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A survey and comparative study of QoS aware broadcasting techniques in VANET

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Abstract Vehicular ad hoc networks are a special type of MANET providing vehicle to vehicle and vehicle to roadside wireless communications. Vehicular ad-hoc network (VANET) have been designed in order to assist drivers on the road with a variety of applications especially in preventing danger and saving lives. For such ends, broadcasting is a suitable scheme to convey emergency messages dissemination to the entire network. Broadcasting in VANETs is a challenging task due to the specific VANET features such as nodes mobility and frequent topology changes. VANET applications, especially those related with human life saving, are delay sensitive and have specific requirements in terms of performances and QoS. A QoS aware broadcasting scheme relies on different factors and has to deal with hard constraints. In this paper, we introduce a survey of broadcasting in vehicular networks and discussion of different performance and QoS related to broadcasting issues. Furthermore, a comparative study of QoS aware broadcasting protocols classifying them according to different taxonomies is elaborated. This survey specifies QoS requirements and performance metrics of VANET services. Furthermore, this survey focuses on QoS aware broadcasting as a challenging problem regrading VANET characteristics.

Keywords VANET · Broadcasting · QoS · ITS · Survey

1 Introduction

The power of information and communication technologies stands behind many significant innovations in human life. In the last years, mobile networks have invaded daily lifestyles providing extended information exchange. The application of such mobile communications in transportation leads to the emerging technology: vehicular ad hoc networks (VAN ET). Allowing vehicle to vehicle and vehicle to roadside wireless communications, VANET is an autonomous and sel-forganizing form of MANETs [1]. This innovating paradigm of exchanging information among vehicular nodes is one of the most up-to-date topics for both academic research and industrial investigations [2]. This technology enables a variety of applications that impact the human daily life such as infotainment, traffic management services and safety applications. Actually, travelling experience is no longer a tradition transportation service. Drivers need to maintain social connection during their trip with messages and multimedia contents exchange make emerging mobile social network(MSN) [3] likely services to be projected on vehicular networks. Moreover, Intelligent Transportation Systems (ITS)aim at encountering traffic congestion espe-

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cially in big cities [4]. VANET as a form of ITS has to include cooperative driver assistance with essential information such as traffic jams, road maps. One of the major VANET applications is safety-related information providing. It would avoid collisions or warn passengers about hazardous situation after determining which vehicles are near to an accident site to reduce vehicles pile up or fix responsibility. It also alert driver about road breaking or high speed [5]. This latter category of applications is the most important for saving human lives by avoiding road accidents and decreasing number of deaths. Once a hazardous road condition or an imminent dangerous incident occurs, an event driven safety message has to be generated and disseminated in order to warn drivers and passengers about the situation to appropriately react so as to avoid the danger. Forward and backward communications between vehicles and also communication between road infrastructure and vehicles are needed; therefore this type of applications requires broadcasting and rebroadcasting of data messages from the source, warning generator, to all nodes in the network. However, the broadcasting mechanism has to deal with VANET specific features [1] such as rapidly changing topology, vehicle high mobility, heterogeneous and unbounded environments, time critical, limited transmission radius of a vehicle constrained by the deployed technologies and others many VANET characteristics which make broadcasting in VANET more challenging in terms of performances and QoS than in the rest of MANETs. In literature many elaborated research works in the aim of improving broadcasting over VANETs [6]. Thereby, we find several reviews studying and discussing existing broadcasting schemes and presented algorithms [7]. Nevertheless, there are too few surveys assembling works on broadcasting in VANET and studying them from a QoS perspective. In this paper we give a detailed review of VANET main features and issues. We try to define QoS in a broadcasting context and according to different VANET services. This definition leads us to educe current QoS-related broadcasting problems and elaborate a detailed review and comparative study of QoS aware broadcasting protocols. The rest of the paper is organized as follows. In Sect. 2 we introduce related surveys. Section 3 summarizes VANET main applications. Section 4 describes VANET architecture and characteristics. In Sect. 5, we discuss broadcasting issues and unsolved problems in vehicular networks. In Sect. 6, a characterization defining QoS in a VANET context is introduced. In Sect. 7, we review QoS aware broadcasting works in literature with a detailed comparison according to performance features. Section 8 outlines some challenges, trends and future research directions. And finally a conclusion with our eventual perspectives.

2 Related surveys

Many surveys dealt with VANET issues over several fields of research and according various points of concern. Next we list some of these VANET reviews.

2.1 General surveys

There is a great number of works dealing with general VANET features and issues. In [8–10] authors reviewed general vehicular networks characteristics, network topology and architecture, wireless communications and VANET International deployed projects. Authors of [11] focus on reviewing VANET different applications and services. In [12] context-aware VANETs applications are reviewed. Authors in [13–16] elaborated surveys about specific VANET aspect especially in data communication and listed most important challenges in this research area. An other important subject for VANET reviewers is Technological aspect, a survey of different technologies deployed in vehicular networks is introduced in [17]. Authors of [18] introduced an advanced review of general VANET characteristics, routing and congestion control issues and main technical challenges, they also conceived a road-map for future development.

2.2 Security surveys

Similarly to other mobile networks, security is a major issue in VANET. Hence, several research work treated privacy and security challenges in vehicular networks. Authors in [19] tried to review all risks threatening VANET users and informations exchanged over the networks. Also main challenges towards VANET security research work are reviewed. In [20] a general survey of security problems over vehicular networks is introduced. Misbehaviours are one of network security known threats in vehicular networks. Authors in [21] elaborated a survey about different techniques to encounter this issue. Many of such risks are expected to occur during routing process. Authors of [22] surveyed trust based techniques for securing routed messages over VANET.

2.3 Routing protocols surveys

VANET routing protocols related surveys could be classified into three main categories: broadcast routing surveys, clustering techniques surveys and other routing protocols surveys. There are many routing related VANET surveys in litterature. For instance there are reviews which focus on a special type of routing such as [23,24] which deal with position based routing protocols in Vehicular environment. [25]

focus on geographic routing and [26] surveys dynamic routing, while [27] reviews topology based protocols. [28] is a survey of bio-inspired VANET routing protocols and [29] is about heuristic-based ones discussing their technical challenges and future trends. There are other surveys such as [6,30–32] which try to classify different routing mechanism into subcategories. In the other hand, some research works are interested in reviewing routing protocols based on the problem they aim to solve. For instance, authors of [33] provide a survey about collision avoidance mechanism in vehicular networks. Routing protocols performance evaluation is also an important point. Some related surveys are provided in [34–37]. For broadcasting related surveys, authors of [38] classified broadcasting schemes according to their related VANET applications. Based on this classification they elaborated a survey on the main protocols. Meanwhile, authors do not give any comparison between the lised protocols neither a detailed study of their performances metrics. Authors of [39] gave a broadcasting protocols survey which focus on relaying mechanism feature to compare them. Although this aspect is very important in the hole broadcasting process performance, it is not sufficient to decide of its QoS awareness. Many other parameters have to be taken in account in order to compare protocols performance levels. Another similar survey is introduced in [40]. Here authors focused on classifying broadcasting protocols into proactive, reactive and hybrid schemes. The survey does not provide any performance comparative metrics. The survey of [7] is more enhanced since they give a clear classification of protocols and a detailed comparison study. However, this study do not show clearly different performances of these protocols. Also, authors do not define any VANET QoS measures requirement related to broadcasting mechanism. Clustering is also an important technique related to routing protocols and which enhances their performance. Authors of [41,42] provide surveys about main clustering techniques in VANET.

2.4 QoS related surveys

In a VANET environment, QoS represents a real challenge for researchers. Therefore, many QoS related surveys exists in literature. In [20] main QoS related issues in a vehicular context are discussed while authors of [43] surveyed and compared different approaches and techniques for providing QoS support in vehicular networks. In [44] authors give a comparative sutdy of QoS improvement in Mobile, vehicular and wireless sensors ad hoc networks. In the other side, authors of [34,45–47] studied QoS aware routing protocols in VANET. Meanwhile, there is no specific survey which especially focuses on studying VANET broadcasting mechanisms from a QoS perspective neither defines what a QoS-aware broadcasting scheme in a vehicular context. That is what motivated us to elaborate a such survey.

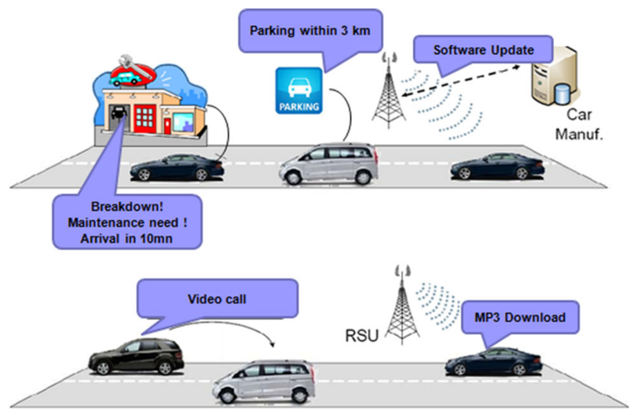

Fig. 1 Example of infotainment application

3 Application fields of VANET

This section presents various VANET related fields of application in regard to human interests and needs while travelling on roads.

3.1 Entertainment and comfort applications

Generally known as Infotainment applications [48], this category presents all services including applications contributing in driver comfort and luxury. These services include meteorological data provisioning, information of current traffic and different drivers interests such as nearest parking, gas stations, supermarkets, hotels, restaurants, games and multimedia share like geo-tagged photos [49]. Figure 1 shows how road passengers can enjoy videos calls applications while driving or also multimedia file download e.g. MP3. Communication with car manufacturers is also possible if driver needs for assistance or car software update. Nearest parking, gas station and mechanical maintenance are information that vehicular network user can get with high precision and extensible alternatives.

3.2 Traffic management applications

Traffic efficiency and management applications aim to improve vehicles traffic and avoid congestion by providing updated information and maps about neighborhood staggered in space and/or in time. Two typical example of this category of services are *Speed management applications* [50] and *Cooperative navigation applications* [51]. Figure 2 illustrates a traffic management scenario at road intersection. When a vehicle detects a street breakage or an obstacle it disseminates a warning message for neighboring vehicles to inform the rest of concerned road users about it. This task can be achieved either by one of the vehicles detecting the unusual road state or by the roadside unit.

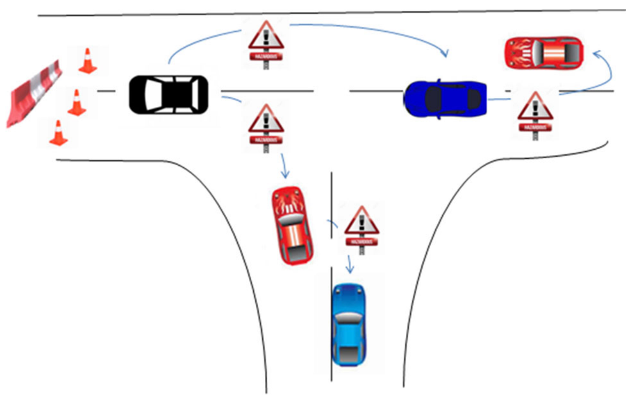

Fig. 2 Traffic management application

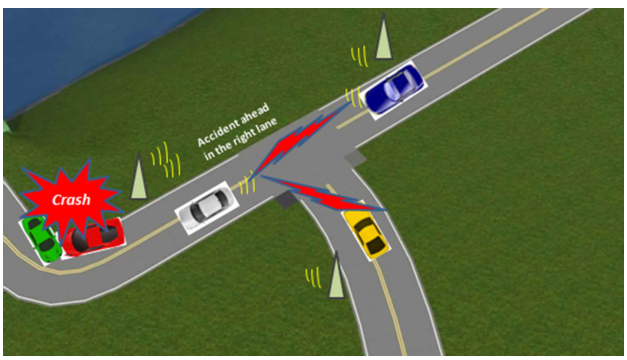

Fig. 3 Public safety application

3.3 Public safety applications

Active Road safety applications are used particularly in order to reduce road accident probability and thus reducing loss of lives. A major part of accident occurring around the world every year is associated to vehicles collisions. This type of applications offers basically: assistance to driver to avoid collisions with other vehicles through. This assistance consists of improving his field of sight and suggesting driving helps in order to enable incident anticipation and pre-act in a way to make driving more safe [48]. Therefore, messages generated by this type of application are offered the highest priority during the broadcast process. Figure 3 describes a safety vehicular application scenario following an accident. The involved vehicle in the incident or another one in its proximity disseminates an emergency message for all vehicles in the same road to alert them about the danger. The message is forwarded from one hop to another through a broadcasting procedure. To provide such services an entire vehicular architecture is deployed, next we describe this architecture with its components details. We also focus on VANET special characteristics and features.

4 VANET architecture and characteristics

The current advances in ad hoc networks and mobile communication technologies led to the deployment of varied VA-NET architectures in different environments. VANET is the projection of Mobile Ad hoc Networks in a vehicular context. Therefore, they have many common characteristics. However, VANET networks are scarified for vehicular embedded applications which require specific techniques and protocols and thus have unique characteristics and architecture.

4.1 Characteristics

Topology VANET is a part of intelligent transportation systems (ITS), where vehicles communicate with transportation agencies and other road components in order to exchange information about traffic and road conditions. Vehicles are equipped with interconnected radio interfaces enabling the formation of short-range wireless ad hoc networks [9]. In addition, GPS and other positioning transceivers are required to be attached on vehicles to provide information about location using Location Based Services (LBS) [52]. Road site units (RSUs), connected to the backbone network, are fixed on the road in different positions facilitating the communication and their number depends on the adopted protocols. Thus, consisting of a set of moving vehicles in communication with each other and with RSUs, VANETs do not have a fixed topology or architecture but is considered as a type of Mobile ad hoc Networks (MANETs). Nevertheless, VANET is different from MANET in the way that vehicles in VANET follow random but predictable paths constrained by the road architecture. Considering VANET a subtype of MANET is correct but it is important to specify VANET characteristics, a brief comparison between the main VANETs and MANETs properties are shown in Table 1.

VANET, being in progressive fusion with internet, could also be seen as a part of cloud computing platforms for intelligent transportation systems. This fact is evolving in the sense that VANET is expected to enhance and optimize the travel experience for road users by gathering and broadcasting real time information about current traffic and imminent events. Data upload/download is achieved by the mean of various technologies especially developed for intelligent vehicles, streets and road infrastructures such as intelligent sensors, transceivers and actuators. Recently, many projects are being investigated in order to study and develop the concept of vehicular clouds. Figure 4 illustrates an example proposed in [53] of a hierarchical architecture integrating cloud computing in vehicular networks. This architecture is composed of three interactive layers: vehicular cloud established within cooperative vehicles provided by V2V communications. The second layer is the road side cloud where local cloud server

Table 1 Comparison of VANETs and MANETs characteristics

Property	VANETs	MANETs
Nodes	Vehicles (mobile) and RSU (fixed)	Mobile devices (mobile)
Communication	V2V/V2I/I2I	Device to Device
Hops	One hop/multi hop	One hop/multi hop
Energy	unlimited	Limited by battery life
Bandwidth	75Mhz (USA)	variable
Topology	Self organizing—predictable pattern (road models) and quick movement—frequent topology changes due to high mobility	Self-organizing—non frequent topology variations (human walking)—unconstrained movement pattern
Dynamic nature	Dynamic and frequent network joining and leaving nodes—correlated Vehicle movements	Relatively stable nodes—uncorrelated movements of mobile devices
Nodes mobility	0–40 m/s	0–5 m/s
Signal reception	Poor signal reception(radio obstacles, such as roadside buildings and interference of noisy radio waves	Good signal reception, no such obstacles
Connection life	Short; depends on road conditions, traffic lights, traffic jams,	Relatively longer
Channel	Variable state	Stable channel
Connectivity	Non guaranteed End-to-end connectivity	guaranteed End-to-end connectivity
Sensors	High-quality GPS	Weak GPS sensor
Infrastructure	RSU as a gateway to the backbone network	infrastructureless

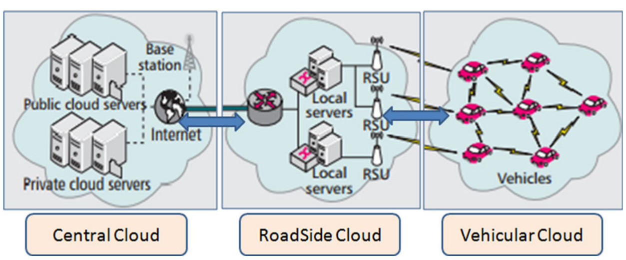

Fig. 4 Example of vehicular cloud network architecture

are attached to roadside units. The third layer is the central cloud established among Internet servers. Vehicular nodes can access to central cloud either through V2I communications or via cellular networks.

Energy One of the major worries and performance crucial features in MANET was the power consumption minimization due to limited battery life of wireless mobile devices [54]. Thus, energy aware protocols and algorithms were developed in order to enhance a MANET lifespan and performance. In contrast, VANET vehicular nodes have no issue with energy thanks to ample power supply they are provided while travelling. Therefore, high QoS aware broadcast protocols could be implemented on vehicular networks due to the expected relatively higher processing capabilities of VANET vehicles in comparison with usual MANET devices.

Communication and access technologies Due to the heterogeneous VANET architecture, communication technologies used to interconnect the ad hoc network and the external networks components have to be adapted to their characteristics in order to get a tradeoff between performance and cost. Actually communication and access technologies deployed in VANET networks could be classified into three domains:

- Telecommunication networks: such as GSM/GPRS, 3G/4G,UMTS, LTE/LTE-A,...
- Radio broadcast systems : RDS/TMC, DAB/DMB, DVB-T/DVB-H
- External Networks: WiFi, WiMaX, WAVE (IEEE 802.11p),DS

For more details about this topic we refer the reader to [17]. In order to deploy these technologies, base stations installation in the telecommunication networks is generally required to control channel access and to manage the roaming process. In radio systems these equipment are used to broadcast messages to vehicular nodes.

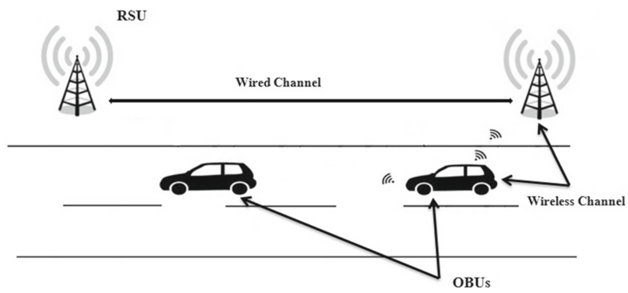

Fig. 5 VANET components

4.2 Architecture

In VANET there are three main components: On Board Units (OBU) devices mounted on vehicles, Road Side Units (RSU) placed all along roads and the channel which could be either wired (inter-RSU) or wireless (OBUs to RSU). Vehicles communicate among each other through OBU in order to exchange traffic and infotainment information via broadcasting messages. RSUs have generally many network interfaces allowing connection to OBU, other RSU and ISP (Internet Service Providers). RSU provide also internet access for the OBU. VANET main components shown in Fig. 5 are described next.

- **OBU** is a hardware device equipped with a radio antenna transceiver joined to a processor. In addition, it has also a R/W memory to allow the information storage, a user interface and eventually other USB or Bluetooth interfaces and GPS sensors. The device have to support IEEE standards for communication.
- **RSU** is equipped with same components as the OBU with wired and wireless interfaces. They are generally positioned at high density places such as intersections and gas stations. The RSUs not only support all IEEE related protocols for wireless communication and channel access but also Ethernet-like protocols for wired communication and channel access.
- **Channel** the wireless channel in VANET is characterized by two main aspects; the first one is spectrum allocation which is reserved for different VANET applications and the main international frequency band divisions are shown in Fig. 6. Notably, in the United States and Europe, the spectrum is divided between service and control channels of 10 MHz size. In Japan, channels are divided as downlink channels and uplink channels, which are of 5 MHz in size. Luck of reliability, signal degradation and path loss are the main issues of the wireless channel.

Communication domains The already described architecture of a vehicular network has to allow different communication domains. Figure 7 summarises the following description of these domains.

- ***Vehicle-to-Vehicle Domain (V2V)*** The ad-hoc network allows vehicles, represented by the OBUs component, to interconnect and communicate among each other without infrastructure support intermediate in order to exchange security and other applications messages. The configuration of this communication domain generally uses a multi-hop broadcast in order to disseminate information to a set of receiver vehicles.
- ***Vehicle-to-Infrastructure Domain (V2I)*** Via the ad-hoc network a vehicle could communicate with Road Side Units in order to collect information about traffic, meteorological or geographical data or even to connect to Internet. The RSU may connect to OBUs too so as to broadcast such information. This communication domain generally adopts a single hop broadcast with a large

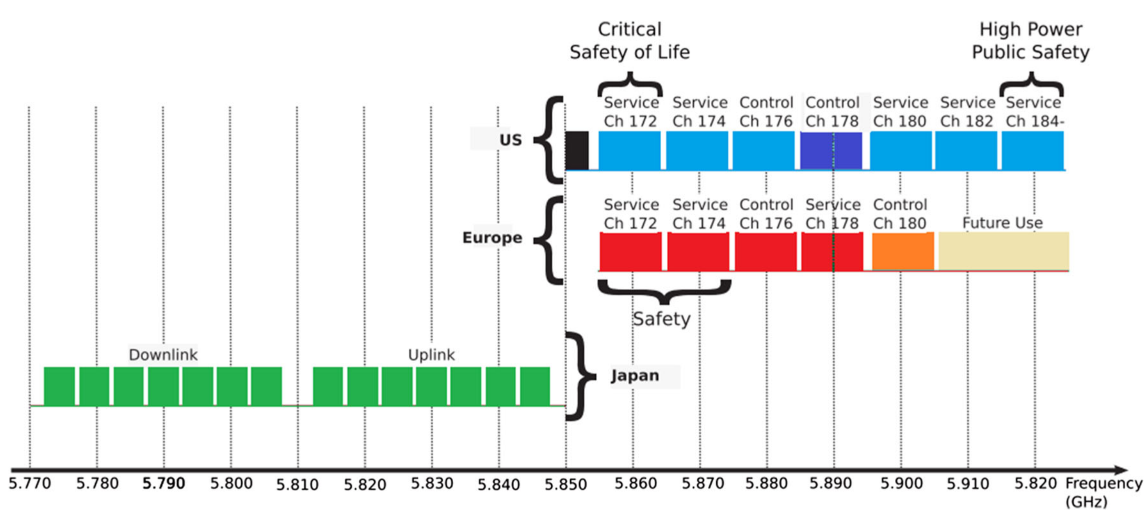

Fig. 6 Channel spectrum allocation

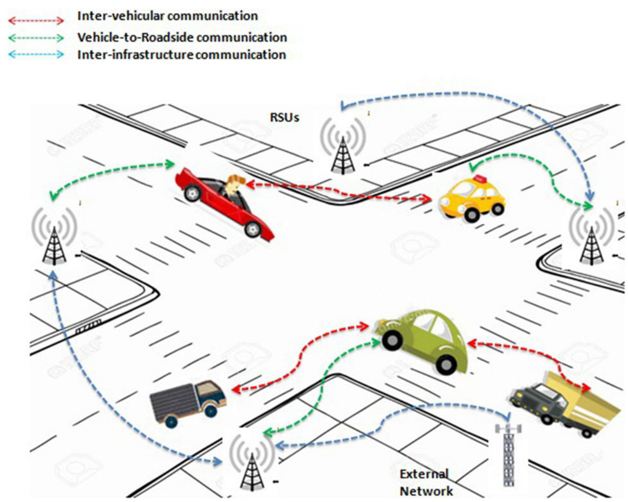

Fig. 7 Different communication domains

bandwidth provided for nearby positioned RSUs (every Kilometer).

- ***Infrastructure-to-Infrastructure Domain (I2I)*** Within a wired channel, the RSUs are enabled to connect among each other in order to collaborate for road security or within external cellular networks such as GSM, GPRS, UMTS, HSDPA, WiMax and 4G in order to connect to Internet.

Deployment environment In addition to its specific unique architecture, many other features such as the surrounding deployment environment make VANET an exclusive domain for wireless communications. Actually, VANET architecture could be deployed in a highway or urban road infrastructure.

- *Urban environment* In an urban environment the vehicle driver has many choices to take due to the variety of streets and the nearby squares which gives more options for communication and information forwarding between vehicles. Therefore, more options for the broadcasting protocols could be adopted. Besides, the constrained vehicle speed inside cities and especially in small towns, commonly restricted to lower than 50 Km per hour, enhan-ces the connection time between nodes which an important factor for relaying broadcast protocols in real time applications [48]. However, within cities there are many buildings, crossroads and corners representing obstacles for the transmission and resulting in signal degradation and packet loss. A multi-hop broadcast can be applied to encounter this issue [9].
- *Highway environment* On highways there are usually no obstacles, single hop message broadcast for neighborhood is possible within the transmission range of a vehicle. On the other hand, a vehicle driver has not many choices on a highway, given that there are no junctions or squares. So, normally, it stays during it lifespan on the same road. That result in a relatively stable network topology. Vehicular clustering is an adaptive useful technique to specify forwarding nodes sets for broadcast protocols. However, the high speed of vehicles in highways, over 120 Km per hour, hardly affects the network connectivity especially between vehicles travelling in opposite directions or between vehicles and RSUs.

Thus, the diversity of VANET deployment environment characteristics is one of many features making VANET a very particular type of Mobile Ad Hoc Network. For instance, the road infrastructure with its mobility patterns results on constrained and predictable movement of vehicles. On the other hand,the type and quality of the road infrastructure are highly dependant on the deployed network technologies. This fact has a great impact on many aspects of the wireless communication among vehicles such as resources consumption management and performance of broadcasting schemes. Other geographical and meteorological conditions could also influence the communication performance and the quality of services provided by VANET networks.

Norms and Standards

- ***DSRC*** Dedicated Short Range Communication (DSRC) is a short to medium communication service which was utterly designed so as to meet the VANETs requirements such as self-organizing and configuring, high mobility and dynamic topology and was developed in order to support V2V and V2I communications [55]. Such communications cover a wide range of VANET applications. DSRC is designed to provide high data transfer with law latency in small communication areas. In 1999, United Nations Federal Commission for Communications allocated 75 MHz of spectrum at 5.9 MHz for DSRC usage. DSRC is free but the spectrum is under license which means that the specific channels use and all radios has to fallow the standard [9].
- ***WAVE*** The WAVE architecture is a set of standards organizing the communication stack and physical links between vehicular nodes. RSUs and OBUs may have two interfaces; one for the WAVE wireless stack and the other for external links such as Ethernet which is used for Internet access. WAVE describes the standards suite of IEEE p1 609.x focusing on MAC and Network layers and built over IEEE 802.11 standards. Although WAVE actually represents the DSRC core element, the two terms are usually used to mean the same thing but DSRC is relatively more general. Figure 8 shows detailed WAVE protocol suite and interfaces, Fig. 9 shows the WAVE communication stack in comparison with the OSI model equivalent layers. We can notice many differences between the two references especially in the WAVE secu-

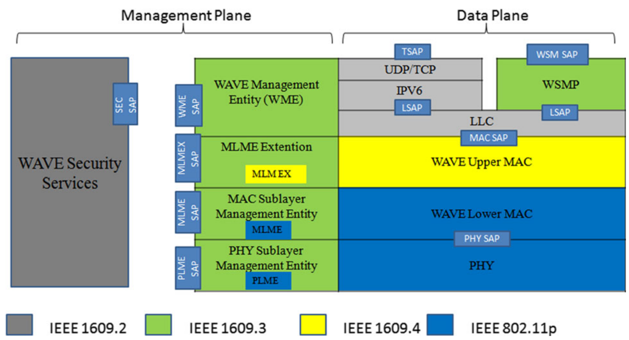

Fig. 8 WAVE protocol suite and interfaces

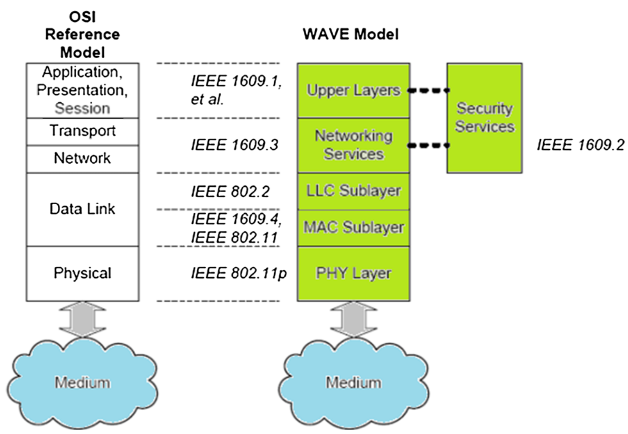

Fig. 9 WAVE architecture in comparison with the OSI reference

rity layer and multi-channel coordination [56]. For more details on WAVE and DSRC definitions and architectures we refer to [57].

- ***LTE*** LTE represents the new generation of mobile radios defined by the 3rd Generation Partnership Project (3GPP) [58]. The LTE system illustrated in Fig. 10, is based on an all-IP flat architecture with a reduced number of network services. IP data, voice and signal transmissions allow a better feasibility and deployment extensibility with respect to former cellular networks. Due to its simplified architecture, LTE could provide a Round Trip Time lower than 10 ms with a latency almost 100 ms. This is especially advantageous for delay sensitive applications [59]. The access network is composed of eNodesB(eNB) managing radio resources and brutal incidents; the core network contains three central units: MME responsible of process control (authentication, security and data storage), S-GW taking in charge routing and data transfers and finally the P-GW allowing connection to the external IP networks.

5 Broadcasting in vehicular networks

The value of broadcast in vehicular networks becomes more and more far from a simple routing question. Next a new con-

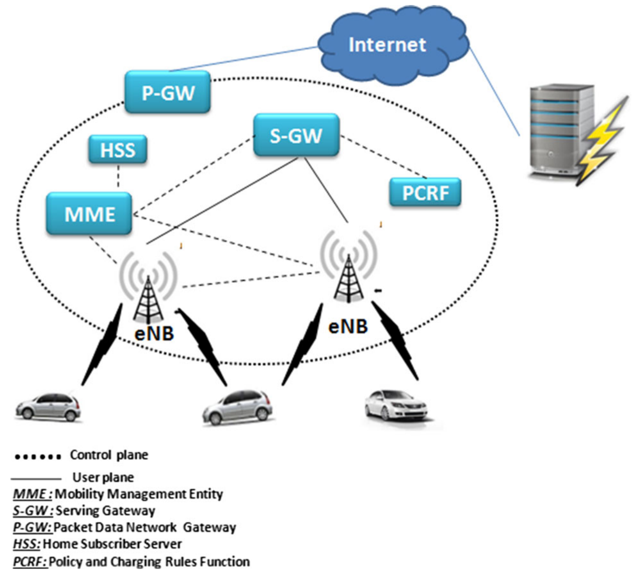

Fig. 10 LTE architecture

cept of broadcast is introduced with a description of varied broadcasting taxonomies and main issues.

5.1 Broadcasting as a service in VANET

In road security applications, emergency messages are sent from a particular vehicle identifying a danger situation on the road. This information have to be disseminated in order to alarm other road users. In the other hand, VANET is considered as a high mobility network where nodes speed exceeds 120 km/h (especially in highways), which means around 33 m/s. So, the danger could rapidly reach even far away vehicles. In such emergency situations, time is of great importance to avoid danger and save human lives [60]. Due to the vehicles high mobility, the node distribution over the network changes in a frequent and rapid way and the wireless links among the network entities are built and broken frequently, rapidly and unpredictably. Hence, particularly in safety applications and generally in all delay sensitive services, message broadcasting plays a fundamental and essential role in the information dissemination and then for the performance and quality of the service. Furthermore, traffic data distribution is a major issue in VANET. In most of applications, more than a unique receiver is concerned by the exchanged messages; rather there is a whole dissemination area composed of neighboring vehicles, which are targeted. In other words, the purpose of such applications is public benefit and non-individual one in particular. Consequently, rather than using unicast message transmission it is more appropriate to adopt a broadcast scheme. In addition to the advantages of allowing data dissemination for more nodes in less time as a service for VANET users, broadcasting has many other strength points.

One major advantage of broadcasting in VANET is when a vehicle has no information about the route to a destination or a specific address. Therefore, difficulties usually faced in high dynamic mobile networks such as the complexity of routes discovery with unicast routing strategies, topology management and addressing could be overcome with a broadcast scheme. Nevertheless, broadcasting in VANET, unlike other mobile ad-hoc networks has many issues; we will detail and discuss some of them later in this paper. Therefore, it stills an open research field with many challenges and need of more studies efforts in order to obtain better solutions.

5.2 Dissemination strategies and broadcast protocols

A big issue that has to be solved in VANET is how to exchange information between vehicles in a relevant and scalable way. In some applications, there is a need to proactively broadcast information, whereas, in some others it has to be obtained on demand. In the other hand, during the dissemination process, broadcasting information can be either toward vehicles in all directions or restricted to vehicles in backwards. Also, the relaying vehicles could be moving in the same direction, in the opposite direction or in both two directions. Hence, there are different dissemination strategies which can be classified according to different axes. One possible classification is according to models depending on the type of targeted applications: push model, pull model or hybrid model:

- **Push model**
  In this model, information, e.g. vehicle position and speed, are exchanged among all or a cluster of vehicles within the communication range in regular periods of time in order to allow to each vehicle to be aware of and evaluate forward road traffic conditions. Each time when a vehicle identifies an emergency situation, it sends an alert message to be disseminated over VANET. The generated push message is transmitted to the targeted area within the dissemination range via a geocast routing. Next, this message will be broadcasted to all concerned vehicles [61]. The push model illustrated in Fig. 11 is suitable for road safety applications where alert messages of emergencies, collisions and hazardous situations are exchanged.
- **Pull model**
  In this approach, data is disseminated on demand i.e. a request-response paradigm. Unlike the push model, the pull model described in Fig. 12 does not require neither much overhead nor latency constraint. In pull model, a requesting node sends a query message to the broadcasting site (either OBUs or RSU).This technique is used in service provision context, such as traffic flow evaluation in a particular area or location. The propagation of the query message from the requesting node to the targeted site occurs via relaying nodes using geocast routing i.e. similar to the push model. Each query is treated according to its semantic. In the target site, a virtual ad-hoc server is created in order to provide response message. Once a return constraint is satisfied, the last vehicle detecting this fact will create the response message and forward it to the requesting vehicle via the same scheme. Such a strategy is suitable with for delay tolerant applications which are generally comfort and infotainment services.
- **Hybrid model**
  In addition to the two already defined push and pull models, some applications need the combination of them in one hybrid model. For instance, some service infrastructures over VANET that specify messages syntax and semantic among vehicles. These services may use a push approach for alert and safety messages and a pull technique in order to process on demand queries about vehicles location information.

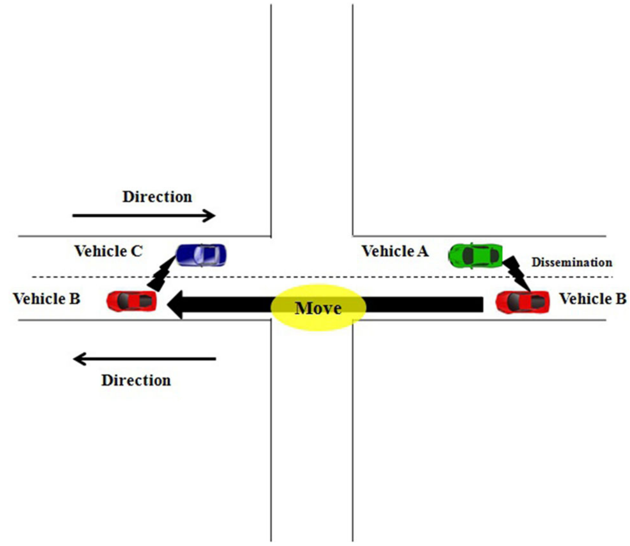

Fig. 11 Example of push dissemination model

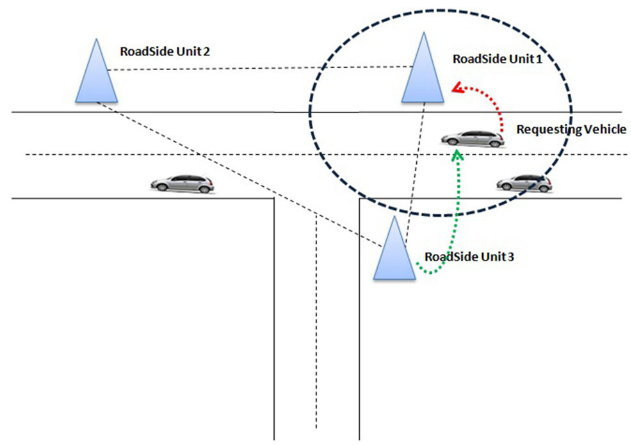

Fig. 12 Example of pull dissemination model

Another way to classify dissemination strategies is according to the direction of message propagation. Actually, in a VANET context, every vehicle is generally interested by knowing about forward traffic information. Indeed, information has to usually propagate rearward and that respecting vehicle's travelling direction. That's why there are three propagation models for data dissemination according to this approach: same-directional model, opposite directional model and bi-directional model.

- **Same-directional model**
  In this first strategy, for every broadcasted message, only vehicles in the same lane with the same direction are concerned by relaying it until its last target. There is no vehicle from the opposite way participating in this type of strategy. In this model, in addition to the relayed data, a generated and stored data about vehicle state or other road condition and network topology is sent in the same message.
- **Opposite-directional model**
  In the opposite-directional model, data is propagated only by vehicles in the opposite direction after being aggregated which means that relayed and generated data are not necessary sent in the same message. The two models are described in Fig. 13.
- **Bi-directional model**
  This third model is a combination between the first and the second models; it means that both vehicles in the same and opposite directions participate in the broadcasting process.

There is wide range of broadcasting protocols in literature relying on these dissemination strategies. Broadcasting routing protocols play a crucial role in many VANET applications especially those related to safety and road security. Beyond the dissemination range restricted by the DSRC standard,

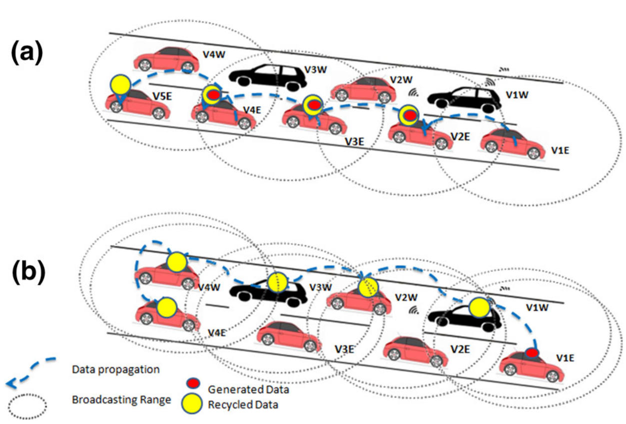

Fig. 13 Dissemination/propagation models: **a** same-directional model, **b** opposite directional model

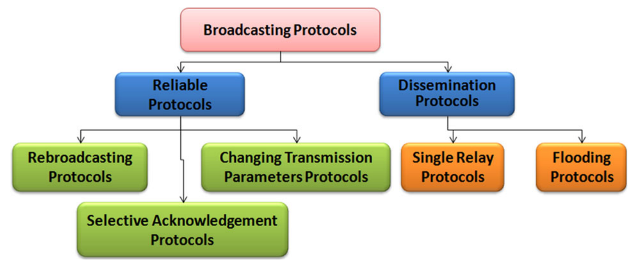

Fig. 14 Broadcasting protocols example of taxonomy

broadcast is required in order to disseminate data towards vehicles far away commonly using single hop or multi-hop transmission. Packets are flooded within the network so as to insure a best delivery rate. Therefore, a broadcasting protocol in a VANET context has to be reliable, rapid and robust [38]. Almost broadcasting protocols usually share the same principal: delivering the message within the dissemination range and relaying it beyond the dissemination range to the rest of the network. However, many classifications of broadcasting protocols have been suggested and defined according of different axes. An example of taxonomy is according to whether the target applications concern direct neighborhood or the entire network (see Fig. 14) : reliable protocols (collision avoidance) and dissemination protocols (traffic management). Reliable protocols also can be classified into three categories: rebroadcasting protocols, selective acknowledgement and changing transmission parameters. Even dissemination protocols are of two types: flooding protocols and single relay protocols.

Safety applications in VANET require broadcasting protocols which are as reliable and rapid as to perform a best quality of the service provided by the application in order to satisfy VANET users. A reliable broadcasting protocol has to deliver an emergency message to from its source to the entire of the target area with a least latency. The performance of reliable routing protocols can be measured by the message delivery success rate and the latency of a single broadcast stage. The performance can be improved by three methods:

1. Message rebroadcasting
2. Selective acknowledgment
3. Parameters changing

Rebroadcasting policy consists in the retransmission of the same broadcasting message but here important questions have to be answered: how and how many times can the rebroadcasting process occur better? This question leads us to another classification of broadcasting protocols which depends on the routing techniques used in the selective retransmission process [62]:

- ***Distance-based broadcasting***
  In this broadcasting protocols type, relative distances

are used by vehicles in order to select relaying nodes. Thanks to GPS transceiver mounted on vehicles the signal strength within neighborhood can be estimated and then determining the best next hop.

- ***Topology-based broadcasting***
  Some broadcasting protocols rely on VANET network topology in order to retrieve relevant information for message dissemination. Density and links connectivity between vehicles are important parameters for packet forwarding. These protocols are further classified into proactive, reactive and hybrid protocols.
- ***Location-based broadcasting***
  Similar to geocast routing protocols, location-based broadcasting protocols deliver the message from the source to all nodes in a specific geographical area (called Zone Of Relevance ZOR). The nodes having received the packet evaluate the coverage area based on their position. If it is under a threshold value the vehicle will not rebroadcast. These protocols are generally applied to send messages within a pre-defined geographical region.
- ***Position-based broadcasting***
  Position-based broadcasting protocols share with location-based protocols the feature of using geographical information in the selection of the relaying node. However, in this type the message is firstly sent without any prior-knowledge about the map of neighborhood. Thus, no routing tables have to be either known or stored by each node.
- ***Table-based broadcasting***
  Table based broadcasting protocols use beacon messages which are periodically exchanged between nodes in order to update the neighbor list table maintained by each vehicle
- ***Cluster-based broadcasting***
  In this category of protocols the network is divided into clusters. Each vehicle may belong to one or more clusters. In each cluster there is a cluster head which is responsible of forwarding messages to all cluster members, and a gateway which propagates messages from its cluster to another. Only the cluster head and the gateway are concerned by the rebroadcasting process.
- ***Probability-based broadcasting***
  The selection of the relaying node is depending on a predefined probability value. This value takes its relevance from the number of neighboring nodes having similar coverage area; the probability value is as much significant as this number increases.

5.3 Broadcasting issues in VANET

Despite having many advantages especially for safety applications, broadcasting in VANET networks is related with many problems. Some of these problems are linked to the principal of broadcast itself such as ”broadcast storm”, ”hidden node”, ”congestion” and ”transmission failure” and some others are technical issues.

A first problem with the DSRC standard is that the message broadcasting reaches only vehicles in the source coverage area which is restricted by the DSRC standard to around 1 km, with potential signal degradation due to obstacle and noise this does not seem sufficient to reach far away vehicles. The probability of message reception that can attain 99% in short distances may be lower than 20% towards the mid of DSRC range. Broadcasting techniques and protocols have to be improved in order to enhance message reception rate with a best trustworthiness and availability.

Furthermore, the communication technologies defined by IEE-E 802.11 deployed in vehicular networks are not well adapted to simultaneous broadcasting transmission manipulations due to frequent collisions resulting in many retransmission from vehicular nodes. These collisions, in turn, affect the message delivery rate and increase latency which is very troublesome for road security and other time sensitive applications.

Broadcasting process is the core of road safety applications. When an emergency incident occurs and there is a need to warn all travelling vehicles in the same location, there is a need to use broadcasting [63]. The key idea of the process is clear: the source vehicle firstly broadcast the message within its neighborhood, but surely not all nodes will hear it due to the limited transmission radius. So, one or more of the receiving nodes have to relay to the rest. The problem here is how to choose the relaying nodes in order to maintain a best reliability and reducing network resources utilization. So, the goal is to provide a reliable and rapid protocol that does not cause congestion and floods the network with useless messages.

The selection of relaying node may be a difficult task since there is no central coordinator in a VANET context. Many other elementary but important issues may face a researcher when developing a broadcasting solution for VANET. Some of these are listed below:

- *Asymmetrical dissemination radius* The selection of the relaying node in almost broadcast mechanism generally depends on distance. The farthest vehicle from the broadcasting node would be selected for relaying message. Given that, in almost research the dissemination radius of all vehicles is commonly supposed as equal. However, this is not actually true since vehicles do not usually have the same dissemination radius which can make the task of selecting best relaying node more difficult.
- *Threshold value* the issue here is related with the number of rebroadcasting; if this number is depending on a counter parameter, there would be a problem in stopping

the variable for interfering messages and also retrieving intersection areas from after every broadcast.

- *Clustering* in case of using clustering techniques in a broadcasting scheme many parameters have to be fixed. For instance, selecting the cluster head is a challenging task especially in a highway context where clusters topology rapidly changes. Also there is a problem of cluster gateways disconnection which generally occurs in sparse areas where there is no enough number of vehicles for relaying broadcast messages.
- *Broadcasting in road junction* Many parameters of the adopted broadcasting scheme have to be revised when coming to a particular situation such as road junctions. Indeed, the distance based selection of next hop doesn't give good results since there are areas in the different lane of the relaying hop that will not hear the broadcasted message.

6 Quality of service in VANET

The QoS is defined as the set of requirements that have to be fulfilled by the network during the packets transmission flow from its source to destination [64].

The E.800 Recommendation of the United Nations Consultative Committee for International Telephony and Telegraphy (CCITT) defined the QoS as: the collective effect of service performance which determines the degree of satisfaction of a user of the service [65].

In wireless communication systems, performance metrics of QoS may be categorized into: bit-level QoS, packet-level QoS and call-level QoS. Different VANET applications normally and usually require different levels of QoS. For instance, real-time applications (e.g. voice conference) are generally delay sensitive. So, packets have to be transmitted in a time limit with a less packet loss, however these applications tolerate some bit errors.

In contrast, data-related applications such as files sharing are generally delays tolerant but need high packets accuracy. Next, we distinguish applications specific QoS requirements according to the already presented classification of VANET applications.

6.1 QoS for traffic management applications

Traffic congestion has usually been a daily issue for drivers particularly in big cities [66]. Every day, traffic jam causes the waste of long hours of time for passengers. Therefore, an efficient traffic management is an important service provided by VANET.

Mainly this type of service does not require high priority, in terms of delay and channel access, during communication and packet transfers, neither a higher quality of delivered data, in term of packet delivery ratio (PDR) and noise rate,. Nevertheless, it requires a minimum of performance for road user satisfaction, which means an acceptable trade-off between QoS parameters.

6.2 QoS for infotainment applications

A nominal requirement for comfort and entertainment VANET applications is the support of best-effort services such as commercial ads, web browsing and multimedia file sharing [54]. Even inside this category of services, there is heterogeneity between applications. It is rather relevant to distinguish different priorities for different functions. For instance, an e-mail service requires less priority than a live video streaming. In order to insure a best QoS, fair resources management aware routing protocols have to be developed.

6.3 QoS for safety applications

Security warning applications impose severe requirements in terms of QoS such as low latency and high reliability. These applications require a minimal peer-to-peer transmission delay given that every additional time delays in packets delivery risk resulting in useless message in the incident avoidance because rescue vehicles have to instantly receive warning messages. These messages specify incident location in order to reach it as rapidly as possible. Furthermore, a high priority for channel access has to be given to applications delivering this type of messages to guarantee efficient road security measures [54]. In addition to warning messages, real time traffic potential dangers information, that can be introduced in maps and navigation systems and broadcasted by RSU, are also worthy of priority to provide instant alternative driving itineraries [20].

VANET is a type of mobile ad-hoc networks that provides a variety of services not only related to road safety but also commercial and infotainment services. RSUs may play assistance role for drivers by broadcasting traffic information and meteorological and geographical data. Neighbouring vehicles are allowed to exchange and share multimedia or establishing video conversations. Passengers may entertain by watching a live match or playing games, etc. Whatever the VANET service provided, a minimal level of QoS satisfying users have to be guaranteed.

Due to this variety of applications, it is hard to define a unique model with a fixed set of parameters for evaluating QoS. Moreover, the type of data transmitted is also a relevant factor to evaluate the system performance. Next, we will more detail QoS evaluation parameters in VANET and particularly in a broadcast context.

7 Performance and QoS of broadcasting protocols in VANET

In this section we focus on the question of QoS in vehicular networks as a big issue for achieving successful broadcasting schemes. This part includes evaluation parameters, literature survey and comparison study.

7.1 Evaluation parameters

In wired networks, QoS is generally defined by two terms: delay and throughput. However, in vehicular ad-hoc networks QoS seems difficult to be defined, and also to be satisfied due to many features such as the changing topology of VANET networks, scalability, delay constrained broadcasting, vehicles high mobility and density and deployment environment heterogeneity.

Within a VANET network two main types of data may be transferred: real-time data such as safety warning messages and audio/video streaming and non-real-time data such as e-maps and meteorological information. This classification in turn imposes many requirements in terms of performance and QoS for VANET developers.

Maintaining a good level of QoS became a challenging task in a conflict based environment under IEEE 802.11 standards for resources managements. In such environment, packet delay, congestion and collision highly increase because of exploding number of vehicles competing for common wireless medium allocation. Sending and receiving correct data in fixed time limits seems to be a crucial task in such a network [20].There are many parameters that can be taken into consideration for QoS measuring:

- *Data latency*
  Data latency is evaluated by the time interval between the message issuing from its source until its reception by the target node. This duration has a threshold value beyond which a packet transmission time delay will be considerate to calculate throughput rate [11]. Furthermore, the data latency value is respectively affected by the high mobility of nodes given that the vehicles speed result on frequent links breaking.
- *Bandwidth utilization*
  A system performance is closely depending on the frequency band use. A bad or unfair bandwidth sharing between network components decreases the system performance and thus the QoS provided. In VANET, bandwidth utilization is very high due to the increasing number of vehicles with high speed and in contention on resources sharing [11].
- *Packet delivery ratio (PDR)*
  This parameter is calculated with the ratio of received packets number by the original number of packets issued from the source. The value of this parameter may be influenced by many features such as packet and cluster size, dissemination radius, nodes speed and mobility model. For a 100% PDR value, the message transmission is said robust which means that all message packets were received by the target within a limited time delay.
- *Reachability*
  In broadcast context, reachability in a vehicular network estimates the percentage of vehicles receiving a broadcast message to the total number of targeted node in the network. A good broadcasting scheme can achieve 100% reachability.
- *Overhead*
  This parameter is related to useless data transiting over the wireless channel and causing errors, collision , delay or failure of the original transferred data. In vehicular networks periodic beacons messages among vehicular nodes are one of the most causes of the network overhead.
- *Propagation speed*
  Generally in wireless networks propagation speed means time taken by data travelling on a wireless channel from source to destination. In our context, propagation speed in a broadcasting scenario is related to the total number of hops needed by a broadcasting protocol to disseminate a data from a source to the furthest destination.
- *Throughput*
  It is the rate of information arriving at and passing through a particular point in the network system.
- *Scalability*
  This parameter is difficult to both define and achieve. Indeed, a broadcasting scheme is said scalable according to its adaptability to be efficiently applied to several situations and scenarios.
- *Success rate*
  When testing a broadcasting scheme under many simulations and scenarios, success rates is estimated as the number of time the executed process successfully ended by achieving the desired goal.
- *Redundancy*
  While forwarding a data from a vehicular node to another during a broadcasting scenarios, some local transmission failures may happen at specific nodes. The forwarding node has then to retransmit the same message to encounter this failure. Redundancy is calculated as the total number of retransmissions for a single message broadcast from its source to final destination.

Many other QoS parameters such as transmission speed, end-to-end connection, cost, error rate and noise are worthy to be considered respectively to the VANET service concerned [67].

In vehicular networks broadcasting is useful for some services for which delay and reliability are not crucial requirements. However, the emergence of VANET network has created new challenges for providing a reliable and rapid broadcasting to insure a QoS of public safety applications.

One of the major challenges of broadcasting in VANET is to guarantee similar or even better performances than unicast schemes.

We may define main parameters for QoS evaluation in a Broadcast context: reliability which here means PDR and reachability, Cost which includes bandwidth utilisation and overhead and also rapidity which is estimated by delay and propagation speed. We will also use later in the comparative study throughput and scalability.

7.2 Literature survey and comparative study

The simplest way to broadcast a message into the entire network can be achieved through flooding. Flooding guarantees the message delivery by allowing to all vehicles in the network to rebroadcast it to all nodes in their transmission range. Meanwhile, flooding causes broadcast storm, network overhead and other problems that affect the QoS in the network. Therefore, many research works in literature have tried to find appropriate selective transmission approaches able to perform QoS aware broadcasting. Next, we present a descriptive survey of some works along with detailed comparative study based on the evaluation parameters appropriately defined in the previous subsection. Our strategy to review these works is to classify them according to the second taxonomy described in Sect. 5.2. This classification helps to pick out the pros and cons of each dissemination approach through emphasizing their points of strength and detecting their weaknesses.

7.2.1 Topology based broadcasting protocols

- *DECA* [68]: Periodic beacons messages are exchanged between nodes in order to gather 1-hop neighbor local density information. The sender node selects a neighbor with highest density to forward the message. After receiving a message, each node randomly sets its waiting timeout. If it does not hear any rebroadcast before timeout expiration, it immediately rebroadcasts the message. The DECA protocol doesn't rely on any position knowledge which makes it flexible with different deployment environments. However, Beacon messages could result in a broadcast storm problem increasing network overhead. In addition, after timeout expiration it is possible that all neighbors rebroadcast the message and the network would be flooded.
- *STB* [69]: Spanning Tree-based broadcasting for VANETs protocol mainly reduces the end-to-end delay by reducing number of retransmissions. Once a node receives a broadcasted message, it builds a spanning-tree of nodes into its transmission range relying on local topology information. The Prim's algorithm is applied in order to select the relaying vehicle which satisfies a minimum cost spanning tree. The calculation of the spanning tree and the relaying decision requires high resources consumption.
- *ROB-VAN* [70]: It is a topology based reliable opportunistic broadcasting protocol. Relying on beacon messages, it is based on 802.11 MAC layer and uses node signal strength for relaying decision. Each time a node receives an emergency message, it has to check reliability for all vehicles into its transmission radius. If there is any node that does not received the message, it rebroadcast it to that node. Consequently, the beacons with the reliability control messages simultaneously exchanged between all nodes in the transmission range would highly occupy the channel and cause an overhead.
- *RLMB* [71]: The protocol mainly addresses the broadcast storm problem. It uses beaconing messages in order to locate neighbors and a subset of nodes is a priori selected to forward the message before the current relay. The list of forwarders is attached to the message header. The selection of relaying node is decided depending on highest distance between the source and nodes in every direction within the transmission radius according to a dynamic direction factor. RLMB protocol provides good QoS measures but its performance is restricted to specific highway scenarios with limited constraints.
- *QoS-OLSR* [72]: Quality of Service Optimized Link State Routing protocol aims to optimize clustering mechanism taking in attention mobility constraints in VANET. Relaying vehicles are selected using an Ant Colony Optimization algorithm. The protocol optimizes delay, PDR and bandwidth utilization.
- *RTBP* [73]: Efficient Road Topology based Broadcast Protocol is designed for multimedia message dissemination in urban environment. It is uses contention based forwarding (CBF). Relaying process is based on minimal forwarding radius which varies according to vehicles density. The protocol essentially aims to reduce delay and increase reachability. Although it is dedicated for urban context were vehicles density can be very high, the protocol shows good performance with low densities but this performance decreases as soon as the number of vehicles increases.
- *ZoomOut HELLO* [74]: Is one-hop broadcasting technique which works under broadcasting protocol using periodic hello messages to define front and behind relatives information of each node maintained in a Neighbors-cum-Forwarding table. Several analytical model have been designed by author for different broadcasting schemes to test and compare the proposed approach. Experiments studies Delay and rebroadcast number and give very good values. However since each

node according to this protocol has to maintain link with its relatives(front and behind neighbors) using periodic message this would highly increase network overhead and affect reliability. We already notice that PDR and reachability are not considered in the analytical results.

- *FAST-OB-VAN* [75]: Fast Opportunistic Broadcast Protocol for VANets which mainly aims to reduce delay achieved by the previous OB-VAN protocol and considering contention that OB-VAN did not deal with. The protocol is tested in a linear scenario but the vehicle maximum speed is set to a very low value. Protocol delay, reachability, number of rebroadcasts and success rate are compared to those of OB-VAN. Results need to be confirmed in a more realistic highway scenario where vehicle speed is highly greater than the considered value.
- *BRNT* [76]: Broadcast protocol with Road Network Topology employs road segmentation to classify vehicles into adjacent groups using Connected Dominating Set(CDS). After node classification a forwarding waiting time is fixed and then relaying selection according to local topology of the set (intersection, CDS or normal road). The protocol is tested in urban simulation system with digital road map. Results are compared to exiting alternatives including flooding. BRNT achieves good PDR but redundancy and delay rates are worse than other approaches.
- *BSM* [77]: Broadcasting of safety messages in vehicular ad hoc networks which goal is to reduce broadcast redundancy. The protocol is fully distributed and uses local vehicles density and distance to source node to make forwarding decision. Farthest node with higher neighbors' density relays the message as soon as it receives it. Other nodes are fixed a delay waiting time in order to avoid useless retransmissions. Simulations are conducted with use of a simple grid network topology to measure reachability, overhead and propagation speed. The result are compared to a unique other approach which need to be reinforced with other comparison and other performances feature such as delay time as crucial parameter for emergency applications.

We elaborated a detailed comparative study of the above listed techniques. Table 2 concludes this comparison with different parameters.

7.2.2 Cluster-based broadcasting protocols

- *DBA-MAC* [78]: Dynamic Backbone Assisted MAC protocol is based on the cross layered scheme, this protocol creates a virtual backbone in VANET environment. DBA-MAC is composed of proactive clustering algorithm and a 802.11 based MAC protocol. It guarantees good QoS measures but work only in a highway environment. Furthermore, the backbone stability requires a minimum connection duration which is very difficult to reach in a highway with very speed vehicles even with the adopted maintenance mechanism.
- *DV-CAST* [79]: It is a distributed broadcast routing protocol relying on local topology information obtained by Hello messages . It uses persistence schemes in connected traffic regime. In sparse traffic regime, the message is stored until there is a neighboring node into the transmission range within a timeout period. If the timeout expires before establishing any connection, packets are discarded. In dense regime, the protocol reduces the number of hops. Then it insures low latency, but in sparse regime the waiting time may increase end-to-end delay.
- *CBE-B* [80]: Cluster-Based Efficient Broadcast, this protocol is specific for unilateral streets. It uses different cluster types according to vehicles speed and direction. In front cluster, the cluster head is the fastest vehicle. However, in rear cluster the slowest one is selected. Periodically, a steady-state phase is applied to change clusters heads depending on distance between nodes and current heads. The protocol reduces the end-to-end delay and optimize data propagation rate but the clustering mechanism is difficult to apply in realistic environments.
- *SRB* [81]: A Selective Reliable Broadcast Protocol which mainly deals with broadcast storm problem. It uses vehicles density and velocity to assign Zone of Relevance (ZoR). As a cluster based broadcasting protocol, SRB elects the farthest vehicle inside each cluster as the cluster head. The proposed scheme is tested under urban and highway scenarios. Performance aspects like PDR, delay, propagation time and throughput are proved but numerical results have not been compared to any other approach. Also, in highway as the cluster detection becomes more difficult QoS parameters are negatively affected.
- *DRIVE* [82]: Data dissemination pRotocol In VEhicular networks which is dedicated for emergency message broadcasting in both highway ad urban context. The protocol is exclusively based on 1-hop neighbor local information in order to guarantee data delivery in dense and sparse traffic s. A sweet spot where elected nodes are those more likely to perform better relay is defined. In sparse regime the protocol uses implicit acknowledgments for message delivery. Evaluation was conducted by comparing the proposed scheme with many other works in terms of coverage, delay and overhead. In many cases DRIVE prove good parameters values but a global performance of all parameters at the same time wasnt demonstrated.
- *CBE-CAST* [83]: Cluster-Based Efficient broadcast is a broadcasting protocol for highway VANET environ-

Table 2 Comparison of QoS aware topology-based broadcasting protocols

Protocol	Year	B	Relay selection	Scenario	Mobility model	Simulator	QoS measures							
							Delay	Propagation speed	PDR	Reachability	Band	Overhead	Throughput	Scalability
ZoomOut HELLO [74]	2015	Yes	Speed and istance	Highway	Group model	MATLAB	√		√		√	√		
RTBP [73]	2014	Yes	Density	Urban	Manhattan	NS-2	√			√	√	√		
FAST-OB-VAN [75]	2015	Yes	Farthest node	Highway	Nakagami	NS-3	√	√		√		√		
BRNT [76]	2015	Yes	Directions	Urban	Manhattan	Scenargie	√		√			√		
DECA [68]	2010	Yes	Neighbors density	Highway/urban	SUMO	NS-2	√			√	√	√		
STB [69]	2014	No	Furthest vehicle	Urban	Random two way	NS-2	√		√		√		√	
R-OB-VAN [70]	2009	Yes	Signal strength	Highway	Shadowing model	NS-2	√		√		√	√		
RLMB [71]	2014	Yes	Farthest vehicle by direction	Highway	IDM	OPNET	√		√			√		
QoS-OLSR [72]	2013	No	Ant colony optimization	Highway	Shadowing	Matlab	√	√	√	√	√	√		
BSM [77]	2014	Yes	Local topology	Urban	SUMO	OMNET			√	√		√		√

ment. It is based on rebroadcasting possibility and vehicle speed. The road side units are responsible for detecting clusters and electing clusters heads. The faster node is assigned as cluster head. The relaying nodes election is also based on vehicles speed and distance from the source. As protocol is exclusively designed to deal the broadcast storm problem it succeeds to avoid network overhead and guarantee good delivery rate. Nevertheless, other methods seems to have better speed.

- *CBNCR* [84] : Cluster Based Neighbor Coverage Relaying is a protocol which combines cluster based broadcasting and multi-hop relaying to encounter some broadcast problems such as redundancy, overhead and contention. In this approach clusters are formed according to inter vehicular distances and cluster heads are assigned to be the farthest from source and nearest to destination. Many performance parameters are used by authors to compare CBNCR to other existing broadcasting techniques such as throughput, PDR and delay. Theoretically, the protocol outperforms others methods but in analytical result the proposed scheme was only faced to flooding which does not strongly confirm its level performance already shown in the model.
- *VMaSC-LTE* [85]: Is a multi-Hop cluster based IEEE 802.11p and LTE hybrid architecture for VANET safety message dissemination. Its core algorithm is based on cluster head selection for fast and less overhead message forwarding. Simulation experiments are tested in highway with different hops scenarios. Compared to other cluster techniques, the proposed architecture shows better values of packet delivery, average delay, reachability and overhead.
- *CBR* [86]: Is a cluster based broadcasting protocol for vehicular networks based on a partition of the geographical area into logical grids. Each grid is assigned a single cluster. Cluster headers forward message among each other based on their distance to grid center. The nearest node is elected as cluster head. The performance of the proposed scheme is theoretically proved but there are no simulation results shown to confirm the given affirmation.
- *DADCQ* [87]: Distribution-Adaptive Distance with Channel Quality protocol is both a cluster based and statistical approach for broadcasting in VANET. It employs an adaptive decision threshold function depending on neighbors' density, clustering spatial distribution pattern and wireless channel quality. Forwarding procedure is distance-based.The protocol performance is tested by a dedicated simulation tool in both urban and highway scenario.Two mobility models are used: for urban scenario Washington D.C.(WDC) and Intelligent Driver Mo-del (IDM) for Highway. The main QoS parameters improved by this approach are reachability and bandwidth utilization. However, shown results still very dependant on initial assumption such as channel quality.

Table 3 summarises a comparison with different parameters used in the previous table between cluster-based broadcasting protocols.

7.2.3 Probabilistic broadcasting protocols

- *OAPB* [88]: Optimistic Adaptive Probabilistic Broadcast protocol was primarily designed to handle the broadcast storm problem by reducing the number of relaying vehicles. Local information about each node is obtained from the periodically exchanged "HELLO" messages. Then, the forwarding probability is calculated using node density, this probability increases when node neighbor density is higher. The protocol performs well with a small network size but performance metrics deteriorate in larger networks with frequent disconnections. Also, constraints under which the protocol could be applied are not clarified.
- *EAEP* [89]: Edge-aware epidemic protocol does not rely on beaconing messages which reduces control overhead. For every broadcasted message, EAEP performs a number of transmissions between nodes in order to evaluate within a timeout period the probability of message forwarding decision. This could incur a high delay. Furthermore, frequent links breakage are not taken into consideration by this protocol. EAEP reaches a good reliability in a dense regime, but in critical sparse regime global message delivery is not insured.
- *ProbT* [90]: Temporal Probabilistic protocol is an hybrid protocol which combines probabilistic and delay-based protocols techniques in the forwarding process. The relaying node selection is based on both node neighbors density and common neighbors number between current and next hop. For evaluating protocols performance packet loss, redundancy and link load are used in simulation. Results show high performance of ProbT in delivering message faced to other techniques. However author did not give results which prove theoretical evaluation given for transmission delay.
- *E-ProbT* [91] : is new approach as an extension for the previous ProbT based on Game Theory and the Statistic Exponentially Weighted Moving Average (EWMA). The protocol exclusively aims to mitigate broadcast storm problem. QoS measures considered are delivery rate, reachability, propagation speed and redundancy. Simulation results does not show promoting values for the each one of the measured parameters but a trade-off of the hole evaluation model is accepted.

Table 3 Comparison of QoS aware cluster-based broadcasting protocols

Protocol	Year	BM	Relay selection	Scenario	Mobility model	Simulator	QoS measures							
							Delay	Propagation speed	PDR	Reachability	Band	Overhead	Throughput	Scalability
VMaSC-LTE [85]	2015	Yes	Relative mobility	Highway	Friis	Ns-3	√		√	√		√		
CBE-B [80]	2013	No	Furthest vehicle	Highway	–	NS-3	√		√	√		√		
SRB [81]	2012	No	Distance	Urban and highway	Mobisim and OSM	NS-2			√	√		√		
DV-CAST [79]	2010	Yes	Local connectivity	Highway	Ricean fading	NS-2	√		√	√		√		√
DBA-MAC [78]	2009	No	Furthest vehicle	Highway	–	NS-2	√		√		√	√		
DRIVE [82]	2014	No	Furthest	Urban	Manhattan	OMNeT++	√		√	√		√		
DADCQ [87]	2012	Yes	Farthest node	Urban/highway	WDC/IDM	WiBDAT			√	√	√	√		
CBE-CAST [83]	2013	No	Distance and speed	Highway	Real road	NS-3	√	√	√	√		√		
CBNCR [84]	2014	No	Farthest node	Urban	–	R console	√	√	√	√		√	√	
CBR [86]	2010	No	Closer node	Urban	–	–	√		√			√		

- *AWPP* [92]: Adaptive Weighted Probabilistic Persistence scheme is an adaptive broadcasting protocol for vehicular networks. Probability of relaying the message by a next hop depends both on its distance to the current node and its transmission range. The adopted scheme differentiates sparse and dense traffics in order to get more realistic scenarios. It is also based on beaconing messages to collect neighborhood information. It was tested on an urban environment and proved good reachability and connectivity compared to other protocols. However to be considered an efficient VANET protocol especially for emergency message broadcast the protocol has to prove high speed which is not confirmed here.
- *CPROB* [93]: It is a dynamic hybrid broadcasting protocol for vehicular ad hoc networks designed in the aim to reduce network congestion and latency. Relaying process considers distance, probability and generated time. The general system uses an energy consumption model designed for mobile ad hoc networks which do not seem to be a suitable for the protocol goal and the VANET context. The final experimental results show good values of delay and saved rebroadcast.
- *SAB* [94]: Speed Adaptive probabilistic Broadcast a protocol which consider vehicular networks high mobility aspect in order to enhance message broadcast scalability. It relies on vehicles speed to assign forwarding probability. The adopted scheme do not require any knowledge about neighboring nodes. The protocol is tested in a highway scenario to evaluate PDR, delay, overhead, rebroadcasts and propagation speed. The results are compared with p-Persistence method and it show promoting values especially with a few number of vehicles. Results have to be faced to other techniques in order to show protocol outperformance and also in different complex scenarios.
- *N2DCAST* [95]: Network-aware Double-layer Distance-dependent Broadcast which uses piggybacking compressed information over periodic basic safety messages. The system is composed of two layers: the first one is distance dependent. It controls the messages size at each hop to guarantee a fast forwarding. The second one tries to decrease number of relays while the distance from source increases. Hence, the overall system could reduce the end-to-end delay with high scalability. Experimental result are only compared with uniform probabilistic methods, other comparisons with existing works have be performed. Also protocol needs to be extended to other more realistic scenarios.
- *Efficient broadcasting in VANETs using dynamic backbone and network coding* [96]: It is a lightweight and reliable broadcasting protocol for emergency message dissemination over VANET. It consider changing vehicles movement and interlinks breakage to generate

dynamic vehicles backbone. It also employs network coding to deal with network overhead and enhance other QoS features. Although the protocol is tested in a freeway scenario vehicles maximal speed is fixed to a non high value. Experimental results compared to existing alternatives show good end-to-end delay, PDR and number of rebroadcast. However control messages generated by this protocol seem to cause a greater overhead than other methods.

- *Virtual slotted p-persistence scheme* [97]: It is a robust broadcast scheme which do not consider either of vehicle distribution and density in vehicular ad hoc networks. The proposed protocol uses periodic beaconing message to maintain a table of neighbors' information about position. This information is employed for emergency message broadcast to generate a vehicle set called virtual slot. The relaying nodes are selected inside the farthest virtual slot from the message source. Experiments are conducted in highway and evaluate delay and overhead. Results show good values but only compared to p-persistence uniform method. More significant comparisons are needed with other probabilistic existing sche-mes.
- *SFBB* [98]: It is a Broadcasting protocol which use future prediction of vehicles speed and direction for adaptive message forwarding. The next hop selection by the current node has to be performed very fast. The protocol assumes that all nodes have the same transmission range which is not totally realistic (ref Sect. 5.3). Tested in an urban network SFBB improves PDR and reduce delay compared to other protocols. However, there are other QoS features such as reachability, overhead and scalability which are not considered by this protocol.

The detailed comparative study of the above listed techniques is presented by Table 4.

7.2.4 Other broadcasting protocols

- *PDB* [99]: Preset Delay Broadcast protocol dedicated for emergency message dissemination. It is based on a fixed delay according to the farthest vehicle. The protocol uses beaconing messages to calculate and sort neighbors distances. So, the lowest delay is assigned to the farthest node and the warning message will contain a list of ten farthest nodes IDs with the corresponding delay. This information will be used in each retransmission in order to check and perform the next relay. The protocol is tested in a highway environment and the vehicles maximum speed was fixed to 4.5 m/s . This is a very low value because the authors aim to obtain suitable vehicles density to maintain connectivity and achieve a good reliability. However, in a realistic environment, this does not seem to be accepted because vehicles speed in a highway is extremely higher. This makes unproved the results obtained for the protocol performances.
- *UMBP* [100] : Urban Multi-hop Protocol is a broadcasting protocol using unidirectional and bidirectional broadcast schemes according to current hop position. Since it is designed for urban scenarios, it uses multi-directional broadcast at roads intersections. The protocol tries to reduce delay and increase delivery of emergency messages. It also consider network overhead therefore there is no use of beaconing messages. For performance evaluation, authors compared the designed algorithm with a unique other one which does not clearly prove its efficiency and over performance of other proposed schemes. Also, authors did not consider packet loss caused by channel errors.
- *AFCS* [101]: Adaptive Forwarding message and Cooperative Safe driving. In context of hazardous situation, the designed protocol aims to avoid flooding problem of emergency messages broadcast. For real time applications support, the protocol tries to achieve QoS of videos messages sharing within the network users. The protocol begins by sensing network information about node location, density and speed. Then it tries to reduce the number of retransmission by varying the forwarding range accordingly to the information already gathered from network. The designed protocol take in consideration nodes which are not equipped with Cooperative active Safe Driving systems in an urban environment in order to get more realistic scenarios. The protocol performance is compared with four other approaches including flooding. It succeeds to reduce end-to-end delay and propagation time which are important QoS metrics especially for safety application. However, there is no reach ability level proved by the numerical results. Also, considering videos sharing, packet delivery and packet loss ratio are critical parameters which were not analyzed. Highway scenarios, where vehicles speed highly increases have to be considered since to confirm connectivity feature results proved in urban scenario.
- *DAYcast* [102]: Dynamic trAnsmission delaY based broadcast firstly define a set of effective neighbors according position information of all 1-hop neighbors of the sender. Each node of this set would wait for a delay time before relaying the message; this delay is assigned based on neighbors densities and distance to the source. The protocol was tested on a straight way and it shows good performance in term of reachability, delay and PDR. However this does not seem to be compatible with more complex scenarios in a realistic environment.
- *Intelligent broadcast protocol based on transfer learning* [103]: Is a position based protocol for highway

Table 4 Comparison of QoS aware probabilistic broadcasting protocols

Protocol	Year	Beacons	Relay selection	Scenario	Mobility model	Simulator	QoS measures							
							Delay	Propagation speed	PDR	Reachability	Band	Overhead	Throughput	Scalability
ProbT [90]	2015	yes	Number of neighbours	Highway	Nakagami	NS-3	√		√	√				
E-ProbT [91]	2016	Yes	Trust value	Highway	Nakagami	NS-3	√	√	√	√		√		
AWPP [92]	2015	Yes	Density	Urban	Manhattan	NS-2.34			√	√		√		
CPROB [93]	2016	No	Distance and probability	Urban	MOVE	NS2.35	√			√		√		
EAEP [89]	2007	Yes	Probability value	Highway	IDM	Java			√	√	√	√		√
OAPB [88]	2005	Yes	neighbourhood density	motorway	–	NS-2	√		√	√		√		
SAB [94]	2014	No	Speed	Highway	SUMO	OMNET++	√	√	√	√		√		√
N2DCAST [95]	2015	Yes	Distance	Highway	Nakagami	NS-3	√	√	√			√		√
[96]	2015	Yes	Fuzzy rule	Urban	Real straight road	NS-2	√		√	√		√		
[97]	2014	Yes	Neighbours density	Highway	Two-ray ground	NS-2	√			√		√		
SFBB [98]	2013	No	Neighbours number and speed	Urban	–	GloMoSim	√	√	√			√		

VANET networks. It is based on a self-learning mechanism using fuzzy rules for message forwarding and the relaying nodes selection. Protocol performance is compared with the FUZZBR algorithm [104]. Considering various scenarios, QoS parameters evaluated by the analytical results which are PDR, delay and number of retransmission degrades one the other. For instance, when the protocol achieves a high PDR in a specific scenario one or other parameters are negatively affected. If this or these parameters are improved in a different scenario, PDR decreases. Also, the protocol outperforms the compared approach in specific context and feature, a global comparison do not give the desired conclusion.

- *SVB* [105]: Efficient multi-hop wireless broadcast protocol is a statistical broadcasting protocol for urban VANET context. The core of the protocol is based on threshold function using multi-layer perceptron (MLP) in the optimization algorithm of the fitness value. The protocol uses combination of different statistical methods such as stochastic and distance-to-mean methods in order to select the most suitable ones. Although the designed protocol achieve good reachability and reduces number of rebroadcasts it does not consider delay and PDR which are very important in message dissemination. The protocol mainly focus in the broadcast storm problem.
- *FUZZBR-NC* [106]: Fuzzy logic based Broadcast with Network Coding uses beacon messages to gather vehicles information from network. Selection of the relaying node is based on a fuzzy rule considering node mobility, distance and signal strength. The protocol considers PDR, delay, reachability and Packet Loss as QoS parameters. The simulation result were compared with only one other approach.
- *GTO* [107]: hiGhway broadcasT prOtocol is a location based broadcasting protocol which consider adaptability in different traffic condition as the main broadcast problem. The proposed protocol uses periodic hello messages to determine dense and sparse traffic zones. According to this classification a Zone of Preference (ZoP) is defined for message retransmission. Authors analyse the proposed scheme performance by evaluating reachability, delay and number of packet retransmissions. They compare it to four other protocols including simple flooding but for almost scenarios the designed protocol performance is only better than flooding.
- *RBLSM* [108]: Reliable Broadcasting of Life Safety Message : As a distance-based protocol, RBLSM selects the nearest node for safety message forwarding. It adopts the head way model for considering naturalistic behavior of drivers and gives highest priority for vehicles in most dangerous situation. The choice of that vehicle is performed locally based on the location, direction, and the speed of the receiving vehicle. The theoretical algorithm of the protocol shows a reliability that could reach 100% but real simulations result were only based on latency and collision rates which do not really prove the protocol reliability.
- *ODAM-C* [109]: It is based on ODAM protocol, it uses a distance based scheme in the aim to increase the PDR and reduce redundancy of relaying nodes relying on dissemination area interference. Many QoS measures are not considered by this protocol. In addition, its evaluation was not applied in realistic environment.
- *LW-RBMD* [110]: The sender selects the furthest vehicle as a relaying node according to its location. The rebroadcasted message plays the role of acknowledgers for the sender. The protocol performs well in term of delivery rate especially in road intersection, but the end-to end delay behavior is not taken in consideration.
- *LDMB* [111]: Link-based Distributed Multi-hop Broadcast is a distributed broadcast protocol which does not use any handshake messages before the broadcasting process. The forwarding scheme is based on the link status of each vehicle which is estimated by the probability of packet reception. This probability depends on many varying parameters according to vehicular densities and number of broadcasted messages which may affects the protocol performances and scalability.
- *FUZZBR* [104]: It is a location based protocol which uses beacon messages to gather position information inserted in the broadcasted message. Distance, mobility and signal strength are parameters of relay node selection. A Fuzzy logic method is applied in order to get the best relay decision. A lightweight retransmission mechanism is used when relay fails. The different mechanisms used in this protocol are highly dependent on beacon messages frequency. Therefore the trade-off between exchanged local information relevance and network overhead is very difficult to obtain.
- *BROADCOMM* [112]: It uses a geographical routing and designed for highway network. It is based on a hierarchical structure. The network of vehicles is virtually organized into two levels of cells. A down level including all vehicles in a cell and upper level composed of cell reflector behaving as cluster head in cluster-based protocols. BROADCOMM performs similar to flooding protocols for message broadcasting and routing overhead.
- *POCA* [113]: Position-aware reliable broadcasting protocol. It is similar to DECA protocol, it uses beacon messages to get neighbors local information such as position and speed. The relaying node selection is based on preferred distance between source and other nodes. A timeout is set, after if it expires without hearing any rebroadcast, the nearest node to the source will firstly rebroadcast the message. This protocol also handles

intermittent connectivity by the use of piggybacking. It reaches a good reliability but do not respect low delay. Also if a relay fails, many neighboring vehicles may rebroadcast the message causing a network flooding.

- *V-TRADE* [114]: Vector Based Tracing Detection is an improved version of the TRADE protocol. It relies on GPS information and works similar to ZRP unicast protocol. To forward a broadcast message, neighboring vehicles are classified into different groups and a small nodes subset is selected for rebroadcast. This protocol optimizes resources consumption by improving bandwidth utilization but with increasing vehicle density. So-me routing overheads may incur when selecting relaying hops.
- *HyDi/VoV* [115,116]: It is a broadcasting protocol designed for highway environments. It applies a combination between two mechanisms: store-carry-forward and the broadcasting suppression strategy. It guarantees a go-od delivery for varied traffic regimes but its application is limited for highway scenarios. VoV is the extended version of HyDi protocol in urban environments. Both of protocols are not generic since they are specified only for video dissemination which is mostly needed in infotainment applications
- *UMB* [117]: Similar to RLMB this protocol UMB is also designed to handle with broadcast storm problem and additionally with the hidden node problem. According to the protocol strategy, the transmission range is divided into segments and the relaying nodes are selected to the furthest one in a non-empty segment. In intersections, forwarding vehicles which are positioned in the intersection have to perform new directional retransmissions. UMB is specific for urban environments, it achieves good performance in dense traffic. Nevertheless, in sparse regimes, the selection of non-empty segment would be difficult.

We elaborated a detailed comparative study of the above listed techniques. Table 5 concludes this comparison with different parameters.

8 Challenges and future trends

Although many research works have been led to propose solutions for broadcasting issues in VANET, there still be many other unexplored problems that need to be more focused in. Even though vehicular nodes are ad-hoc organized, VANET is different from usual MANETs in terms of architecture, mobility model, energy constraints and real time applications scenarios. It was clearly demonstrated that adopting MANET designed approaches does not fit to VANET model. Many challenges are facing researchers in this subject.

8.1 Challenges

- *Connectivity and communication*
  Being related to high mobility of vehicles, the changing topology of VANET usually causes frequent breakage in communication links. Therefore, managing and controlling network connections among VANET components entities seems to be the most challenging task [118]. So, a primary challenge in designing VANET communications is to guarantee good connectivity performance under strict constraints of vehicles speed, dynamic topology, and limited resources.
- *Heterogeneity of services*
  VANET networks have to support a large scale of services. Generally, security and road safety applications require low latency and high reliability. However, packet loss and resources consumption are performance measures common for infotainment applications [54]. Given this heterogeneity of services, well adapting access, routing protocols and resources allocation strategies are worthy to be deployed in VANET projects so as to insure fair communications on the network.
- *Resources management*
  In order to hold diverse road applications in different vehicular environments, efficient resources management strategies such as storage optimization, bandwidth allocation, packets scheduling are needed to guarantee equity in resources distributions [54].
- *Broadcasting protocols*
  Even though many efficient broadcasting schemes and algorithms have been suggested, crucial challenges arise in realizing best protocols that trying to solve all VANET issues [119]. Due to the absence of a central coordinator for network management, every node has to have a minimum awareness of network topology, consisting in its neighborhood, in order to broadcast a message. In other hand, this topology is highly dynamic and extremely changing. Therefore broadcasting protocols have to be personalized in a way to encounter this phenomenon. While broadcasting protocols try to benefit from mobility models of vehicles, generally constrained by road infrastructure model, frequent links breaking create problems in maintaining routing parameters such as selection of next relaying hop or election of cluster head.
  Generally, a broadcasting protocol performances are estimated with reliability, delay, network congestion and throughput. These protocols usually aim to improve one or a set of these measures, nevertheless the optimization of all of them simultaneously is a challenging issue [56]. Moreover, it is commonly assumed that only warning

Table 5 Comparison of other QoS aware broadcasting protocols

Protocol	Year	Category	Beacons	Relay selection	Scenario	Mobility model	Simulator	QoS measures							
								Delay	Propagation speed	PDR	Reachability	Bandwidth	Overhead	Throughput	Scalability
PDB [99]	2016	Position based	Yes	Farthest neighbour	Highway	Nakagami	SUMO	√		√					
UMBP [100]	2016	Position based	No	RTS/CTS handshake	Urban	Manhattan	NS-2	√	√	√					√
AFCS [101]	2015	Location based	Yes	Neighbours velocity and density	Urban/suburban	VanetMobiSim	.NETC/C++	√	√				√		
[103]	2015	Position based	Yes	Distance	Highway	Nakagami	NS2.34	√		√	√		√		
SVB [105]	2015	Hybride	Yes	Distance (statistic)	Urban	WDC	JiST/SWANS			√		√		√	
FUZZBR-NC [106]	2015	Location-based	Yes	Fuzzy rule	Freeway/street	Nakagami	NS-2	√	√	√	√	√			
GTO [107]	2014	Location-based	Yes	Density	Highway	SUMO	OMNet++	√			√		√		√
DAYcast [102]	2014	Position-based	Yes	Direction/ position	Straight-way	VanetMobiSim	NS-2	√		√	√				
RBLSM [14]	2007	Distance-based	No	Nearest vehicle	Highway	Headway	Matlab	√	√	√		√	√		
ODAM-C [109]	2011	Distance-based	no	Furthest vehicle	Urban	SUMO	NS-2	√		√	√		√		√
LW-RBMD [110]	2012	Distance-based	no	Furthest vehicle	Urban	knife-edge	OPNet14.5	√	√						
LDMB [111]	2010	Link-based	Yes	Packet reception probability	Urban	Expressway	–	√	√	√			√		
FUZZBR [104]	2012	Location-based	Yes	Fuzzy method	Freeway/street	Nakagami	NS-2	√		√	√	√	√		
BROADCOMM [112]	2005	geographic-based	No	Nearest vehicle	Highway	workload model	–	√		√			√		
POCA [113]	2014	Position-based	Yes	Preferred distance	–	–	–	√	√						
V-TRADE [114]	2000	Location-based	No	Vector of ZRP	Highway	RWP	–	√		√	√	√			
HyDi/VoV [115,116]	2012	Distance/ geographic-based	No	Distance	Highway	–	–	√		√		√		√	
UMB [117]	2004	Location-based	No	Furthest node	City	Simple structure	MATLAB	√		√	√	√			√

messages generated by safety applications are concerned by broadcasting protocols. However, with the emergence of VANET and popularity of social networks it would be challenging to get the same performances with also messages broadcast by infotainment applications.

- *Security and privacy*
In a VANET context all vehicles continuously try to communicate among each other in order to exchange vital information with critical privacy. Therefore, it is important to insure that the correct data is delivered to the correct target [15]. A message has to be protected against hacking operations such as snooping and spoofing [56]. The changing topology of the network makes the management of security and privacy policies very difficult. Consequently, researchers have to integrate attacks aware knowledge models in VANET design in order improve the robustness of security and privacy mechanism in the system.
Furthermore, in most critical road emergency situations, VANET users do not have much time in order to verify the trustworthiness of a data. Therefore, the authentication mechanism has to be robust and time reduced so as to enable real time verification of messages. Moreover, almost driving services allow access to user's relative context such as location information using Location Based Systems (LBS) like GPS. These intelligent systems can intuitively extract extended information about user like his gender, preferences, age, profession, etc. which make his privacy in risk [120].
In the light of this literature review, designing appropriate authentication mechanisms and strong security protocols seems to be an interesting research axe in VANET [15].
- *Standards*
IEEE 802.11 primary standard presented some weakness in facing VANET requirements as guaranteeing robust connectivity and also the IEEE 802.11p for the MAC layer configuration do not support the increasing density of vehicles [121]. Consequently, more research has to be focused on standards improvement.
- *Cooperation*
In addition to the communication among VANET components, there are also communications between VANET and external networks. These networks are more and more emergent in a common environment in the context of cloud networks and the internet of things. VANET as a part of these emergent systems could be considered as a mobile cloud [118,121]. Studying the deployment and management of VANET applications in a context of cooperation between the vehicular cloud and external pervasive systems appear as interesting research orientation [119].

8.2 Future trends

- *Broadcasting schemes*
The important role which plays broadcasting as a service for VANET users makes it among the strongest open research area. Every second a significant number of data is disseminated over VANET via a broadcasting scheme. Regarding the failure of other disseminations and routing strategies to face some applications requirements, broadcasting shows more strength. Consequently, improving existing solutions and developing new effective, scalable and co-operative broadcasting schemes continues to be one of the major concerns for VANET researchers.
- *QoS provisioning*
VANET presents various particularities, such as dynamic topology and frequent connection breaks which results in many routing difficulties during the broadcasting process. This fact makes QoS support in this environment a heavy job [122]. Its difficulty resides in insuring a trade-off between optimized data delivery with quick broadcasting protocol and fair resource allocation. We believe that research on this topic will be more enhanced in the next years.
- *QoS-oriented backbone infrastructure*
Plenty of issues in QoS provisioning result from the lack of studies on road side backbone infrastructure in vehicular communications. Therefore, providing QoS oriented broadcasting platforms for V2I as well as V2V communications are among hottest research topics. Also, designing consistent and modular road side infrastructure with synchronous capabilities is likely to lead many research works in the future.
- *Service scheduling*
Vehicular networks users usually want to send or access data in a real-time which causes much contention between RSUs. Users Requests, delivered from various applications, need to be handled in a way that the whole service ratio and the QoS for each user are optimized. Future research has to lead to broadcasting solutions that consider number and type of queries in order to assign respective weights according to their impact on QoS [123].
- *Wireless access and radio technologies*
Every day vehicular applications are more and more extending with exploding number of vehicles especially in big cities. Not only safety applications but also growing infotainment services with multimedia applications use broadcasting to disseminate information among users [124]. This excessive bandwidth demanding may lead to band overloading and thereby resulting in degraded quality of the service. So guaranteeing a QoS support in

these conditions would be easier if we encounter IEEE 802.11p spectrum scarcity. From this view, we believe that improving research on radio technologies such as Cognitive Radio (CR) could allow more efficient QoS broadcasting solutions for VANET applications.

- *Intelligent architectural frameworks*
From an architectural point of view, there has been a drastic enhancement of distributed architectures with the introduction of mobile agents over the common client/ser-ver ones. Applying agents technology provides several advantages such as flexibility, efficiency, scalability, maintainability and adaptability. Therefore, deploying broadcasting future solutions for VANET via an agent based architecture may improve performance and QoS.

8.3 Future challenges

The present survey guided us to determine main challenges facing our research work and makes our problematic more clear. Actually, studying QoS-related VANET broadcasting problems helped us to mark off our future focus span exclusively in two points:

- After reviewing the above discussed issues and topics, our future major concern is to enhance previous and current researches on VANET QoS aware broadcasting with new rewarding contributions. In fact, although existing works solved many problems and contributed in the development of vehicular environments, there still be a need for QoS fulfilment optimization. Our future work will focus exclusively on modelling and designing new QoS aware broadcasting solutions that could improve the overall system performance.
- Observing all previous works, we can note that studying and comparing QoS of broadcasting proposed solutions is always based on some performance features fixed beforehand by researcher according to their motivation or relative area of interest. However ,QoS in a VANET context has actually two aspects: qualitative and quantitative. Qualitative aspect is more imposed by VANET end users needs and their satisfaction degree by the services provided. Quantitative aspect can be a function of services requirements. For instance, following a vehicular broadcasting scenario, a given set of performance parameters values are produced. Here we need to have a generic model to quantitatively evaluate the applied scheme performance which can be adaptive to compare the achieved QoS by any other schemes and regardless of any previous assumption related to scenarios.

9 Conclusion

Currently, broadcasting in VANET is one of the hottest research topics. Indeed, Broadcasting is used to achieve many tasks like emergency message dissemination and traffic status information. On the other hand the specificities of VANET such as the highly changing topology and frequent links breakage make the broadcasting as a challenging problem. Nevertheless, performing the service of broadcasting requires an acceptable quality regarding many criteria such as delay, delivery, network reachability and overhead. In this paper we discuss main issues that may face a researcher in this context by performing a literature survey with a comparison study based on some selected QoS and performance features. Furthermore, current challenges and future trends are presented and discussed. According to our survey, future research works may focus more on the most efficient existing mechanisms that can be improved to give new proposal of QoS aware broadcasting scheme able to perform trade-off between main QoS criteria.

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