CHAPTER 2: LITERATURE REVIEW

A lot of research has been carried out in the last decade regarding the development of wireless communication methodologies and applications that meet present day vehicular scenarios. With this background, we are predominantly interested to the most outstanding experiments that have been so far implemented, and hence will focus on their characteristics in this chapter.

- **Opportunistic Broadcast of Event-Driven Warning Messages in Vehicular Ad Hoc Networks with Lossy Links (OppCast) :**

  In [26], Li et al proposed a fully-distributed opportunistic broadcast protocol (OppCast) for multi-hop dissemination of event-driven warning messages in VANETs with lossy links, which aimed at simultaneously achieving high warning message packet reception ratio (PRR) and fast multi-hop message propagation, while minimizing the number of transmissions. A double-phase broadcast strategy was proposed to achieve fast message propagation in one phase and to ensure high PRR in the other. OppCast exploited opportunistic forwarding in each transmission to enhance the warning message reception reliability and to reduce the hop delay. Also to carry out reliable and efficient broadcast coordination; authors proposed the use of explicit broadcast acknowledgements which effectively reduce the number of redundant transmissions. This technique was also extended to handle sparse and disconnected VANETs, where the protocol adaptively switched between fast opportunistic forwarding and the store-carry-and-forward paradigm.

- **Efficient Data Dissemination in Vehicular Ad Hoc Networks**

  With paper [27], Ye et al gave the idea about the inter-vehicle data dissemination problem based on WAVE/802.11p vehicular ad hoc network, using network coding. Due to download rate limitations of present wide-area cellular connectivity such as 3G, direct peer-to-peer data sharing among vehicles can supplement vertical downloading with horizontal dissemination. Authors derived the probability mass functions (PMFs) of dissemination completion time in a prototypical three-node case for both random broadcast and with network coding. The PMFs of dissemination completion time in the three-node case for both random and NC (network coding) based broadcast were explicitly derived. For a 1-D infinite network, they proved that NC based broadcast reached steady-state, and derived a closed form result for the dissemination velocity in equilibrium.

- **An Adaptive Approach For Information Dissemination In Vehicular Ad Hoc Networks (AID) :**

  Before few years, several statistical-based broadcasting schemes for information dissemination had been proposed with reference to MANETs. The mentioned scheme was based on various threshold parameters to help nodes to decide whether to rebroadcast or discard received messages. However, in VANETs, it is difficult even impossible to determine a priori these threshold values. Because values change dynamically, to minimize the number of redundantly received messages, while maintaining good latency and reachability, was a complex issue in the absence of centralized controllers or constant threshold parameters. So in the paper [28], Bakhouya et al presented a decentralized and adaptive approach for information dissemination (AID) in VANETs. Authors focused on statistical-based broadcasting schemes and introduced an adaptive approach in which each node can dynamically adjust the values of its local parameters using information (i.e., inter-arrival time, number of redundant messages) about the messages received from neighbouring nodes without requiring any additional effort, such as distance measurements or exact location determination of nodes. Simulations and results are presented to show that adaptive approaches have a better performance over statistical-based approaches in terms of average latency while maintaining good reachability.

- **DV-CAST: A Distributed Vehicular Broadcast Protocol for Vehicular Ad Hoc Networks :**

  DV-CAST [29], A distributed vehicular broadcast protocol for vehicular ad hoc networks, utilized local topology information (i.e., a list of one-hop neighbours) as the main criterion to determine how to handle the rebroadcast of the message. DV-CAST used local topology information by using the periodic *hello* messages for broadcasting the information. Each vehicle used a flag variable to check whether the packet is redundant or not. This protocol divided the vehicles into three types depending on the local connectivity as: well connected, sparsely connected and totally disconnected neighbourhood. In well connected neighbourhood it used persistence scheme (weighted p-persistence, slotted 1&p-persistence). In sparsely connected neighbourhood, after receiving the broadcast message, vehicles could immediately rebroadcast with vehicles moving in the same direction. In totally disconnected neighbourhood, vehicles were used to store the broadcasted message until another vehicle entered into the transmission range, otherwise, if the time expired it would discard the packet. This protocol caused high control overhead and delay in end to end data transfer.

- **A Directional Data Dissemination Protocol for Vehicular Environments**

In [30], Schwartz et al presented a directional data dissemination protocol similar to DV-CAST to address highway scenarios, where vehicles equipped with sensors detected an event (e.g., a hazard), and broadcasted an event message to a specific direction of interest. Dissemination protocol was designed in such a way that:

i) it prevented the so-called broadcast storm problem in dense networks by employing an optimized broadcast suppression technique; and

ii) it efficiently dealt with disconnected networks by relying on the store-carry-forward communication model.

The novelty of the protocol lied in its simplicity and robustness. Existing protocol DV-CAST required the complete knowledge of the local (1-hop neighbourhood) network topology. This knowledge was usually acquired by means of *hello* messages sent by every vehicle periodically. Notably, *hello* messages introduced undesirable side-effects such as increase of the network load, contention and collisions when not properly coordinated. All these effects together might harm the correct delivery of event-driven messages, which were of primary importance in vehicular environments. Unlike DV-CAST, in [30] authors presented a protocol, which required only limited local topology information with an efficient periodic *hello* message mechanism in which only a subset of vehicles was required to participate. This protocol required only the knowledge of whether the vehicle was currently the front, tail, or simply a relay vehicle in the cluster.

Although the conventional *hello* message mechanism described above sufficed to gather such information, the use of a suppressed periodic *hello* message mechanism was proposed. In essence, such mechanism relied on the optimized suppression technique to broadcast *hello* messages. The simulation results showed that the protocol achieved higher delivery ratio and higher robustness when compared to DV-CAST under diverse road scenarios.

- **Group Communication on Highways: A valuation study of Geocast Protocols and Applications (DBA-MAC):**

In [31], Felice et al proposed a cross-layer scheme, called Dynamic Backbone Assisted-MAC (DBA-MAC) protocol as a general solution to support geocast communication on highway scenarios for different classes of vehicular applications. Most of the applications proposed for VANETs rely on geo-casting, i.e. on the possibility to identify the end-points of the communication through their geographic coordinates instead of their network addresses. DBA-MAC combined the benefits of proactive and reactive schemes through a cross-layer architecture which included:

i) a novel distributed clustering algorithm; and

ii) a fast information dissemination mechanism.

First, DBA-MAC created and maintained a virtual backbone of vehicles inside the highway scenario. Then, it provided fast dissemination of geocast messages through a combination of contention-free and contention-based forwarding mechanisms at the link layer. Then, the performance evaluation of DBA-MAC compared to traditional geocast schemes for three classes of vehicular applications:

- active-safety applications,
- traffic-information applications, and
- multimedia streaming (audio/video) applications.

DBA-MAC was able to greatly reduce the delivery delay for active-safety applications, and to adequately meet the requirements of multimedia applications for VANETs. The evaluation results had revealed that creating a backbone of maximally spaced node can enhance the delivery delay of safety-related applications. On the other hand, a metric which created a backbone of high-quality links was suitable for vehicular applications which implement traffic monitoring and information systems, based on the period exchanges of traffic updates. Finally, multimedia (audio/video) streaming applications for VANETs could be best supported by a metric which attempted to minimize the delivery delay at each hop.

- **Evaluating The Impact of A Novel Message Dissemination Scheme For Vehicular Networks Using Real Maps (eMDR):**

  We can find counter-based, distance-based, location-based, cluster-based, and probabilistic schemes, which have been mainly tested in non-realistic simulation environments. In this paper [32], Fogue et al presented, Enhanced Message Dissemination based on Roadmaps (eMDR), a novel scheme specially designed to improve the performance of the warning message dissemination process in real map urban scenarios, to increase the percentage of informed vehicles and to reduce the notification time; at the same time, it mitigated the broadcast storm problem in real time urban scenarios. This scheme considered the effects that buildings have over the signal propagation to improve message dissemination in real urban scenarios. Authors proposed a model in which vehicles operated in either warning or normal mode. Normal mode represented a default behaviour; however, when a vehicle detected a dangerous condition, it would start operating in warning mode. In warning mode, vehicles informed other vehicles about abnormal situations by sending warning messages periodically using the highest priority at the MAC layer. With respect to warning messages, each vehicle only propagated them once for each sequence number, i.e., older messages were dropped. The eMDR scheme was especially suitable in situations where there were few vehicles able to forward messages, which could be due to either the low vehicle density or the low market penetration rate of wireless devices. This scheme relied on GPS systems containing integrated street maps locations to decide the next forwarding nodes. Distance and location-based schemes could be excessively restrictive, especially when buildings interfere with radio signal propagation. Inaccuracy on GPS data could result in performance degradation. (Modern GPS devices usually produce an average positioning error ranging from 10 to 15 m, which could be reduced to less than 5m using correction techniques).

- **Repetition-Based Cooperative Broadcasting for Vehicular Ad-Hoc Networks (RB-CD):**

  In vehicular ad hoc networks, most of critical applications involved with safety rely on reliable broadcast communications with low latency. Recently, repetition-based protocols had been proposed to meet the requirements of timeliness and reliability for broadcasting. The existing protocols faced serious problem such as deterioration of the signal quality caused by wireless fading. In [33], Yoo et al proposed a novel repetition-based broadcast protocol, which exploited a cooperative diversity technique (called RB-CD) making a small number of repetitions robust for wireless fading. To support the cooperative diversity, neighbouring nodes transmit the same message almost simultaneously (i.e. using the same repetition pattern for each other) in order to form a virtual antenna array. The virtual antenna array achieved a diversity gain at the receivers. In the RB-CD protocol, the virtual antenna array consisted of the source and some of its neighbours (called relays), which participated in repeating the transmission of a broadcast message.

  In addition, a new distributed relay selection algorithm was introduced in the RB-CD protocol. The performance of the cooperative transmissions depended mainly on how the relays were selected. Using the geographic topology of the source's neighbourhood, RB-CD selected the best relays to maximize the probability of successful transmissions in a distributed manner.

- **Multi-Hop Vehicular Broadcast (MHVB):**

  Lin et al [34], proposed a scheme to disseminate information in vehicular ad hoc network by efficiently flooding the packets among vehicles based on their position information. Based on the requirements of ITS active safety applications, a mechanism to detect traffic congestion and a method to suppress unnecessary packets for improving the bandwidth utilizations was introduced. The introduction of congestion detection technique gave a significant impact on the improvement of the performance of flooding protocols in ITS context. However, the scalability of the protocol was not satisfactory because too many packets transmitted by many nodes lead to packet collisions and the consequent packet losses.

- **Enhanced Multi-Hop Vehicular Broadcast for Active Safety Applications:**

  Authors focused on the enhancement of Multi-Hop Vehicular Broadcast (MHVB) in [35]. This protocol was fundamentally a flooding algorithm with special characteristics in order to efficiently disseminate information such as the positions and the velocities of the vehicles for the sake of active safety applications. The main purpose of this paper was to show the performance improvement obtained by adding more special characteristics to the existing version of MHVB. The enhancement procedure was carried out in two steps: first, by changing the shape of the backfire region in the algorithm and then by introducing a new Dynamic Scheduling algorithm, which prioritized the packet transmission based upon processing of the received packets from the other vehicles. The key point in the proposal made to enhance the broadcast protocol was the balance between the application requirement and the performance of the protocol.

- **Delay-Bounded Data Gathering In Urban Vehicular Sensor Networks (DB-VDG):**

  Protocol DB-VDG [36], proposed by Palazzi et al aimed at spreading information corresponding to a certain geographic area and satisfying a specific delay bound. It used fixed base stations (BS), which created the information and determined a target area for the data propagation during a fixed time interval. According to a delivery probability related to a distance that DB-VDG calculated, it switched between two options:

  i) immediately forwarding the message to another node if it has a great probability of successfully relay this message; and

  ii) waiting a moment and probably aggregating data from different sources.

  This second choice depended on the delay bound of the data and allowed to reduce the bandwidth consumption and to wait for a more adapted broadcaster. The concept of linking between the space and the time criteria for the data diffusion is the same as proposed method.

- **Acknowledgment-Based Broadcast Protocol for Reliable and Efficient Data Dissemination In Vehicular Ad-Hoc Networks:**

  In [37], F. Ros et al proposed a broadcast algorithm suitable for a wide range of vehicular scenarios, which only employed local information acquired via periodic beacon messages, containing acknowledgments of the circulated broadcast messages. Each vehicle belongs to a particular connected dominating set (CDS). Vehicles in the CDS used a shorter waiting period before possible retransmission. At timeout, a vehicle would retransmit if it was aware of at least one neighbour in need of the message. To address intermittent connectivity and appearance of new neighbours, the evaluation timer could be restarted. It is inherently adaptable to different mobility regimes, without the need to classify network or vehicle speeds. The performance resulted good for the highway scenario but remained insufficient for the urban scenario.

- **Dissemination And Harvesting of Urban Data Using Vehicular Sensing Platforms:**

  Another very interesting approach for VANETs was proposed in the Smart vehicles for Urban Monitoring with a Vehicular Sensor Network, called MobEyes [38], whose performance analytical model was presented in [39] by Lee et al, with more detailed simulation results. MobEyes ensured proactive urban monitoring by taking advantage of vehicle mobility. The exchanged messages can include 2 to 10 minutes of summaries regarding the captured data. This method targeted a specific surveillance application where data were harvested by police officers. A bloom filter was applied to retrieve the missing information tightly linked to avoid redundancy. However, MobEyes was proposed for a specific delay-tolerant application but its generalization was not straight forward.

- **Transmission Rate Adaptation:**

  To reduce the delivery delay due to excessive number of transmissions, various 802.11 based solutions had been proposed. For example, in [9], S. Biswas et al proposed a backoff mechanism that reduced the frequency of message transmission or retransmissions when congestion was causing collisions, and hence unnecessary propagation delays.

  In [40], Yang et al proposed a scheme in which, the moment a car received a broadcast message from a following vehicle, it refrained from forwarding it, as the reception of that message was a clear confirmation about subsequent cars had already received it. Unfortunately, both the schemes did not consider a very important factor in determining the final propagation delay of a message: the number of hops a broadcasted message traversed before covering its whole area-of-interest.

- **Topology Awareness-Based Optimization:**

  Minimizing the number of hops that a message has to traverse to reach its car group may be obtained through building a minimum connected dominating set (MCDS) from a graph, whose nodes represent vehicles in the group, and an edge connects one node to another if the second node is in the transmission range of the first node. The above concept was proposed by Zanella et al in [41]. However, the implementation of this algorithm for inter vehicular communication lead to great practical difficulties as it would require complete and continuously updated knowledge of the network topology. Moreover, the high mobility of vehicular networks might render and obsolete the MCDS even before its completion. It is confirmed without saying that this is not a scalable solution.

- **Intelligent Message Forwarders:**

  Another scheme trying to statistically achieve a minimum number of hops when propagating a broadcasted message is discussed in [42] which is proposed by Fasolo et al. To minimize the number of hops that a message experiences during its propagation over the vehicular network, [42] and [43] assigned different contention windows (CWs) to each car receiving a message; their respective CWs were inversely proportional to the distance from the previous sender. Each car randomly selected a waiting time within its CW before forwarding the message. However, these schemes were affected by the assumption that there was a unique, constant, and well-known transmission range for all cars in every moment. This is obviously not realistic.

Korkmax et al implemented the hops' minimization in [44]. To achieve this aim, jamming signals were emitted by each car with a duration that is directly proportional to the distance between the considered car and the source of message. As per their logic, car with the longest jamming signal would clearly be the farthest car from the source. Even if this guaranteed a minimum number of hops to cover the whole area-of-interest, the time wasted to determine the next forwarder through jamming signals could make this scheme not suitable for a tight time delay scenario.

The scheme proposed in [45] by Claudio et al also introduced the hops' minimization using multi-hop protocol. But the scheme was successful only with no inter junctions. In this way, the scheme is effective but it is limited to straight path only.

One of the determining Traffic Information Systems is Self-Organizing Traffic Information System (SOTIS) [46] proposed by Nadeem et al. In this scheme, each road was divided into several segments, and vehicles could send the average velocities of the segments periodically. Another scheme proposed in [47] was Traffic View, which had similar mechanism as SOTIS, but instead of doing average of the velocities, it disseminated the positions and velocities of the individual vehicles at regular intervals. After inspiration from TrafficView, the authors of SOTIS expanded the idea and developed a Segment Oriented Data Abstraction and Dissemination (SODAD) scheme in their most recent work [48] that had an adaptive approach. Another architecture proposed by Palazzi et al in [49], named as Privileged Inter Vehicular Communication Architecture (PIVCA). The architecture proposed by them with limited features and without security concern, so not much suitable for urban scenario.

- **Advanced Heterogeneous Vehicular Network (AHVN) architecture for vehicular telematics**

  A work proposed by Hossain et al in [50], meant to use all possible technologies i.e. WiMAX, 3G-4G cellular services, satellite network, UWB etc. They put a doubt that DSRC standard would not work well as there wasn't ubiquitous deployment of the DSRC government legislation. But still we can say that the situation and direction of VANETs will be changed from grass root level and new look of VANETs will be seen within the next 10–20 years. Therefore, a heterogeneous platform will not work perfectly.

All these studies, however, are fully ad-hoc systems and suffer from large delays at far distances and not having a reliable mechanism to make sure that every vehicle is provided with all the traffic information it needs. Unfortunately, each of these schemes is affected by at least one of the following problems:

- redundant multi-hop transmissions,
- unrealistic assumptions about the vehicular environment, and
- generation of an elevate number of control messages.

This causes an inefficient utilization of the available limited resources, thus negatively affecting the overall performance of the system. Furthermore, this situation is exacerbated by the fact that different applications have peculiar characteristics, such as the generated network traffic, that existing solutions address in a specific way without a general vision.

Sensors, on-board computer, and communication devices are now ready to be used to increase driving safety by avoiding accidents or, at least, minimizing their harmful effects. Moreover, cars are becoming computing platforms that can access any data at any time, thus evolving from a simple transportation means to an office on the move, as well as an information provider, and an entertainment centre. There are lots of research papers devoted to the study of V2V communication to work out smart position-aware broadcast protocols to propagate urgent information. This could be done by having a random car sending a broadcast message to all cars in a certain area so as to make them record relevant data for the safe-driving (i.e., speed, safe distance from other cars and obstacles, smooth driving). This message should be reached all the cars within a small threshold of time, say 100ms. An efficient multi-hop broadcast scheme could hence quickly deliver messages to a higher number of cars, also dispersed on a wider portion of road. The solution which we want to propose is regarding quick broadcasting of a messages to all cars in a given area of interest. Our solution can be thought as an advancement of that proposed in above papers. In fact, most of the applications in VANETs are sensitive to per packet delivery delay, even few fraction of seconds, represent a massive waste of time that can disrupt their performances in all ways. The problem is so critical since the unreliable behaviour of these applications may either cause danger to human lives, or large monetary investments, or both [40]. One of the important vehicular applications is non-safety applications also called comfort or entertainment applications. Non-safety applications are so diverse, ranging from real-time or non real-time multimedia streaming and interactive communications such as video conferencing & interactive games; to roadside service application such as location and price lists of restaurants or gas-stations, weather information or internet access such as data transfer, web browsing, music download etc. Note that multimedia streaming is used for a wide range of applications. Even in traffic or safety applications the traffic situation or emergency message can be generated by video sensors already installed along the roadside. We have proposed the work for both safety applications and non-safety applications under V2V communication mode.