Vehicular Ad Hoc Networks: Growth and Survey for Three Layers

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Article Info	ABSTRACT
	A vehicular ad hoc network (VANET) is a mobile ad hoc network that allows wireless communication between vehicles, as well as between vehicles and roadside equipment. Communication between vehicles promotes safety and reliability, and can be a source of entertainment. We investigated the historical development, characteristics, and application fields of VANET and briefly introduced them in this study. Advantages and disadvantages were discussed based on our analysis and comparison of various classes of MAC and routing protocols applied to VANET. Ideas and breakthrough directions for inter-vehicle communication designs were proposed based on the characteristics of VANET. This article also illustrates physical, MAC, and network layer in details which represent the three layers of VANET. The main works of the active research institute on VANET were introduced to help researchers track related advanced research achievements on the subject.

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1.   INTRODUCTION

Road accidents have become a global public safety issue. Accidents caused by strong mass destruction have been became the number one killer in the world. Vehicle networking in an intelligent transportation system provides an important foundation to resolve this issue. Vehicular ad hoc networks (VANETs) are self-organizing networks dedicated to inter-vehicle communication and design. VANET utilizes mobile ad hoc network (MANET) technology to instigate inter-vehicle communication [1] which allows the driver to obtain the status information of other vehicles (e.g., BVR speed range, direction, position, and brake pedal pressure) and real-time traffic dispatch.

The design goal of VANET is to establish an inter-vehicle communication platform that improves traffic efficiency, safety, and reliability, as well as provides convenience and multiple access to drivers and improves passenger comfort [2], [3] During the 2003 ITU-T Telecommunication Standardization Conference on cars, national car experts proposed to reduce traffic accident by 50% [4] Over 90% of the deaths occur in low-income and middle-income countries, which have only 48% of the world's vehicles, according to the Global status report on road safety more than 1.2 million people die in road accidents every year. A wireless ad hoc network is a distributed architecture with emphasis on hopping (routing), self-organization, and decentralization. VANET is defined as a fast-moving outdoor communication network [5]. It is also referred to as a self-organized traffic information system. The basic idea behind VANETs is the exchange of data and

information (e.g., vehicle speed and location) between vehicles within a communication range through the use of vehicle sensors, thus automatically establishing a mobile network connection. The single-hop communication range of a node is only between a few hundred meters to kilometers. Each node (vehicle) is a transceiver and a router, becoming a multi-hop node that further forwards data to other vehicles.

1.1. Network structure
VANET communication is divided into two parts: (1) vehicle-to-vehicle, where vehicles communicate with one another; and (2) vehicle-to-infrastructure, where vehicles communicate with facilities. Figure 1 shows a real-world application of a VANET schematic model [6].
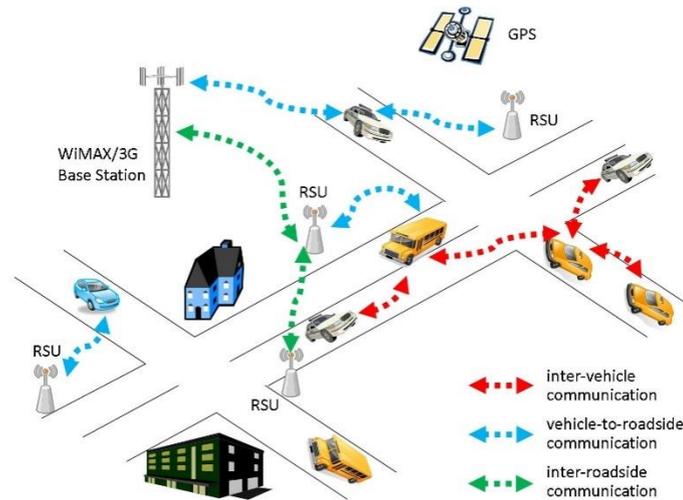
Figure 1. VANET schematic structure

Satellite communication systems are global positioning services for VANET (GPS, global positioning system) and enable communication between cars and trucks so the vehicles can be automatically interconnected via a multi-hop manner. The systems play a role in security and ease the traffic flow to improve vehicle operations. Moreover, VANET can be used as a separate access point gateway (e.g., through lights and gas stations) to create local communication networks with other fixed or mobile communication networks, thus providing rich entertainment, interior offices, and other services. In this study, the characteristics and technical difficulties of VANET are discussed, with particular focus on self-networking communication between vehicles.

1.2. Main Features of VANET
VANET is a special form of MANET, but it has its own unique characteristics. Unfortunately, VANET possesses the inherent problems of MANETs (e.g., hidden point, exposure point, and channel capture) [7]. The main features of VANET include the following:
a. The path life of VANET is short because of high-speed node movement (general speed is between 5 and 42 m/s), which leads to rapid changes in network topology. For example, if the node coverage radius is 250 m and the average speed is 100 km/h, then the probability of the existence of a 15s link is only 57% [8].
b. VANET has unstable wireless channel quality, which is affected by several factors (e.g., street construction, road conditions, vehicle type, and vehicle speed).
c. A node that provides a steady power stream that the engine supports. Space vehicle carriers can ensure the antenna dimensions and additional communication equipment, but also have strong computing power and storage capacity.
d. The node moves with a certain regularity: it only has two-way movement along a one-dimensional single lane.
e. VANET has road shapes where static vehicle movement is restricted, thus making vehicle tracking generally predictable [9].

f. GPS provides accurate node positioning and precise clock information, which help to obtain location information and clock synchronization.
g. The use of the path planning function for GPS and electronic maps allows VANET to easily achieve the set policies.

1.3. Applications of VANET

The use of VANET expands the field of vision of the driver and the functional components of the car, thus improving road traffic safety and efficiency. Typical applications [10] of VANET include:

a. Drive safely warning. A mutual exchange is conducted between the use of vehicle status information through VANET and the advance notice to the driver. The driver is recommended to observe timely and appropriate driving behavior accordingly, which effectively improves driver attention and driving safety.
b. Driving assistance. This application accurately and swiftly assists the driver through a "blind spot" (e.g., highway entrance/exit or coordination of vehicular traffic intersection).
c. Distributed traffic information. The traditional vehicle is modified to obtain traffic information in a center-based network structure from VANET in order to improve real-time traffic information; for example, updating electronic maps for efficient path planning decisions associated with the integration of the traffic situation.
d. communication-based control within vehicle networking and vehicles cooperate among themselves (i.e., the vehicle can communicate with a vehicle in front of it or even with vehicles out of its line) form harmonious queues to avoid accidents.
e. Passenger office and entertainment. Passengers are provided entertainment (e.g., video-on-demand), car meeting venues, street supermarket drops, and access to Wi-Fi-based applications (e.g., online gaming and the Internet).

1.4. Challenges of VANET

VANET is a dynamically changing wireless channel based on a self-organizing network. The main challenges of VANET include [11]:

a. A large-scale network that must be able to handle segmentation even if ensuring a one-dimensional network connectivity is difficult.
b. The VANET multi-hop wireless channel is a shared multi-channel. Network performance plays a vital role in how the radio channel technology can be accessed through the channel access control node.
c. VANET multi-hop routing is conducted in collaboration with the common node. Adapting to frequent changes in network topology is also necessary. Therefore, an efficient and dedicated multi-hop routing protocol must be designed.
d. QoS guarantees. Network data are mainly used to transfer small amounts of information. MANET requires real-time transmission of high-security information (i.e., bandwidth), and delay and jitter are highly demanded.
e. Broadcast and multicast issues become complicated because of the special nature of VANET (i.e., the broadcast is sent during a traffic accident, leading to a sudden increase in communication load). The link and network layers need to be supported, and cross-layer research needs to be conducted.
f. Safety. MANETs are less secure and vulnerable to interception and attack. Nodes cannot guarantee the reliability of the vehicle. Therefore, an automotive ad hoc network security architecture and dedicated security technology need to be studied [12].
g. Network management. VANET network management covers a broad area (i.e., mobility management, address management, and service management). A corresponding node localization mechanism is required to solve problems and address auto configuration.

1.5. Literature Review

The earliest studies on inter-vehicle communication began in Japan in the early 1980s. DEMO2000, the cooperative driving system of Japan, presented an important vehicle communication application in subsequent years (early 2000s) [13]. At present, the United States and Europe have several research institutions that have launched active large-scale research projects on VANET. Several of these research projects are listed below.

a. CarTalk2000 [14] was a three-year-old project that began in 2001. The project was committed to developing a new pilot-plant-based communications driver assistance system for driving safety and comfort. The study was initiated by INVENT and was composed of eight projects that dealt with different driver assistance system issues (e.g., safe driving issues to relieve traffic congestion and traffic management).

b. FleetNet [15] was an "Internet on the Road" project started by six companies and three universities to promote the development and establishment of communication workshop projects. The FleetNet project started in September 2000 and ended in December 2003. The project presented its finished product through a series of tests to obtain valuable data. A follow-up project called "NOW" [16], that is, "Network on Wheels" [17], was started in 2004. World-class car manufacturers BMV and Volkswagen were both attracted to this follow-up project. The main goal of NOW is to address workshop communication protocols on how to ensure data security. Final results of the project were submitted to the C2C-CC organization for standardization.

c. C2C-CC [18], or "Car2Car Communication Consortium," is composed of six European car manufacturers (Audi, BMW, DaimlerChrysler, Fiat, Renault and Volkswagen) with the goal of establish an open car-to-car communication system based on European standards. The system will allow different car manufacturers to communicate with one another. The Car2Car communication system is based on the use of WLAN technologies to ensure normal plant operation in the context of European communication.

d. WILLWARN [19], or "Wireless Local Danger Warning," is a three-year-old child prevention project focusing on road safety through research and verification of preventive security technologies and applications. The goal is to provide an alarm signal to the driver when any safety-related vehicle condition occurs.

e. ADASE [20], or "Advanced Driver Assistance Systems in Europe," is a project that aims to increase European road traffic safety and to reduce traffic accidents. ADASE aims to avoid collisions before they occur through the use of active safety systems and the connection of side-of-the-road infrastructure equipment.

f. COMCAR [21], or "Communication and Mobility by Cellular Advanced Radio," is a project that presents an innovative concept and a prototype mobile communication network. The main difficulties for COMCAR concern asymmetric, interactive IP-based mobile services, where critical communication vehicle workshops and problem-solving techniques are necessary.

g. DRiVE [22, 23], or "Dynamic Radio for IP-Services in Vehicular Environments," is a project whose main objective is to provide automotive multimedia services that allow convenient access to services such as education or entertainment networks.

h. CHAUFFEUR 2 [24] is a follow-up project of CHAUFFEUR 1. This study is mainly concerned with the "Platooning of Vehicles," in which the vehicle in front can send messages to the vehicle behind it, which, in turn, can have an impact on the person driving behind the vehicle.

Other research institutions focused on VANET include the Japanese JSK Leadership's "Association of Electronic Technology for Automobile Traffic and Driving", the "Group Cooperative Driving" [25], the U.S. VII [26], the University of Maryland's TrafficView project [27], and several research institutions in France in cooperation with CIVIC and so forth.

2.   PHYSICAL LAYER PARAMETERS OF VANET

Determining the physical layer requirements of VANET is demanding because of its unique nature. VANET is strong and robust in a fast-moving environment to reduce the impact of the signal that mutations in high-speed mobiles bring (especially the Doppler effect produced at high speed). Moreover, it must support high-speed transmission to provide multi-hop connection (even when node density is relatively small) and ensure adequate information exchange. It must have a small security alarm delay to support guaranteed bursty data streams, a matching MAC layer protocol interface, and work within the unlicensed band to ensure universal application. The current physical layer technology applied in the VANET system is mainly based on 802.11 (Wi-Fi) [28] standards and UTRA-TDD (TD-CDMA) [29] techniques. These projects adopted CarTalk with FleetNet for the UTRA-TDD technology, and the C2C alliance advocates the use of 802.11b technology. Table 1 shows a simple comparison of several different parameters in 802.11b and the UTRA-TDD physical layer.

Table 1. 802.11b and UTRA-TDD

Parameter	802.11b (1 Mbit/s)	UTRA-TDD
Carrier frequency	2.4 GHz	2 GHz
System bandwidth	22 MHz	1.67 MHz
Chip rate	11 Mchip/s	1.28 Mchip/s
Spreading factor	11 (Barker code)	16 (OVSF code)
Multi-code transmission	No	1–16
Modulation	DBPSK	QPSK

The Table 1 shows that 802.11b performed less than UTRA-TDD. However, the 802.11b wireless module is widely popular because it is cheap, simple, and free to work on a 2.4 GHz band, which is widely used in scientific experiments. Complexity and high costs of the UTRA-TDD technology are some of the non-technical factors that hinder its application.

Moreover, our most popular GSM mobile communication technology needs to have stable performance to be accepted. Lucent Technologies, Inc. financially supports the GSM network (A-GSM) of the organization [30] for further studies on the next generation of GSM cellular network relay capability. Researchers attempted to minimize changes to the existing GSM system (e.g., the mobile station having a relay function) to enhance GSM network coverage. Thus, GSM technology is feasible in ad hoc networks. The performance of GSM technology also fully meets VANET requirements. The VANET physical layer can try to employ GSM technology.

The application of 802.11b, UTRA-TDD, or GSM technology as a central network structure in distributed networks needs to be improved in several aspects: (1) adapting to the dynamically changing high-speed air interface network topology; (2) modifying into a wireless media access control mechanism that centers the distributed medium access mechanism; (3) controlling the modified radio resource management mechanism through the base station node manager collaborative mechanisms; and (4) facing severe multipath effects, energy control algorithm, and slot synchronization issues. For slot synchronization, the GSM terminal equipment access base in the base station is responsible for synchronization, unlike in UTRA-TDD and in regularly sent 802.11b AP beacon frames, which retain the same physical network workstation synchronization. By introducing a rough GPS synchronization with specific mechanisms for precise synchronization (i.e., specific time slot design in the frame synchronization [31]), we conclude from the theoretical analysis of simulation testing or from actual highway or city road results carried out that UTRA-TDD has greater advantage over IEEE 802.11b for time slot synchronization issues in VANET.

Some non-technical factors arise aside from the physical layer hindering its selection (e.g., occupied band). In 2003, the U.S. Federal Communications Commission divided a 75 MHz (5.85 GHz to 5.925 GHz) free frequency bandwidth for dedicated short-range communication (DSRC) specifically for inter-vehicle communication. The European Post and Telecommunications Organization also issued an exemption license for UTRA-TDD technology 2010 MHz to 2020 MHz band for the Japan DEM02000 mining project.

Using DSRC [25] requires a special free band. VANET technological development in a free country has better band use. Therefore, the free band VANET must be divided in a country to facilitate good promotion and use.

Based on the physical layer characteristics, the selection criteria for the VANET physical layer are summarized as follows: (1) suitable node speed movement = speed limit of 150 km/h; (2) communication range = approximately1 km; (3) bandwidth = 1 Mbit/s or higher; (4) support real-time synchronous transmission (only small delay allowed); and (5) best free frequency bands (consideration of free 2.4 GHz ISM band).

IEEE 802.11p

The IEEE 802.11p allows the use of the 5.9GHz band (5.850 - 5.925) GHz with channel spacing equal to 20MHz, 10MHz and 5MHz and lays down. IEEE 802.11p operates on about 9 channels, as shown in Figure 2. The frequency band as described in Figure 2 CH172-5.860 GHz and CH184-5.920 GHz both are safety dedicated channels [32]. The first one provides a serious security solutions while the second plays a protective role against congestion on other channels [33]. Channel CH178-5.890GHz is a control channel responsible for controlling the transmission broadcast and link establishment. Also, there are six service channels allocate for bidirectional communication between different types of units. In 802.11p the channel bandwidth is halved in order to keep abreast the requirements of VANETs. If compare to 802.11a which is 0.3125MHz While the symbol length for 802.11p is twice (8μs) that of 802.11a (4μs). We summarize the physical layer of IEEE 802.11p in the Table 2.
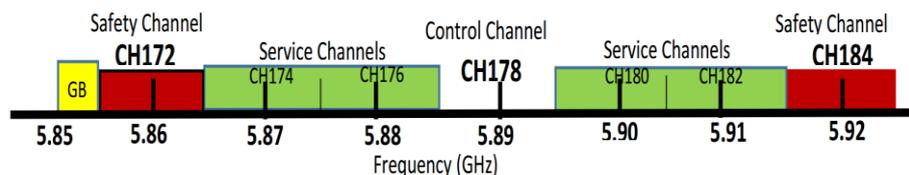

Figure 2. The IEEE 802.11p Frequency

Table 2. The IEEE 802.11p physical layer

Parameter	Value	Remarks
Frequency	(5.850-5.925) GHz	Optional 5,9 GHz. The choice of the channel depends on the results of interoperability and propagation tests.
Channel Bandwidth	20,10,5 MHz	the pair of channels 174, 176 and channels 180, 182 can be combined together to form a single 20MHz channel, channel 175 and 181 respectively. a 10 MHz bandwidth instead of 20MHz in 802.11a. There is 5 MHz in the beginning of the band at 5.85used as guard band (GB).
Transmit Power	20 dBm	Recommended value, roadside infrastructure (V2I) within a range of 1km
Default Rate	3Mbps to 27Mbps	Provides the most robust modulation scheme. Higher rates could be used according to the results of the propagation tests.

3. MAC LAYER PROTOCOL

MAC protocol directly controls packets sent and received by the channel. The protocol directly affects the efficiency of use of limited radio resources [34]; thus, VANET performance plays a decisive role. The MAC layer needs to address the common problems and resource allocation fairness of the hidden and exposed terminals. The specific application environment and business needs of VANET face one particular problem: cars usually move fast. Therefore, the highly dynamic structural changes of the network topology need to support high priority real-time traffic safety. Based on the in-vehicle communication network system, MAC protocols need to have the following characteristics [35]: (1) supports high-speed mobility vehicle, (2) guarantees timeliness and reliability of communication, (3) good scalability, (4) supports high bandwidth utilization, (5) supports fully distributed networking, (6) provides fair communication opportunities for each user, and (7) provide efficient and timely broadcast mechanisms.

3.1. Structure

The VANET physical layer is generally based on the 802.11 standard and UTRA-TDD technology because of its current application. The MAC layer frame structure built on top of the physical layer generally has two types. The physical layer adapts the UTRA-TDD communication module because the UTRA-TDD center structure needs to be applied to distributed systems for adjustments and improvements in many areas. First, the redesign of the MAC layer frame structure of each frame is 10 ms in length. Each frame consists of 15 time slots, and every four time slots constitutes a super frame shown in Figure 3.
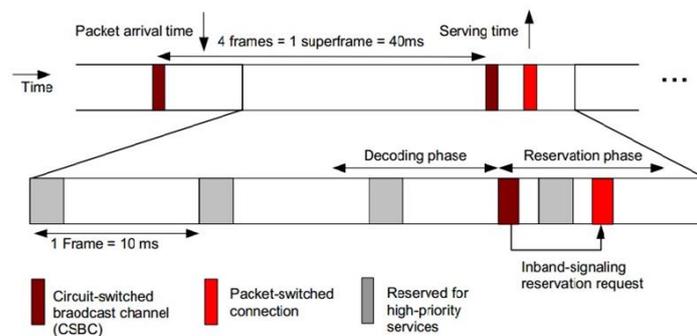

Figure 3. MAC layer frame structure

A study [8] has shown further improvement to the frame structure and provides different priority services. A circuit-switched broadcast channel (CSBC) was introduced to avoid being retained in the request conflict of the random channel access mechanism. The CSBC is mainly used for signaling purposes. If the frame does not have sufficient capacity to support data transmission, then the node will transmit the extra capacity CSBC reservation request. The physical layer selects the 802.11b wireless communication module by setting different lengths of time interval between frames (IFS) to achieve different levels of channel access priority mechanism [36]. High-priority nodes use short frame intervals.

3.2. Access

The MAC layer mainly distributes radio resources to complete arbitration and administrative work. Access needs to be considered from two perspectives based on a question of fairness: from the perspective of

a node to ensure equality in an occupied channel bandwidth, and from the perspective of traffic to ensure equality in the traffic flow in the occupied channel bandwidth. However, the angle from which to consider the issue is important. Ultimately, ensuring equitable access to each network node in the MAC protocol is the priority.

3.2.1. 802.11 DCF

The ad hoc network of the MAC protocol currently used widely is the IEEE 802.11 DCF [37]. The protocol is based on CSMA / CA. Node first sends by RTS / CTS exchanging information, to achieve the distribution channels, on the basis of the process shown in Figure 4.
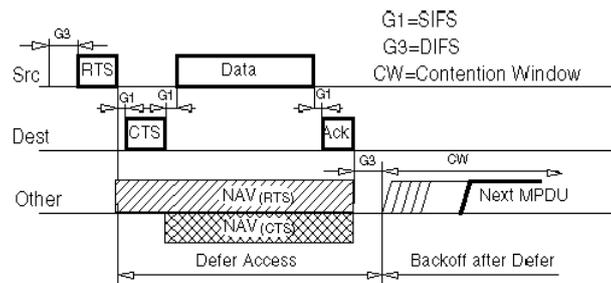

Figure 4. RTS / CTS packet

The 802.11 DCF interactive protocol is essentially a small RTS/CTS packet, but its radio resource allocation is large, which improves radio resource utilization. The sender should transmit data and the RTS control frame. The recipient should transmit CTS control frames and confirmation message ACK. The sender receives CTS after waiting SIFS time and then sends the data package. The receiver receives the data packet and sends ACK after waiting SIFS time. The sender receives ACK and waiting DIFS time.

However, the 802.11 DCF protocol is designed to support packet bursty traffic but not real-time services. The 802.11 DCF protocol also uses a random back-off time synchronization mechanism that does not apply to the network. The VANET has high requirements for real-time data for synchronous MAC protocol-based appointment. Therefore, the competitive 802.11 DCF-based approach is not suitable for applications in an automotive ad hoc network.

3.2.2. RR-ALOHA

Many broadcast features is required for in-vehicle communication, and thus reliability requirements are strict on the MAC layer. Few studies have been conducted on connectionless service reliability assurance. Reliable broadcast for VANET research are rarely found in the proposed methods: increased control frame on the radio [38, 39] and divided sections of forwarding packets. A new random access mode, reliable reservation ALOHA (RR-ALOHA) [35, 40], is presented to achieve the distributed access policy according to VANET characteristics. The RR-ALOHA protocol [41] improves the resolution for hidden and exposed terminal issues, and the provision of broadcast frame per frame period information. All neighbors are aware of each time slot's channel usage, and thus the RR-ALOHA protocol can run properly in VANET. Frame information (FI) is a transmission node status sensing slot of the previous frame. RR-ALOHA uses different physical layer standards that are especially suited to the physical layer slot structure. The basic idea of the protocol [40] is to assume a composition of N slots. When a node joins the first listener time frame, an idle slot is selected to send a packet to appoint this time slot. If the neighbor receives the packet correctly, the neighbor marks it in the FI. When all new FI nodes within a frame indicate through neighbor time that a packet is received correctly, this is considered a successful reservation. The slots of each fundamental channel frame is considered the base channel (BC) until the node leaves the network; other nodes cannot be accessed during this time slot. BC for FI transmission and other signaling information is the bearer payload. The node must send the BC FI information in each frame, and update the information in accordance with its FI neighbors and their own channel usage. When the bandwidth provided by the BC channel does not meet business requirements, other nodes occupy the idle channel through channel reservation to obtain additional ways to meet business requirements. If point-to-point (P2P) communication is used, the peer nodes can be booked. Channel utilization must be improved to achieve reuse of the hop group adjacent slot. Figure 5 shows an example of FI node exchange information.

Seven nodes (1 to 7) are presented in Figure 5. The elliptical region A, B, C represents the hop (OH) cluster. All the nodes in each cluster OH enjoy full connectivity within a cluster. The cluster nodes in different clusters that do not belong to the common subset cannot communicate directly. A, B, C of the set of child nodes of the cluster together, and all the nodes can communicate with other clusters. All of the OH groups are considered a two-hop (TH) cluster. FI-4 FI-5, and FI-3 are known to all nodes in the cluster in the time slot occupancy. In FI-3, if all nodes (2, 3, 4, 5, 6) within its cluster kN slots OH are available, then k time slots are available; if at least one of the OH cluster nodes (shown in green, yellow slot indicated) of the kN slot is busy, the node labeled 3 in slot k is reserved.
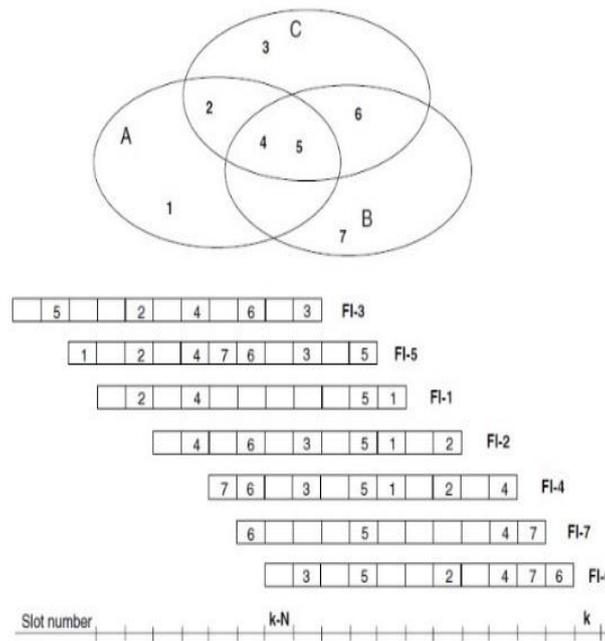
Figure 5. FI Schematic diagram

3.2.3. Comparison of CSMA/CA and RR-ALOHA

Two types of MAC protocols are generally used for common ad hoc networks: (1) CSMA/CA MAC protocol for asynchronous type of competition, and (2) reservation-based slot synchronous MAC protocol. The latter type is more suitable for the special nature of VANET. Table 3 presents the CSMA/CA and RR-ALOHA. Both MAC protocols are presented for simple comparison. The RR-ALOHA is more suitable for VANET. However, neighbor nodes within the communication range of not more than one in the slot number in the RR-ALOHA should be further analyzed [42]. Research institutions and universities conduct VANET research on MAC protocols, but more research is carried out in the military field. The PLA Information Engineering University proposed the BR-TDMA, a new type of MANET MAC protocol. This protocol uses distributed control and emergency services and supports real-time business grouping resource reservation. This protocol is not sensitive to network size, which is a good solution for hiding exposed terminal problems. A new CCR-ALOHA MAC protocol for MANET vehicle communication system is introduced. The distribution protocol takes a competitive combination and makes an appointment to control the appointment slots and slot operation phase separation. It provides a reliable single-hop broadcast channel and efficient multi-hop broadcast service. The small average packet delay has good scalability.

Table 3. Compare MAC layer protocol

	CSMA/CA	RR-ALOHA
Mobility	√	√
Time Synchronization		√
Real-time QoS	√	√√
Transmission reliability	√	√√
Network Capacity	√√	√

IEEE 802.11p (MAC layer):

The MAC layer of the communication system is based on IEEE P802.11p. This clause only fixes the Parameters to be used and, optionally, values that differ from this standard draft, when necessary for interoperability. The recommended value for a Slot Time is 13 μs (IEEE P802.11-2007). Optionally, a value of 16 μs. WAVE BSS mode is not used. Instead, only WAVE mode with the predefined BSSID "FF:FF:FF:FF:FF:FF" is used. The Frame format for IEEE 802.11p becomes data frames of subtype 0000 and 1000 (Data and QoS Data) are used. STAs must be able to process both subtypes. The maximum size uses to payload data is 1500 Bytes. The Figure 6 shows the MAC layer stack for 802.11p [43].
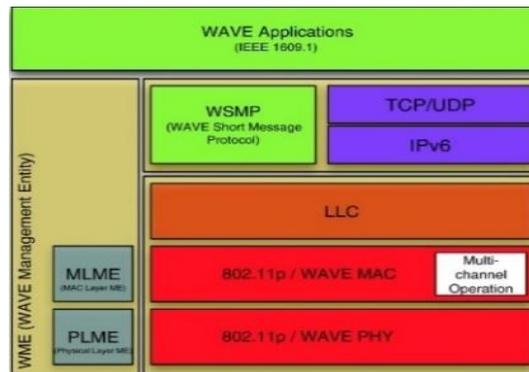

Figure 6. MAC layer stack for 802.11p

3.2.4. Token Ring

Based on the CSMA/CA MAC protocol and slot classes, we find other types of MAC protocols (i.e., token ring). Vehicles with GPS systems can use the delay based on the non-competitive access of the token ring (e.g., WTRP protocol [44]) to improve channel utilization, avoid channel conflicts, and meet the communication between vehicle safety warning requirements. A broadcast channel-to-channel through a token ring consists of logical access to facilitate presentation. The vehicle is positioned (corresponding to the local node communication network) to TS (this station) before a vehicle is positioned (corresponding to communication network nodes) to PS (previous station), and then the following vehicle is positioned (corresponding to subsequent nodes in the communication network) to NS (next station). The actual vehicle queue is considered. Set vehicle A, B, C to constitute a queue. The token passing sequence for a queue wireless token ring protocol consisting of three vehicles in the logical token ring is A-B-C-A. B is the time set by the token owner. B is TS, A is PS, and C is NS. The network structure schematic is shown in Figure 7. The arrow direction indicates the passing direction of the token. When the vehicle holds the token to begin data transmission, that vehicle cannot hold the token for the data received. When the transfer is complete, the data token owner follows the vehicle to pass on the token and start data transfer to the next vehicle.
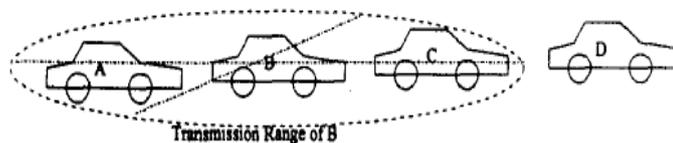
Figure 7. Inter-vehicle token ring

4.   ROUTING PROTOCOL

Routing technology has become one of the major challenges in VANET because of frequent changes in car network topology caused by fast node movement [45]. Earlier experiment platforms used simple flood routing techniques [46]. Current routing protocols used in automotive MANET are roughly divided into two categories: topology-based routing protocol and position-based routing or location-based protocols. These protocols are shown in Figure 8.

Figure 8. VANET routing protocol

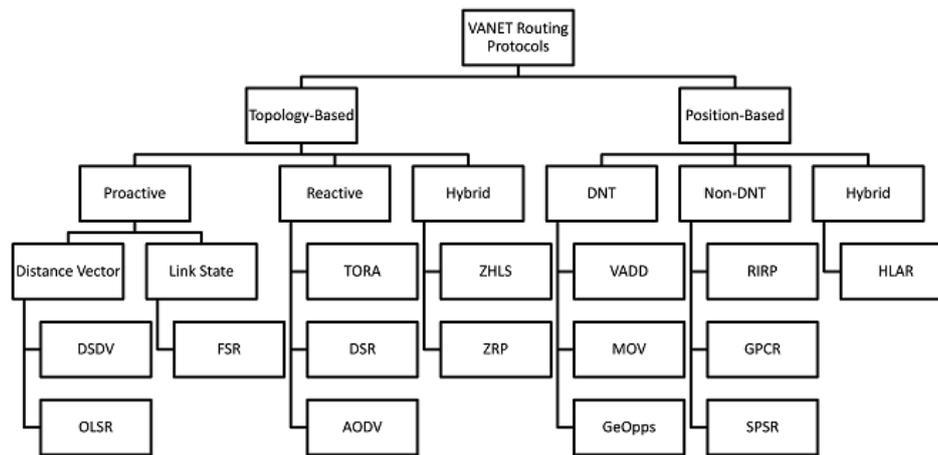MANET routing protocols (Reactive, Proactive, Hybrid, Multipath, Hierarchical, Multicast, and Power) are particularly classified. These classifications are shown in Table 4, including most of the MANET routing protocols.

Table 4. AD-HOC network protocols classification

Reactive	Proactive	Hybrid	Location	Multipath	Hierarchical	Multicast	Power
DSR	DSDV	ZRP	LAR	CHAMP	HSR	DCMP	DEAR
AODV	R-DSDV	FSR	DREAM	AOMDV	CEDAR	ADMR	Singh
TORA	OLSR	LANMAR	GPSR	SMR	H-LANMAR	AMRoute	Scott
ABR	HOLSR	RDMAR	DRM	NTBR	Eriksson	Li	Chang
SSBR	CGSR	SLURP	Colagross	Das		QMRPCAH	MEHDSR
AQOR	WRP	ZHLS	ALARM	TMRP		Wu&Jia	Liang&Liu
ARA	GSR	DST	REGR	Liu		Atzori	
ROAM	STAR	DDR	LAKER	SMORT		Fireworks	
FORP	Tam	A4LP	Blazevic	SecMR		PPMA	
SCaTR	QOLSR	HOPNET	MORA	REEF		Gui	
DAR		LRHR	OGRP			ALMA	
FDG		FZRP	Song			Sun&Li	
LLR		ANSI	SOLAR			AQM	
Beraldi		Bamis	LBLSP			CBM	
OD-PFS		Souihli	GLR			DDM	
QMRB			MER			ROMANT	
AODV-ABR			TBR			DGR	
LBAQ						GAMER	
LSR							
SWORP							
RPR							
GRP							
SLR							
LDR							
DBR2P							
RBR							

Topology-based routing protocol is based on maintaining a continuous path from the source node to the destination node using a proactive or reactive method type to establish the route. The main representatives of this protocol are AODV [47], DSR [48], and OLSR [49]. The fatal flaw of this protocol is that a big time delay cannot stand to establish control overhead. For example, the average interval of search/maintain information Hello neighbor nodes is 1 s, but the reaction time in cross-field pass safety requirements is 100 ms. Location-based routing protocol does not require routing tables or storage paths. Each node only needs to learn the location information of its neighbor and destination nodes to determine its own next node. This protocol type adapts to network size and topology changes, and is thus mainly used in

automotive network [50-51]. The main representatives of this protocol are geographical source routing (GSR) [52] and greedy perimeter state-less routing (GPSR) [53]. Map-based routing protocol does not suggest the current location to a specific protocol, but from the perspective of the characteristics of VANET, the routing protocols used during in-vehicle communication can take advantage of vehicle characteristics (e.g., GPS system and electronic maps), which are nodes that help learn their positions. Neighbors and road stage topology information, and good use of the navigation system with features (i.e., path planning future vehicle development direction of MANET protocol position) should be based on the combination of electronic map routing protocols. The node set, roads, and turn restrictions set several finite set of sets to describe and predict the global topology of the entire network, which establishes a route for providing strong support and fast and accurate calculations from the original best path to the destination node [54].

The basic idea of the VANET routing strategy is the application of location-based routing protocols. Network topology information does not need to be global; the location information one-hop range of the node and destination node are enough. The target node location registration and query-related services are required. Current VANET routing strategies employed are GSR protocols that limit geocast flood zones combined with neighboring greedy forwarding GPSR, and improved spatial perception GPSR SAR and other routing protocols. These routing protocols obtain good results in most road environments.

GSR [52] is proposed for application in urban areas. After obtaining the destination node location information via location-based services, additional information is needed to calculate the use of an electronic map for the best route from the node to the destination node. The route calculation algorithm and Dijkstra shortest path algorithm are chosen [55]. Information passed between nodes also use greedy forwarding. When intermediate nodes in the packet arrive, using the Dijkstra shortest path algorithm can recalculate the best route to increase the flexibility of routing policy and improve performance. The node transmission range is 500 m or more [56]. The advantages compared to traditional VANET protocols DSR and AODV are better packet delivery ratio and lower bandwidth utilization. The disadvantages are not considered in the intersection, that is, whether the two can keep enough vehicle connectivity [57].

[58, 59] proposed the geocast protocol to be used in MANET. The protocol is a special multicast protocol that transfers data to a set of nodes within a specific geographic area [60]. Every region of the node obtains information through flooding. The geocast focuses on the definition of restricted floodplains (forwarding zone) and limited flooding overhead. Representative algorithms include the LBM algorithm, Voronoi diagram algorithm, GeoGRID algorithm, and OFGP algorithm. These algorithms may transfer data rate, but flooding causes broadcast storms that result in serious redundancy, contention, and conflict. Therefore, a new route is created through data transfer to the geocast area to increase transmission rate and reduce transmission overhead. Geocast routing protocol uses the destination area to store and re-dispatch the interest rate strategy at node sparse. This process involves a large multi-hop fashion network environment, where a relatively high rate and low packet forwarding information overhead can still be obtained.

The paper [53] proposed GPSR, which is a famous location to optimize the use of routing protocols. GPSR does not search for routing nodes before sending the data and does not save the routing table. Position information (including location information of neighbor and destination nodes) is taken directly from the mobile node system that gives data forwarding decisions. Data packets are usually carried to the destination node location information. Adjacent nodes in the network obtain the location information of other nodes by periodically broadcasting packets. The source node or intermediate node is based on the location information (data packet for one or more terms of relative distance to the destination node near neighbors). GPSR performs well on the highway, but performs poorly in an urban environment.

Ref. [61] proposed the space-aware routing protocol spatial aware routing (SAR) to further improve routing holes for barriers. SAR can be the basis of further improvements in the GPSR routing protocol. It creates a model diagram of a network of node spaces. The model figure points represent important vehicle network connection points (e.g., vehicles and roadside facilities). The point extracts the figure based on useful GIS information. Finally, a geographic data file is prepared to extract relevant information from the road space model diagram. Mapped locations of the source and destination nodes in the space model are generated. Graph theory algorithms are used to calculate the shortest path from source to destination node path. However, SAR has a drawback. Spatial modeling needs to be accurate to determine an appropriate forwarding node on the path. Thus, [61] proposed recovery strategy solutions. To improve the routing efficiency of a VANET, two issues need to be investigated: routing table size and path selection from source to destination. Given that routing performance depends on routing table size, which is determined by the number of nodes, a detailed table representation is required [62]. Table 5 shows the VANET routing technology used in a horizontal comparison. Several universities and research institutions conduct workshops on communication route studies. These institutions point out that current vehicle MANET forwarding protocols are mostly decided by forwarding node decisions based on new neighbor forwarding node competition policies made. How these nodes are used for inter-vehicle communication also needs to be

studied. In big city vehicle communication environment for MANET communication technology, the analysis and study summed up the regularity of vehicle movement combined with the law. The routing algorithm is improved based on DSR routing protocol on the use of a hierarchical structure. The vehicle of special groups (e.g., taxis and buses) as a cluster head node is responsible for a particular area. Improved ad hoc network routing protocols and network structure applicable to the agreement effectively reduces network cluster head election. Re-clustering of communication overhead is caused by the re-election of broadcast routing and routing exchange.

Table 5. Comparison of VANET routing protocols

Protocols	Message domain	Node localization	Periodically broadcast	QoS	Scalability	Robusting
AODV	1 hop		√			
DSR	1 hop		√			
OLSR	Multi-hop	√	√	√		√
Geocast	1 hop					
GSR	Multi-hop	√			√	
GPSR	Multi-hop	√	√	√	√	√
SAR	Multi-hop	√		√	√	√

5.   CONCLUSION

Along with the improvement of personal communication requirements, people increasingly want secure and efficient ways to reach their destinations. Future developments focus on VANETs. The design of MAC and routing layers is the most significant challenge to VANETs. MAC layer issues need to be resolved, and radio channel division, distribution, and control ability must provide a unified service for the network layer. A physical layer shielding different channel control methods is used to achieve congestion control, priority queuing, packet transmission, validation, error control, and flow control. The focus is on building a fully distributed routing layer suitable for the routing protocols of high-speed vehicle network topology change. Basically, the main goal of VANET is to develop a communication standard protocol that achieves freedom of communication between different vehicles.

We studied the network structure features of VANET and the difficulties experienced because of fast node movement. A fast routing protocol affects the dynamic network topology. We also examined how research on the cooperative driver system of Japan developed through time since the 1980s. In addition, we explained the physical layer of the UTRA-TDD and 802.11 (Wi-Fi). Wi-Fi is widely used because it is cheap and simple, whereas UTRA-TDD provides better performance than Wi-Fi especially through VANET application. Finally, we presented different MAC layer approaches and compared CSMA/CA and RR-ALOHA MAC layers. RR-ALOHA was found to be better than the CSMA/CA in VANET applications. We presented different routing protocol categories of the advantages and disadvantages, as well as studied several VANET protocols based on physical, MAC, and network layers. We suggested a full redesign of VANET layer requirements in generating VANET routing protocols. This redesigned VANET can then be applied in the real world for inter-vehicle communication.

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