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AN EFFICIENT APPROACH OF EXTERNAL COMMUNICATION SYSTEM IN AUTONOMOUS VEHICLES BASED ON CDMA

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ABSTRACT

There are large amounts of cars passing through the streets every day and this increases significantly in the morning or evening rush hours. The automotive industry has evolved greatly and many technologies have been introduced to automate many of its functions. The emergence of driverless vehicles has led to a boom in the world of automotive technology, because of its importance in creating a new environment and new concepts aimed at human conformability and increased productivity. Many solutions have been appeared to offer suitable self-driving vehicles environment that is capable to overcome the arising problems. When the self-driving vehicles are well equipped, the only remaining goal is how to control external communications with other vehicles, with updates that can appear in the road and with main center. This paper proposed code division multiple access as a communication technology to overcome the problems may appeared in time division multiple access. The synergy efforts in both industry and research centers giving powerful push to the intelligent transporting system. The proposed system of robot cars is implemented through high way environment scenario. The communication system is implemented via code division multiple access (CDMA) to realize high security, high quality of services, robustness and high capacity.

Keywords: *V2V, Vehicular Networks, Self-Driving Vehicles, Multiple Access.*

1. INTRODUCTION

The automotive industry has undergone a number of stages before reaching the form we know today [1,2]. The following is a review of the development stages of the automotive industry over time [3,4]. The steam engine was invented by the French inventor Nicolas Joseph Cuneo in 1769 [5,6]. Electric cars began to appear after the invention of Hungarian Anios Gedlik model of a small car powered by electricity in 1828 [7,8]. The actual application of cars powered by fuel engines began by Karl Benz in 1885 and was of a high standard compared to the cars that existed at the time [9,10]. The automobile industry flourished after the invention of fuel-powered engines, and manufacturers began buying engines from Benz and Daimler to build modern cars [11,12]. The automakers began to flourish, and the first company was established in 1890 in France [13,14]. The modern cars that we use today have developed very significantly because of the great industrial development that has entered the car industry [15,16]. The technology and the smart systems have also entered the industry [17,18]. Modern cars have touch screens, voice commands, with a number of functions through the mobile phone, in addition to the modern cars to replace the key with the start button, and became the automotive systems rely on the electrical system helps in its work, and not rely entirely on fuel, and thus help to provide the fuel consumption will be significantly reduced [19,20].

Roads have always been owned and operated by governments, vehicles have been largely owned and maintained by individuals, and the use of road

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space has not generally been based on a user payment model [21]. The future could challenge this model, since the vehicles can belong to a small number of important operators who charge their travel costs to their customers, thus taking advantage of a previously unassigned revenue stream [22].

The World's Road Safety Report 2015, which reflects information from 180 countries, indicated that the total number of deaths in road accidents has reached 1.25 million per year, and that the road mortality rates are the highest in low income developing countries [23]. Most of the accidents that lead to death are due to safety belts, drunk driving, high speed, motorcycle helmets and safety systems for children, this means that the main cause of accidents is human [24]. Therefore, resorting to the adoption of many technical methods to control these causes and reduce them as possible [25].

The cars have evolved and improved very rapidly and become a large part of their functions working automatically [26]. All these aimed to protect people inside and outside the car [27]. The ideas of the driver-less car appeared due to more than ten years ago and that the project Google 2009 was the first launch of those ideas [28]. Driverless cars try to change drivers by driving automation to decrease the number of accidents on the streets due to human error [29]. Autonomous vehicles use ad hoc networks, in vehicular ad hoc networks (VANET) [30]. These networks allow a more flexible and smart communication between vehicles in the radio coverage area [31].

The proposed system is a flexible communication system that is able to communicate between moving license vehicles and to main center considering any obstacle may appear in the environment. Communication system design based on CDMA technique to be more flexible and more secure comparing with TDMA. Basic structure of communication infrastructure in driverless cars is shown in figure 1.

The proposed external communication infrastructure of driverless cars aims to offer an efficient communications environment to work within the expected future Internet of Thinks (IoT).

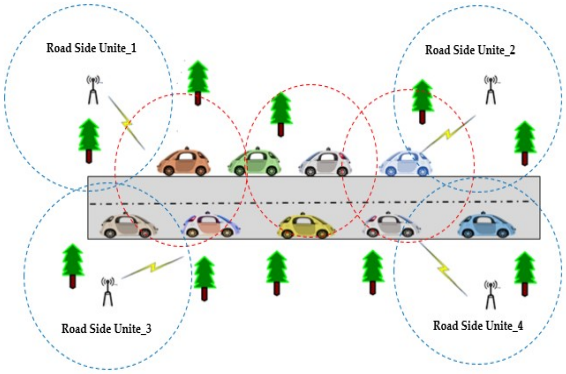

Figure 1 Shows Basic External Communication Infrastructure Of Driverless Cars.

We can easily notice that figure 1 contains from four road side unites (RSUs), driverless cars and semi-driverless cars. These RSUs play significant role in providing sufficient radio signal which help in exchange control data, information, cooperative awareness messages and notification messages.

The research is presented as follows: Section II provides at related works. Section III details about multiple access techniques that are utilised in exiting communication system. Section IV describes self-driving vehicle applications and its positive role on our society and section V explain methodology research. Section VII discusses outcomes of the proposed communication system whereas VIII concluded and a summary of future directions.

2. LITERATURE REVIEW

Autonomous vehicles are heavily based on their communication systems which are internal/ external system to sense surrounding environment to moving from point to others. In this case, researchers are considered communication system plays a vital role in developing and spreading self-driving vehicles. However, some projectors seek to improve current external communication system of self-driving cars. Moreover, performance of autonomous vehicles is enhanced by improving their external communication system as well as employing some new techniques such as, artificial intelligent. Some recent related works are explained in this paragraph.

Bassem Mokhtar et al. (2015) explained the diverse concerns of the VANET network and the protection constraints to obtain the obtainability of universal connectivity, protect infrastructures and

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reputation organization schemes that affect trust in cooperation and negotiation between mobile network units. Then they analyse VANET protection aspects, challenges and attacks, and categorise VANET security intruders due to various layers of network [42].

Ribal F. Atallah et al. (2015) concentrated on the latest developments in each of the research areas mentioned above and highlights the open questions that remain unresolved in each one of them. Then the researchers were also involved in the design of programming policies to increase the efficiency of spectrum access and optimize the performance of vehicle networks based on several conventional metrics [43].

Raffaele Bruno et al. (2015) interested in the utilise of cars as components of a multimedia sensor structure capable of capturing snapshots of the camera on the roads to support traffic observing and urban surveillance tasks. They used sub-modular optimization methods to build robust and efficient information gathering systems for vehicle multimedia sensor networks. They explored an unconventional method to information collection that works on longer period measures and depend on solely on localized decisions instead of centralized calculations [44].

Hao Yang et al. (2016) analyzed analytically the immediate message capabilities of ad-hoc vehicular networks (VANET), that ration the upper limits of the communication broadcast rates of the vehicle. Subject to the interference between wireless broadcasts, the diffusion ability is defined by the extreme figure of successful receivers, and the capacity of unicast by the extreme figure of successful senders. With the procedure communication model and the constant traffic models, they establish closed formulas for capacities based on the broadcast sort, the interference ratio, the vehicle mass and the station size [45].

Jinho Lee et al. (2016) proposed a model of the expected link delay in a bidirectional route segment for reported data transmission schemes in vehicle networks. It is presented that the bidirectional link delay model is more accurate than the inherited bidirectional link delay model. Then, when employing this model to unicast control data, this model shown sufficiently precise to support the efficient unicast of information in VANETs [46].

Daxin Tian et al. (2016) proposed a model to analyze the collisions of the cars convey. It taken into account the effects of the dissimilar penetration amounts, the stochastic nature of the inter-vehicular distance spreading and the various kinematic parameters related to the driver and the car. The ease of use and correctness of this system are verified through comparative experimentations with Monte Carlo simulations [47].

Susana Sousa (2017) presented a VANET agnostic architecture that allows the use of multiple communication technologies in an open and modular framework, which is an adaptation of the current standards approach, to be implemented in intelligent transport systems as a way to overcome its main limitations [48].

Tesnim Mekki et al. (2017) studied the model of the vehicular cloud in which focused on its characteristics and architectures. They present a description of the motivation of the vehicular cloud. Then they explored the challenges of the design. In addition, they highlighted the characteristics of cloud architectures of existing vehicles. They provided a taxonomy of vehicle clouds followed by classification criteria [49].

Gongjun Yan et al. (2017) analyzed the wireless connectivity between vehicles using mathematical models. They considered the consequence of distance, association time, acceleration, the comparative speed of cars, the range and size of messages / data in short-range car to car transportations. The numerical results in the simulations authenticate the analysis [50].

Khattab M. Ali Alheeti et al. (2018) proposed an intrusion identifying scheme to secure the communications system of autonomous vehicles. The security system is depended on clusters, using time division multiple access to expose some of the VANET barriers, such as high density, high mobility and bandwidth limitations in the exchange of messages. This changes the protection scheme to become more effective, precise and able to detect in real time and quickly identify the malicious behavior in the VANET [51].

Lucas Rivoirard et al. (2018) proposed a scheme of clustering that combines information about the configuration of the road, the mobility of the vehicle and the quality of the link, these three factors are used to design a structure similar to a VANETs, whereas it only depends on the vehicles. This method can be joined into any sensitive, active or geographical routing protocol to enhance flow of communications and abridge routing protocols [52].

Rajen Akalu (2018) explained the relationship between privacy, consent and personal information in relation to the car communications. Then

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described ad hoc vehicle networks and the technical proposals to secure data. Then provided guidance on how a code of practice can help determine when individual consent will need to be improved and when alternatives to consent should be implemented [53].

Communication systems play an important issue in developing and implementing self-driving vehicles. Most of the related works are concentrated on improving internal and external communication systems of self-driving vehicles.

In our paper, a novel external communication system is proposed of autonomous vehicles that utilizes CDMA scheme to improve its communication performance. The significant contribution in this paper is enabled autonomous vehicles to exchange essential information and control data between vehicles and RSU in that radio converge area. Moreover, it enables vehicles can communicate event in waste communication case, such as: low bandwidth, accident and jamming.

3. SELF-DRIVING VEHICLES

Many car industries and companies expected that driverless vehicles will be ready on the road by 2020. Self-driving Vehicles will generate powerful benefits as shown in figure 2: [32,33,34,35,36].

1) Reduce accidents

If committed to apply self-driving vehicle laws, so accidents have been reduced to the lowest possible. About 1.2 million people die every year from traffic accidents and about 94% of those accidents, are caused by human error.

2) Increase driving

make driving possible again for people who could not drive such as disabled people or elderly people.

3) Increase productivity

self-driving vehicle increase in human productivity that results from leave thinking about driving.

4) Congestion avoidance

Congestion is a big problem experienced by many of the streets and the self-driving vehicle is equipped with techniques that enable them to choose the best ways to help ease congestion.

5) Fuel saving

Electric self-driving vehicle is considered very economical because it needs only continuous charging which does not cost.

6) Reduce pollution

Since the electric self-driving vehicle relies on electric power, it does not cause any pollution compared to other cars.

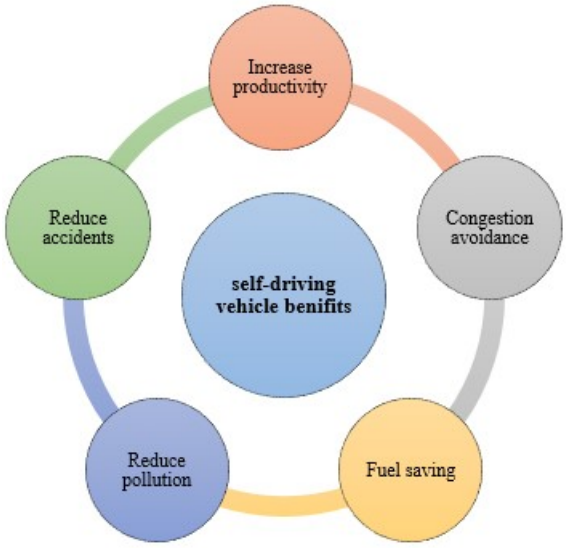

Figure 2 Powerful Benefits Of Self-Driving Vehicle.

The communication system of self-driving vehicles has characteristics that reason its characteristic performance obstacles: rapidity of the vehicle, fast change topology, lack of a fixed protection system, undefended medium communication and density of vehicles. All these obstacles made autonomous vehicles expose big challenges before explicitly on roads. However, we proposed new communication system which help driverless vehicles to overcome these obstacles. In more details, communication system of cars is heavily depended on efficient scheme that is code division multiple access (CDMA), more details in next section [37,38].

As we know, self-driving vehicles are modern fully automated vehicles that involve directly with carrying people, so it is very important to be safe with these vehicles. Thousands of people die every day because of traffic accident and most of these accidents are caused by humans. Recently, many expectations realise that self-driving vehicles will be ready on the road by 2020. Therefore, many motivations in this paper encourage us to find a new technique to improve communication system and overcome some transmission problems which throttle of autonomous vehicles.

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4. MULTIPLE ACCESS TECHNIQUES

Multiplexing is the procedure of joining numerous signals and transferring that in a public station. Then multiple access is the technique that utilised to permit multiple operators to interconnect over a single public network. There are many types multiple access techniques, that here will be reviewed some of these techniques such as frequency division multiple access (FDMA), time division multiple access (TDMA) and code division multiple access (CDMA) [37,38].

FDMA delivers amounts of frequency range to be used for information broadcast. The information is produced at base band and modulated at fluctuating radio regularities. Guard band is presented to escape intrusion. FDMA is used in first group analog communication schemes. FDMA is used to deliver each user with a duplex station [39].

TDMA permits multiple user to share a public frequency group by assigning diverse period times. Signals coming from each user will be transmitted at intervals depends on multiplying number channels into time slot. TDMA technology was used in second generation communication systems. Each operator is supported by eight TDMA in a 200 KHz bandwidth. Dynamic supply distribution predestined more operators could be sustenance 8 active operators at a period [40].

CDMA is a method in that information are modulated by great frequency orthogonal bits arrangement. These codes are used to propagation the signals above a huge band. The destination must have the similar dispersal bits sequence, that is increased by the merged signal in a manner named dispreading. In this case, CDMA is made very safe and forceful. The spreading code is designed to scramble the data signal. The spreading code changing much faster than data signal that meant much higher frequency that data signal.

CDMA was used in third generation communication systems [41]. CDMA is selected in design external communication system of autonomous vehicles for many reasons, such as:

- Speed: efficient consumption for bandwidth;
- Flexible: no need coordination and synchronization for establishing communication;
- Security: it considered an optimal solution for security problem i.e. protection against interference and tapping [41].

5. STATEMENT OF THE PROBLEM

The communication between autonomous vehicles becomes a big problem in the near future because of huge amount of driverless vehicles crossing roads in the modern cities. This research proposed an approach of external communications systems in autonomous vehicles based on CDMA.

6. METHODOLOGY

External/internal communication systems are considered a backbone for any autonomous system without it cannot do anything. Moreover, all fundamental operations of autonomous vehicles are based on communication systems. Research methodology of novel communication system is explained in this subsection.

A. Code Division Multiple Access

Different radio communication methods are employed at CDMA. However, it enter within many access where some spreaders can broadcast data simultaneously over sole channel. This allowed several users to share band of frequencies to compete interference between users. CDMA implies spread spectrum technology and special coding scheme, where each transmitter is assigned to a unique code.

To explain the security of CDMA let us consider the transmitted data is distributed on the spreading code of eight bits in both slot_0 and slot_1, so it will be 16 bits as shown in Table 1. These two values are XORed to generate the output of the transmitter. Bit zero is represented by +1 and bit one is represented by -1. At the transmitter side of user1, the data bits to be transmitted is XORed with the spread code of slot_0 and slot_1 as shown in figure 3. At the receiver side, the received bits will be XORed with the same spread code to generate the received data that is exactly the same of the transmitted data as shown in Figure 4.

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Table 1 CDMA Of Spreading Code For Bits.

	Slot_0 (transmitted)								Slot_1 (transmitted)							
Data bits	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
Data val.	+1	+1	+1	+1	+1	+1	+1	+1	-1	-1	-1	-1	-1	-1	-1	-1
Spread code	0	0	1	1	0	1	0	1	0	0	1	1	0	1	0	1
Code val.	+1	+1	-1	-1	+1	-1	+1	-1	+1	+1	-1	-1	+1	-1	+1	-1
X-OR bits	0	0	1	1	0	1	0	1	1	1	0	0	1	0	1	0
X-OR val.	+1	+1	-1	-1	+1	-1	+1	-1	-1	-1	+1	+1	-1	+1	-1	+1
	Slot_0 (received)								Slot_1 (received)							
Received bits	0	0	1	1	0	1	0	1	1	1	0	0	1	0	1	0
Received value	+1	+1	-1	-1	+1	-1	+1	-1	-1	-1	+1	+1	-1	+1	-1	+1
Spread code	0	0	1	1	0	1	0	1	0	0	1	1	0	1	0	1
Code val.	+1	+1	-1	-1	+1	-1	+1	-1	+1	+1	-1	-1	+1	-1	+1	-1
X-OR bits	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
X-OR val.	+1	+1	+1	+1	+1	+1	+1	+1	-1	-1	-1	-1	-1	-1	-1	-1

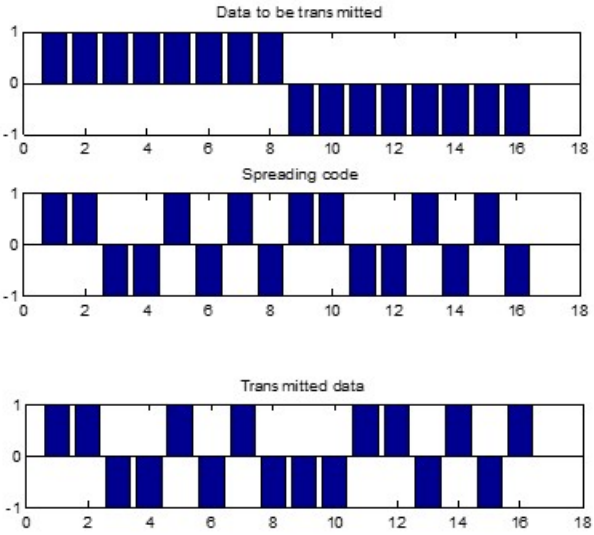

Figure 3 Transmitter Side.

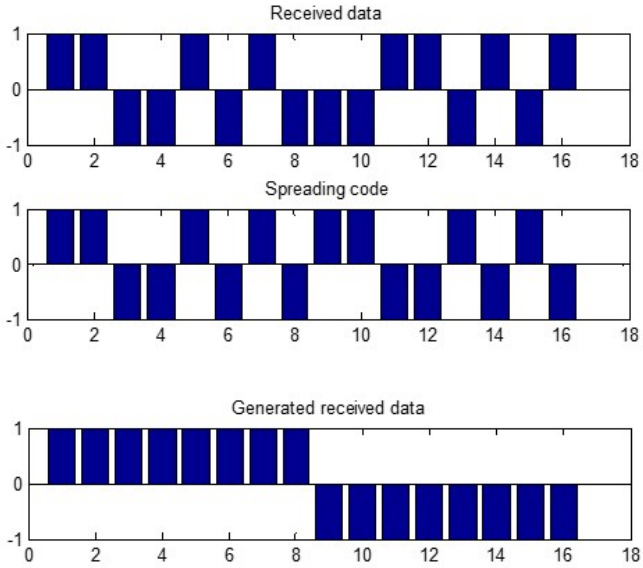

Figure 4 Receiver Side.

B. Transmitter / Receiver Structure

Considering 8 bits of spreading code, this leads to 256 separated users (vehicles) with unique code. All active users sending their spreading data into the channel. These data will be summed to form the composite signal that transmitted to all users through the channel as shown in figure 5. The sending data of the first channel (four bits) is spreaded into 32 bits according to the spreading code of 8 bits. The same thing is occurred for the other channels with their unique spreading code. All these spreading signals are summing to form the composite signal to be transmitted in the channel

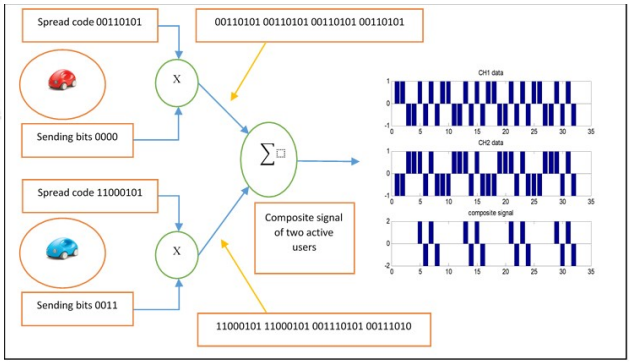

Figure 5 Cdma Transmitter.

On the other hand, the receiver structure is implemented to extract the original data signal of

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each channel as shown in figure 6. The composite signal is received by the receiver, then this signal is spreading by the unique spread code of the indicated channel. After that the channel bits are extracted, then these values are compared. When the value is greater than zero, so it is represented by positive bit and when the value is less than zero, so it is represented by negative bit.

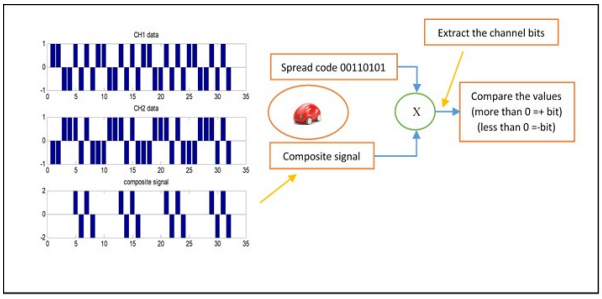

Figure 6 Cdma Receiver.

7. RESULTS AND DISCUSSIONS

In this subsection, CDMA and regular communication systems are tested of driverless and semi-driverless cars to test the suggested communication system performance. It was tested under various communication condition to confirm effective communication. One of the self-driving vehicles is programmed with the new CDMA communication system. The communication performance metrics are calculated of vehicles in two cases under same communication condition. Table 2 demonstrates the performance metrics which have been measured for same vehicle under CDMA communication system with and without the proposed communication scheme.

Table 2 Some Of Performance Metrics.

Performance Metrics	Vehicles without CDMA Communication System	Vehicles with CDMA Communication System
Transmission Packets	28800	28800
Received Packets	20128	26276
Packet Delivery Ratio	69.87%	91.22%
Totally Dropped Packets	9963	3508
Average End-to-End Delay	79.26*ms*	38.30*ms*

According to Table 2, the important part of the suggested communication scheme can be easily noticed distinguishing in two cases of autonomous vehicles. Calculated measured under malicious behaviour. The vital part of the suggested response method can be easily distinguishing in two circumstances of autonomous vehicles.

Conventional communication system need to be modified to adapt with new technology, such as self-driving vehicles. In other words, current security systems need to update to become more efficient with exiting communication systems. In addition, the proposed system plays important role in growing rate of packet that transmit between sender/ received as well as defensive these kids of VANETs.

The proposed CDMA communication system can enhance transmission rate of autonomous and semi-autonomous vehicles by increase packet delivery rate in its external communication communications. It is mainly for dropping any request that target broadcasting packets. Figure 7 shows the role of the CDMA communication in providing slot time for sent/ received packet between cars in that zone.

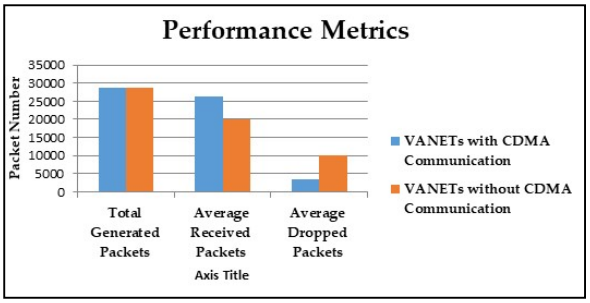

Figure 7 Performance Metrics For CDMA Communication System.

The figure 7 reflects a vital role of the CDMA system in improving the communication system of VANETs. It was evaluated under two various condition. The total number of generated packets is 28800 in two scenarios; the average number of received packets is 28800p in two situations; 26276p is number of packets that received at VANETs with CDMA system and average drop 3508p. However, 20128p is the number of packets that received at nodes and average drop packets is 9963p in VANETs with regular communication system. At this point, the researchers can identify a vital part of the suggested communication scheme in external communication of driverless cars.

This communication system is compared with a recent research paper [51] and conclude that the approach provides optimum communication performance for packets that received, packets delivery proportion, totally fell down packets and average time delay. The proposed scheme has a 91.22% packet delivery ratio, while the rival system does not provide an exact measure of the delivery

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rate [51].

The employing new CDMA communication systems improve the delivery rate and reducing the amount of drop packets. Thus, CDMA system has direct and optimistic influence on the consequence by growing the delivery ration, and reducing the dropping packets, error rate and end-to-end delay ratio. The proposed communication system can be extended to design other communication system which can utilised artificial intelligent to select slot time intelligently.

8. CONCLUSION AND FUTURE WORK

The self-driving vehicles has leading to several advantages in the world of automotive technology, and creating a new environment and new concepts aimed at human road security, because of most of the road accidents are caused by human. The most important part of self-driving vehicles is how to introduce an efficient system to control all the required activities in this environment. Each vehicle has its unique identified code to be recognize from other vehicle and from the center. CDMA is introduced in this approach to generate a spreading code that is unique for each transmitter (vehicle). The spreading also code is used to extract the received data of the identify user. CDMA characterized the same frequency for high bandwidth, in addition of high security.
The recommendation of future work in self-driving vehicles environment is to adapt the overall system via the huge environment of Internet of Thing (IoT).

The most external communications systems in autonomous vehicles including this approach have main limitation due to large differences between existing systems.

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