the same time. This is due to their intrinsic characteristics. The communication overhead of link-based proactive routing protocols is O(n2), where n is the total number of mobile terminals in a network. This means that the routing overhead of such an algorithm increases with the square of the number of mobile nodes in a MANET. For a reactive routing scheme, the disturbing RREQ (route request) flooding over the whole network and the considerable route setup delay become intolerable in the presence of both a large number of nodes and mobility. Consequently, a hierarchical architecture is essential for achieving a basic performance guarantee in a large-scale MANET. Since a cluster structure is a typical hierarchy, many papers focus on presenting an effective and efficient clustering scheme for MANETs. However, until now no overviews of ad hoc clustering issues have been presented. In this article we present a comprehensive survey of several proposed clustering schemes for MANET research, and classify and analyze these schemes based on their main objectives.

[3].M. Gerla and J. T.-C. Tsai, "Multicluster, mobile, multimedia radio network," Wireless Netw., vol. 1, no. 3, pp. 255–265, 1995.

A mobile ad hoc network (MANET) is a wireless network without any fixed infrastructure. All nodes must communicate with each other by a predefined routing protocol. Most of routing protocols don't consider binding internet addresses to mobile nodes. However, in network mobility (NEMO), all mobile nodes can't only communicate with Internet using Bi-directional tunneling but also can be allocated an Internet address. implementaion two algorithms with the nested NEMO topology to reconstruct the Internet based MANET. Additionally, a novel load balancing solution is proposed. The Mobile Router (MR) which acts as a central point of internet attachment for the nodes, and it is likely to be a potential bottleneck because of its limited wireless link capacity. We proposed a load-information in the route advertisement (RA) message. The simulation results show that the proposed solution has significantly improved the connection throughput. Wireless networks provide mobile users with ubiquitous communicating capability and information access regardless of location. Ad-hoc wireless networks consist of a set of nodes such as mobile computers, handsets, PDAs or other mobile wireless terminals and do not need any fixed infrastructures or wireline networks support. There are many applications for adhoc networks such as disaster recovery, rescue missions, military operations in a battle field, conferences and outdoor entertainment activities, etc. The virtual backbone which can be constructed during network initiation and maintained by a background process is a shared structure for information exchanges and routing. Nodes acquire routes from the virtual backbone when they want to communicate with other nodes. A virtual backbone can be used in wireless networks to support flows, multicasting, and even fault-tolerant routing for mobile computers. The virtual backbone in ad-hoc networks is different from the wired backbone of cellular networks in two aspects. First, the backbone may change when nodes move. Second, it is used primarily for information exchanges, e.g., packet routing or flow support. The virtual backbone approach is faster and more scalable than traditional table-driven routing schemes in routing convergence and efficiency because the virtual backbone is a subgraph of the entire network topology and exploits a hierarchical structure. Because the network topology may change when nodes move, table-driven routing protocols are needed to maintain the routing tables. The maintenance overhead is very heavy if the network size becomes large. The virtual backbone approach is better than the reactive approach in terms of the route discovery latency. The on demand routing protocols require time to perform route discovery. In high sending rate and low mobility cases, routing information is dropped and wasted after the communication is finished. Although the virtual backbone exhibits some good features, there are four problems with the virtual backbone that must be considered. (1) The size of the virtual backbone must be kept as small as possible to avoid the scalability problem. (2) The virtual backbone scheme must be stable enough when the frequency of network topology changes is high. (3) The backbone nodes must be the nodes in the higher hierarchical positions so that they can dominate other non-backbone nodes. (4) The average length of the paths in the virtual backbone must be kept as short as possible to reduce the information exchange delay between any two nodes in the virtual backbone. These problems using clustering and distributed labeling techniques and a heuristic Steiner tree algorithm to develop a virtual backbone for ad-hoc networks.

Cluster Head Selection Technique Features and Literature Review

A good clustering and/or cluster head selection techniques should

a) be distributed and not require a central managing entity;
b) minimize the traffic load in the VANET by reducing the number and size of the signaling messages transmitted through the VANET for the cluster head selection;
c) have a fast response and adaptation capabilities, in order to cope with the highly variable nature of VANETs;
d) select cluster heads as stable as possible, so that unnecessary cluster head changes do not increase the signaling in the cellular network;
e) maximize the area covered by the cluster heads; and
f) be robust in highly variable environments, where shadowing might cause coverage holes.

As highlighted in the Introduction, cluster head selection techniques proposed in the literature are not designed for broadcasting RHW messages to distant vehicles. As a consequence, they are not able to comply with some of the previous properties. In the rest of this section, we will analyze distributed techniques, which satisfy property a) above, i.e., those without a central managing entity. The distributed techniques proposed in the literature can be classified as follows:

- Lowest-ID (LID) algorithms. LID is a well-known and studied approach in which ITS stations periodically broadcast their ID numbers. If an ITS station has the lowest ID number among its neighbors, it becomes the cluster head. When the ID number is not the lowest one, it is necessary to check if the neighbors with lower

IDs are cluster heads or not. If none is a cluster head, the ITS station becomes a cluster head itself.

- Highest-degree algorithms. The goal of these algorithms is to minimize the number of clusters. Each ITS station is aware of the number of neighbors. This number is broadcasted like the ID in the LID algorithm. Then, the ITS station with the highest number of neighbors is selected as the cluster head (in case of a tie, LID prevails).

Weight-based algorithms. In this family of algorithms, weights are computed for each ITS station and transmitted, so that the station with the highest weight becomes the cluster head (in case of a tie, LID again prevails). In fact, the two previous algorithms may be seen as special cases of weight-based algorithms, wherein the weights are all ones for the LID algorithm, or the number of neighbors for the highest-degree algorithm. The chosen weights are inversely proportional to the vehicle speed in a quasi-static network (vehicles have a reduced mobility). This approach aims at minimizing the number of cluster head reassignments. (signaling) presented above. In particular, ITS stations , the same approach is extended to any mobile network, without the constraint of quasi-static vehicles. After these two works, the weights computation was extended to include other metrics. In particular, the weights are computed as a weighted sum of factors that depend on the number of neighbors, the distance to neighbors, speed, and the time during which the vehicle has been acting as a cluster head. Other works have considered the cluster stability in the cluster head selection. In particular, in the concept of stability factor is defined and used as weights for the cluster head selection. A similar approach was used in, whereas in vehicles that are expected to remain in a cluster for a longer time are selected as cluster heads.

In a dynamic clustering mechanism is proposed. The clustering procedure is divided into three phases, which are based on direction of movement, signal strength of the Universal Mobile Telecommunications System (UMTS) cells, and transmission range, respectively. Then, the first cluster heads are selected in each cluster by measuring the Time-To-Live (TTL) of a packet inside the cluster. The vehicle with the lowest TTL is at the cluster center and, hence, selected as cluster head. The selection of subsequent cluster heads is managed by the current cluster head and done after computing some weights based on mixed criteria. The work of is extended to consider Long Term Evolution (LTE) and to Quality of Service (QoS) provisioning. Previous techniques require signaling data interchange among ITS stations to select the cluster heads, which increases the VANET load, and hence do not comply with property b) (minimize have to broadcast their IDs (in all previous techniques), the number of neighbors (in the highest degree algorithms) and the weights (in the weight-based algorithms), in addition to other data required to compute the weights, like location, stability factor, direction of movement, received signal strength from the infrastructure, and speed. Moreover, in some cases, the signaling is divided into several phases, which complicates and delays the selection, and, hence, goes against property c) (fast reselection). If other ITS messages that include the station ID are transmitted through the VANET, the LID algorithm does not increase the VANET load significantly, since the IDs of each station are already known from previous messages. However, the LID algorithm does not take into account cluster head coverage (property e)) or robustness (property f)).

A new class of cluster head selection techniques in which ITS stations become cluster heads with a certain precomputed probability is proposed. The main advantage of these techniques is that they are able to combine different parameters that characterize the suitability of a cluster head (similarly to the weights of weight-based algorithms), and, at the same time, they need only one signaling bit (in contrast to weight-based algorithms, which require the interchange of weights among other parameters). This new class, which is described in Section 3, will be evaluated and compared with the LID-based algorithm described in Section 3.1.

3. PROPOSED SYSTEM

3.1 LID-Based Cluster Head Selection Technique

In this section, A LID-based cluster head selection technique that will be used. With this technique, ITS stations manage a database of neighbor ITS stations with three fields: the neighbor ID, a one-bit cluster head flag, and a timer. Let us assume that ITS stations periodically send ITS messages that contain their IDs and one bit indicating if they were cluster heads when the message was generated, i.e., the cluster head flag. When one of these messages is received, the receiver ITS station looks for the sender ID in the database, and, if it is found, updates the cluster head flag and sets the timer to zero. If the sender ID is not in the database, it creates a new entry with the sender ID, the cluster head flag indicated in the ITS message, and a new timer set to zero. Moreover, in this latter case or if the cluster head flag changed, the receiver starts a decision process to resolve if it should or should not be a cluster head taking into account the new situation. At any time, ITS stations can look at the timers in their databases to know how much time has passed since the last time they heard about the corresponding neighbors. If one of those timers exceeds a predefined amount of time, say T_{timer}, it is assumed that the corresponding ITS station is no longer a neighbor. In this case, the entry in the database is removed and the ITS station starts a new decision process. The value of parameter T_{timer} should depend on the periodicity of the ITS message transmission and the ITS station speeds. In particular, it should be large enough to ensure the reception of at least one ITS message from every neighbor, and, at the same time, small enough to be able to adapt the cluster head selection to a rapidly changing VANET, i.e., one where the relative position of vehicles change rapidly. The decision process is as follows: ITS stations become cluster heads if all neighbors have higher IDs or none of the neighbors with lower IDs is a cluster head.

Remarks:

1) With this technique, only one additional bit of information (the cluster head flag) is interchanged whenever an ITS message is transmitted. Note that this is true if some kind of ID is already included in the ITS messages, and, if not, the IDs should be also accounted as an extra payload.
2) When an ITS station starts a decision process, its database can be outdated. In particular, it may consider that a certain neighbor is a cluster head if this neighbor was not able to indicate a change in its state because no ITS message was received yet and the timer for this neighbor has not expired.
3) The databases can be reduced by including only the ITS stations with lower IDs.

3.2 Probabilistic Cluster Head Selection Technique

A new type of cluster head selection techniques. The main advantage of these techniques is that they are able to combine different parameters that characterize the suitability of a cluster head (similarly to the weights of weight-based algorithms), maintaining the low signaling overhead of the LID technique (in contrast to weight-based algorithms which require the interchange of weights among other parameters). In particular, ITS stations decide to become a cluster head with certain probability computed from some parameters, and the decision is broadcasted using a one-bit cluster head flag in the ITS messages. ITS stations do not need to know the probability computed in neighboring stations.

Remarks:

1) A high (low) probability indicate a high (low) suitability of being a cluster head.
2) Due to the probabilistic nature of these algorithms, it is possible that ITS stations with high (low) probabilities decide to not become (become) cluster heads, although this possibility is unlikely depending on the actual probability values. This fact is, however, not critical for improving the timeliness of RHW message reception. In this case, it is more important to reduce signaling overhead and to allow certain overlapping of the cluster head coverage areas, which provides diversity.

3) In order to ensure that the signaling is composed of just one bit of information, i.e., the cluster head flag, the parameters used to compute the probability have to be already known by the ITS stations by either their own measurements or the content of ITS messages.
4) With a probabilistic cluster head selection technique, each ITS station should
1) choose a decision making interval T ;
2) wait for T seconds monitoring the channel;
3) after the T seconds, compute a probability P and become a cluster head with this probability; and
4) return to the first step.

The decision making interval T, can be randomly selected from a predefined set of values, or it can be preconfigured in each ITS station. In any of the two cases, these intervals should be different in each ITS station to prevent their potential synchronization that may produce a ping pong effect, i.e., many ITS stations changing their role as cluster heads in every decision. Key properties that the probability P should exhibit are that (i) it should be 1, i.e. 100%, if no ITS message with a positive cluster head flag is received during the T seconds, and (ii) it should decrease with the number and signal strength of these messages. By controlling how much the probability decreases, the overlap of cluster head coverage areas can be controlled. In particular, by using a method in which P = 1 independently of the received flags, all ITS stations become cluster heads; and by using a method in which P= 0 if one or more positive flags are received, cluster heads tend to be located outside the coverage areas of other cluster heads. This behavior is similar to the one of the LID-based technique of Section 3, and, although it could be seen as a good property, the probabilistic behavior of fast fading and the rapidly changing vehicle locations produce coverage holes. That is to say, it is possible that an ITS station is out of the coverage of any cluster head. Since coverage holes are a serious problem, allowing some coverage overlap, e.g., with P > 0, the formation of those coverage holes can be drastically reduced. A probability computation method with this behavior is proposed. This method can be mixed with the use of weights, as illustrated in Section 3.2.

A. Distance-Based Probability of Becoming a Cluster Head

This section presents an example of how to compute the probability of becoming a cluster head depending on the distance to other cluster heads, which can be known from their ITS messages using either the signal strength or the Global Positioning System (GPS) information embedded in the message. Assuming that during the *T* seconds of monitoring time an ITS station received positive cluster head flags from N different vehicles, this ITS station should

1) estimate the distance to all senders, d_i , $i = 1, \ldots, N$;
2) estimate the coverage range of its own VANET transmitter, R; and
3) calculate $P=\prod^{N}_{i=1}(\mathrm{mid}(d_i,R)/R$.

The coverage range, R, depends mainly on the environment, i.e., road or street shape, presence of objects that obstruct the signal, etc. Therefore, it should adapt to the particular environment in which the ITS stations are located. To this end, it could be estimated from the received ITS messages with GPS information, or from a testbed or simulation campaign and configured in the ITS stations as a fixed value for certain areas or locations.

B. Using Weights With the Probabilistic Cluster Head Selection

The use of weights to select cluster heads is a common method found in the literature, in which the cluster heads are those ITS stations with highest weights. However, the methods proposed in the literature involve the exchange of certain amount of control data in order to (i) compute the weights of each ITS station, and (ii) exchange the weights with other ITS stations to know which one should be the cluster head. In order to reduce the control signals, (i) the weights should be computed from the information sent within the ITS messages without injecting additional overhead, and (ii) the weights should modify the probability of becoming a cluster head in such a way that ITS stations with the highest weights are more likely to become cluster heads, so that no weight information exchange among stations is required. In particular, whenever an ITS station has to decide to become a cluster head, i.e., step 3 in Section 3.2, it should

1) compute a probability P;
2) compute a weight, w ∈ [0, 1]; and
3) decide to become a cluster head with probability Pw.

Note that the weights used in the literature are not typically in the range [0, 1]. In this case, it would be necessary to delimit the weights by a maximum value and normalize them by this value. The weight w modifies P in a different way in each ITS station. In particular, if the ITS station is considered a good (bad) cluster head, the weight is close to 1 (0). Some factors used in other works to affect the weight value are the number of neighbor vehicles, distance to neighbors, speed, and Signal to Noise Ratio (SNR) of the cellular signal.

4. TOOLS AND TECHNIQUES

This section presents the simulation environments used to compare the distribution of RHW messages using a CUC, a CBC, and two HCVC; one with the LID-based cluster head selection technique of Section 3.2 and another one with the distance-based probabilistic cluster head selection technique of Section 3.3. The simulations focus on the DL part of the communication with the cellular network, i.e., the distribution of the RHW message from the base stations to the ITS stations. RHW messages are required to be distributed in the whole simulation area. The ITS stations communicate in the VANET using an IEEE 802.11p-based technology and with the cellular infrastructure using LTE.

A. Description of the Simulation Scenarios

Here considered a motorway and an urban scenario. Two aspects of these scenarios affect the performance of the different alternatives: congestion of the cellular network and propagation conditions. With respect to the cellular network, the two aspects are interrelated. In particular, the motorway scenario presents large cellular inter-site distances that produce high path losses and low Signal to Interference and Noise Ratio (SINR) values. Conversely, the urban scenario is more densely populated with cellular sites, and the SINR distribution is significantly better than in the motorway scenario. This fact leads to a more efficient utilization of cellular resources in the urban scenario, i.e., less resources are required for transmitting the same amount of information. In addition to this, the cellular network has less resources per sector in the motorway than in the urban scenario, due to the lower bandwidth availability in lower carrier frequencies. The use of these carriers in the motorway scenario is motivated by the typical LTE deployments in rural areas, which use lower frequencies because of coverage reasons. Due to the above, it is expected that the use of the HCVCs will be especially beneficial in the motorway scenario, since, in this case, the cellular network is expected to be easily saturated if a CUC is used. With respect to the VANET, the propagation conditions influence the effects of hidden nodes, i.e., ITS stations whose transmissions cannot be detected by the transmitter and that collide and destroy the message at the receiver. These collisions affect the performance of the HCVC, the only configuration that uses the

VANET to distribute RHW messages, cf. the fifth step in Figure 1. In particular, hidden nodes interfere with the distribution of RHW messages, CAMs and the embedded signaling bit, and hence, may affect the cluster head selection. The presence of hidden nodes is a particular aspect of the ITS-G5 technology, caused by the medium access control mechanism inherited from the IEEE 802.11 standard. In LTE, collisions may happen during the random access procedure when terminals in idle state have new data to transmit and demand resources. However, these collisions are more unlikely than in the case of ITS-G5 for two main reasons. First, the resource requests are significantly smaller than the ITS messages. Second, the potential colliding terminals are only new cluster heads, and not the entire set of ITS stations. For these reasons, collisions in LTE are assumed to be negligible in the observations of Section 5. The propagation conditions of the motorway scenario lead to V2V links that are not significantly obstructed, which reduces, although not completely eliminates, the effects of the hidden nodes. Without significant obstruction, hidden nodes are generally located at long distances from the transmitter, and, in this case, their interference in the transmitter neighborhood is not destructive. Conversely, in the urban scenario, buildings significantly obstruct the V2V links. Due to this obstruction, hidden nodes can be located at short distances from the transmitter, which negatively impacts performance. the case in which, due to building obstruction, an ITS station may not know if the channel is being used by another ITS station in a perpendicular street, even if both stations are at a short distance. Therefore, the first station may initiate a message transmission that overlaps in time with the transmission of the second station. As a result, both transmissions interfere with each other in the street junction in such a way that a third vehicle could not receive any of the two messages. Taking these conditions into account, it is expected that the HCVC will beat the CUC in the motorway, but not in the urban scenario, in terms of RHW message reception delay.

The motorway scenario, is composed of a straight 20 km long motorway with three 3.5 m wide lanes per direction, a 2 m wide median, two 2.5 m wide external berms and two 1.5 m internal (beside the median) berms. Two cellular sites are located at 5 km and 15 km of one of the motorway ends, and separated 35 m from the motorway edge. The sites have two sectors, and an antenna height and down tilt of 20 m and 6°, respectively. With these parameters and assumptions, several simulations were carried out to obtain the best antenna azimuth for each sector. The best results were obtained using an antenna azimuth of 3° with respect to the east direction, the motorway being east-west oriented, for one sector, and the symmetric azimuth for the other sector.

B. Propagation and Channel Models

1) **Cellular Channel Model in the Motorway Scenario:** Path loss, shadowing and fast fading effects are simulated. The path loss model is based on the Rural Macro (RMa) model defined in the ITU-R specifications, in which different formulas are used depending on the Line of Sight (LoS) or Non-Line of Sight (NLoS) condition of cellular users. No user mobility is assumed in the RMa model, and a LoS or NLoS condition is selected for each user at the beginning of the simulation following certain LoS probability that depends on the distance to the base station. The selected condition is then fixed for the rest of the simulation. However, since, in this paper, ITS stations are moving, a modified version of this model was used. In particular, both the LoS, L_{LoS}, and NLoS, L_{NLoS}, path losses are weighted by the corresponding LoS probability, P_{LoS}, i.e., the path loss at a distance d, $L(d)$, is The equations for $P_{\mathrm{LoS}}(d)$, $L_{\mathrm{LoS}}(d)$, and $L_{\mathrm{NLoS}}(d)$ were obtained following the indications. Correlated shadowing was simulated using a log-normal map with a standard deviation of 6 dB and a correlation distance of 100 m. For each sector, a shadowing map was generated, ensuring that two close ITS stations experience similar shadowing values. The small-scale characterization is added on top of the large-scale effect using a tapped delay line channel model whose power delay profile is the Extended Vehicular A (EVA) profile, commonly used in 3GPP LTE studies.

2) **Cellular Channel Model in the Urban Scenario:** The used model is based on the METIS proposal for the Manhattan grid layout, with a minimum coupling loss of 70 dB. The METIS model also comprises large and small scale channel characterization. The former is implicitly modelled, together with path loss, thanks to its ray-based approach. The small-scale characterization is the same one used in the motorway scenario.

3) VANET Channel Model in the Motorway Scenario: In this case, the path loss model used for the motorway is based on the model proposed in [20]. According to this model, the path loss at a distance d is calculated a $L(d)=72.63+16\log_{10}d/10+x$ where X is a zero-mean normally distributed variable with standard deviation of 4.4 that represents the shadowing in the large-scale model. This variable is spatially correlated according to an exponential decaying correlation, with a correlation distance of 20.5 m .

4) VANET Channel Model in the Urban Scenario: In this case, the selected channel loss model was the ITU-R Urban Micro (UMi) path loss model, where both the transmitter and receiver heights are assumed to be 1.5 m. This model differentiates three cases: propagation to the same street, to a perpendicular street and to a parallel street. According to, two different models are used for the first two cases, whereas the propagation losses are assumed to be infinite in the third case. In addition to these losses, we considered that vehicles located between the transmitter and receiver cause a 10 dB extra loss.

C. Mobility Models

1) Motorway Scenario: ITS stations were initially dropped uniformly distributed along the motorway lanes. ITS stations then moved, following the indications given, with a constant speed of 100, 120 or 180 km/h depending on whether they are in the rightmost, center, or leftmost lane of their direction. Moreover, when ITS stations reach the end of the motorway, they re-appear at the start of the same lane and with the same speed.

2) Urban Scenario: In this case, ITS stations moved at a maximum speed of 60 km/h, turned at street intersections with 50% of probability (25% left and 25% right), and stopped at red traffic lights or when the vehicle in front was within a distance of 4m. The traffic lights are switched simultaneously using the pattern show

Table 4.1: Traffic Lights Pattern in the Urban Scenario

Seconds	Lights of horizontal streets	Lights of vertical streets
0–30	green	red
30–35	yellow	red
35–45	red	red
45–75	red	green
75–80	red	yellow
80–90	red	red

in Table 4.1 which repeated every 90 seconds. The movement of vehicles was generated using the road traffic simulation package Simulation of Urban Mobility (SUMO).

D. Traffic Models

1) **Encapsulation and Routing of RHW Messages:** The RHW messages were distributed using the Decentralized Environmental Notification (DEN) basic service standardized for C-ITS. The notifications were encapsulated in DEN Messages (DENMs) of size 800 bytes. The DENM source is able to reach an ITS server using the cellular infrastructure. The server analyzes the DENM, decides a region in which it has to be distributed (the whole simulation area in this case), and sends the DENM to the cellular base stations in that region. We assumed that the DENM was received at the same time by all base stations.

Cooperative Awareness Messages*:* ITS stations periodically transmitted Cooperative Awareness Messages (CAMs) to neighbors in the VANET. In particular, every 100 ms the vehicles checked the following rules to know if a CAM had to be generated :

- Generate CAM when absolute difference between current heading (towards North) and last CAM heading is greater than 4°.
- Generate CAM when distance between current position and last CAM position is greater than 4 m.
- Generate CAM when absolute difference between current speed and last CAM speed is greater than 0.5 m/s.

If the time elapsed since the last CAM was greater or equal to 1 second, a new CAM was generated independently of the previous rules. Consequently, all the possible time intervals between CAM generations were 100n ms, $n = 1, \ldots, 10$.

The CAM size followed the indications in, i.e., the size is 209 bytes, plus 213 bytes in CAMs that carry a low frequency container (every 500 ms), and plus 166 bytes in CAMs that carry a security certification (every second). The CAMs were used to transmit IDs, cluster head flags, and to compute distances to neighbors in the cluster head selection techniques of the HCVC. Since the CAMs are not transmitted to and from the cellular network, they affect the performance of only the HCVC, and not that of the CUC and CBC. In particular, in the case of the HCVC, DENMs and CAMs are transmitted in the same channel band and, hence, can collide and compete for the channel. Moreover, they affect the cluster head selection since they carry relevant information for the selection techniques, as described in the previous paragraph.

3) Encapsulation of Cluster Head Flags in Cooperative Awareness Messages:

In this section, a method for encapsulating cluster head flags in CAMs. Although this method is not part of the standard, it is compatible with it. The CAMs are structured as follows.

- ItsPduHeader
- CoopAwareness
  - GenerationDeltaTime
  - Cam Parameters
    * Basic Container
    * HighFrequencyContainer (HFC)
    * LowFrequencyContainer (LFC), optional
    * SpecialVehicleContainer(SVC), optional

The standard defines different types of containers for the three containers in a CAM, i.e. HFC, LFC, and SVC. In particular, there are two types of HFC currently defined, only one type of LFC, and up to seven types of SVC. Each CAM may only include one of these container types. The only LFC defined in the standard is the Basic VehicleContainerLowFrequency (BVCLF), which is transmitted every 500 ms. The proposed method defines a new LFC to carry the cluster head flag, which we called as ClusterheadVehicleContainerLowFrequency (CVCLF). This type of container can be included in any CAM that does not contain a BVCLF. In low mobility scenarios, the CAM generation rate can be reduced to one CAM per second. In those cases, every CAM should include one BVCLF, hence, an extra CAM is necessary to send the CVCLF. In spite of this extra message, this method is not expected to saturate the VANET, since, in this case, the CAM generation rate is very low.

E. IEEE 802.11p and LTE Configuration

The configuration parameters of the different devices used in the simulation are presented in Tables 4.3. In particular, the LTE base station, the IEEE 802.11p station, and the vehicle configuration parameters are given in Table 4.2, Table 4.3 and Table 4.4, respectively. Note that, from Table 4.3, the power per LTE resource block in the two scenarios is the same. With respect to LTE, the LTE scheduler selects users and allocates resource blocks to them following a proportional fair criterion, and giving maximum priority to the RHW messages. Thus, although other types of traffic are present in the simulations, consuming 80% of the LTE resources in average, this traffic only produces interference and does not compete against ITS traffic for resources. Most of the assumptions and parameters shown in Table 4.2 follow the ITU guidelines. In the case of CBC, LTE broadcast is used, i.e. eMBMS. In order to select a Modulation and Coding Scheme (MCS) for eMBMS, a coverage study was carried out by means of simulations to estimate the number of vehicles per sector that

Table 4.2: Configuration of LTE Base Stations

	Motorway scenario	Urban scenario
Bandwidth	10 MHz	20 MHz
Total transmit power	46 dBm	49 dBm
Carrier frequency	800 MHz	2600 MHz
Sectorization	2 sectors	3 sectors
CBC MCS	QPSK with 0.44 coding rate	16QAM with 0.48 coding rate
CBC MSP	80 ms	
Antenna height	20 m	25 m
Number of antennas per sector	2 transmit and 2 receive antennas	
Antenna gain	14 dBi	17 dBi
Antenna half power beamwidth	70° in horizontal plane and 10° in vertical plane	
Antenna downtilt	6°	12°
Cable loss	2 dB	

Table 4.3: Configuration of IEEE 802.11p Stations

Bandwidth	10 MHz
Total transmit power	28 dBm in urban scenario and 23 dBm in motorway scenario
Carrier frequency	5900 MHz
MCS / data rate	QPSK with 0.5 coding rate / 6 Mbps
EDCA access category	Voice

Table 4.4: Vehicle Configuration

Antenna height	1.5 m
Number of antennas	2 transmit and 2 receive antennas
Antenna gain	2 dBi
Antenna pattern	Omnidirectional
Cable loss	0.5 dB
Implementation loss	5 dB
Noise figure	7 dB
Thermal noise level	−174 dBm/Hz

can be supported with each MCS. In particular, the coverage level for a given MCS was computed as the percentage of vehicles that are not in outage for this MCS. A vehicle was assumed to be in outage if it experiences more than 5% BLER. The selected MCS was the highest one with a coverage value of at least 95%. Following this process, QPSK with a coding rate of 0.44 was selected for the motorway scenario, and 16QAM with a coding rate of 0.48 for the urban scenario. Another important parameter of eMBMS is the Multicast Channel (MCH) Scheduling Period (MSP). The lowest value for this parameter allowed in the standard is 80 ms, which is the value used in this assessment in order to minimize the RHW message transmission latency. Note that, depending on the instant at which a RHW message is generated, it has to wait for the start of the following MSP, i.e., between 0 and 80 ms. Assuming that the RHW message generation instant and the beginning of the MSPs are independent, the mean waiting time is 40 ms. With respect to the IEEE 802.11p configuration, the total transmit power of the stations was optimized for the trans-mission of CAMs in both the urban and motorway scenarios. The optimization aims at maximizing the number of CAMs correctly received in the proximity of the stations. The parameters summarized in Table 5.1 are assumed to be common to the LTE and IEEE 802.11p equipment on board the vehicles. Implementation losses are assumed to model the signal losses due to imperfections in the fabrication of the receiver components. In all the configurations, we assume 9 ms minimum delay in the transmission of the RHW messages accounting for 5 ms in the transmission from the originating remote ITS server to the LTE base station, 2 ms of base station processing, and 2 ms of receiver processing.

F. System Level Simulator

The system performance is based on dynamic system level simulations performed on a C++ proprietary simulator with an implementation of both LTE and IEEE 802.11p. The LTE part was used in the framework of the WINNER+ project, which was one of the International Mobile Telecommunications-Advanced (IMT-Advanced) evaluation groups of the ITU-R, and more recently in the METIS project in the evaluation of the 5G system. The IEEE 802.11p part emulates both physical and link layers. With respect to the link to system abstraction, i.e., the error probability given an SINR value, the model in was used for IEEE 802.11p, and the model for LTE.

5. OBSERVATIONS

Table 5.1: Performance of the VANET and CELLULAR Infrastructure Interoperation Configurations

	CUC	CBC	HCVC-PROB	HCVC-LID
Delay (motorway scenario)	medium to high	low	medium	high
Delay (urban scenario)	low	medium	medium	medium to high
LTE resource consumption	high	very low	low	low

From the above observations HCVC-Probability technique is the best technique when compared Cellular Unicast Configuration (CUC), Cellular Broadcast Configuration (CBC), and Hybrid Cellular-VANET Configuration –LID (HCVC) techniques.

6. CONCLUSION

Three VANET and cellular interoperation configurations to distribute RHW messages to distant vehicles have been analyzed. Despite distribution using cellular unicast or broadcast transmissions is a good option in terms of latency, the huge amount of resources required by unicast and the potential non availability of broadcasting features in the cellular network make hybrid configurations a meaningful alternative. Indeed, they are strong competitors of unicast and broadcast in terms of both latency and resource usage.

The hybrid configurations require the selection of cluster heads to distribute the RHW messages. A new cluster head selection technique is used to alleviate the drawbacks of previous techniques. The new scheme is able to reduce the latency of the RHW message distribution, and to select more stable cluster heads. These characteristics facilitate the use of hybrid configurations to distribute RHW messages.

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