Traffic Deadlock Resolution System using Internet of Vehicles

Arpit Roy, Ruchika Bathla, Sonia Saini

***Abstract:** The number of vehicles on the road are increasing rapidly day by day, which leads to massive road congestions and traffic deadlocks. This paper proposes a model for an algorithm-based technique for efficient resolution of road traffic deadlocks, which would work on the technologies related to the Internet of Vehicles (IoV), while keeping the safe and efficient movement of vehicles along with the maintenance of constant communication with nearby vehicles and roadside infrastructure using Vehicular Ad-hoc Networks (VANETs). This would ultimately aid towards the optimization of road traffic, which is very much a need of the hour considering the ever-increasing amount of traffic on the roads today. We make use of two important phases, namely, Deadlock Detection Phase and Deadlock Resolution Phase in order to resolve traffic deadlocks. An equally important focus has been put towards a deep understanding of the motivation behind the efforts put in this paper by examining the present scenario of road traffic conditions and their resulting complications, and how the proposed model could potentially help resolve such complications. It also involves a brief discussion on VANETs, which provides an efficient means of connecting the vehicles together in a network for seamless communications.*

***Index Terms:** Deadlock Detection Algorithm, Deadlock Resolution Algorithm, Gridlocks, Internet of Vehicles, Road Traffic, Vehicular Ad-hoc Network.*

I. INTRODUCTION

Right from the invention of wheels by our ancestors, we have come to witness an exponential rise in the number of vehicles on the road. Also, owning of multiple vehicles has become a status of symbol for many. According to the statistics shown in Fig. 1, the number of vehicles sold worldwide have doubled in the past two decades and are increasing every year [1]. Owing to this rise in density of vehicles on the road, it has created a challenging task for road traffic management.

The fundamental problem of traffic is caused due to the imperfect coordination of human beings, which include brief attention spans and sluggish reaction times, leading to delays in acceleration and deceleration of a vehicle [2]. This causes huge delays for the trailing traffic, as the delay created by one vehicle is propagated along the entire queue of vehicles, and the delay may linger indefinitely, until it eventually diminishes. If a series of vehicles were to accelerate and decelerate together, maintaining a bare minimum gap to account for sudden braking, the vehicles could significantly minimize delay, hence optimizing flow of traffic. But, traveling without enough spacing between the trailing and the following vehicle could be tremendously hazardous due to varying degrees of reaction time in human beings. One of the key blunders that the drivers often commit in traffic is following the next vehicle with a very minute distance from it. A greater distance among vehicles provides additional time to react as soon as the following vehicle engages its brakes suddenly. This allows the driver to evade any possible collisions [3].

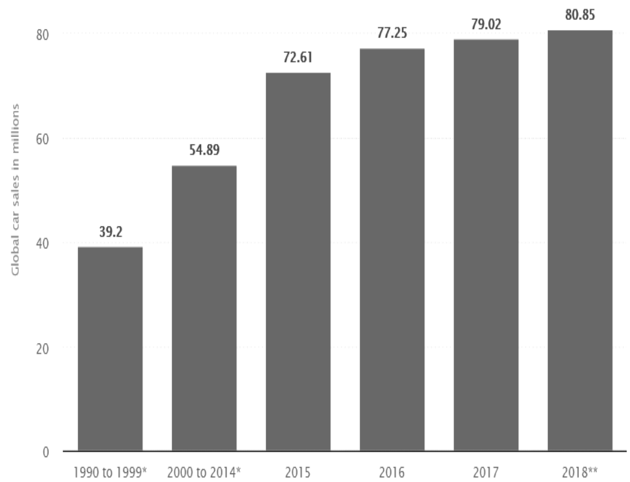

Fig. 1: No. of cars sold worldwide from 1990 to 2018 (in million units) [1]

Another major concern for road traffic management is the traffic congestions on roads, especially at the intersections, which lead to gridlocks. Most of us are very much aware of the China National Highway-110 road traffic gridlock that was a frequent colossal traffic congestion which started to form on August 13, 2010 [4]. The gridlock slowed down thousands of vehicles for more than 100 kilometers (roughly 62 miles) and persisted for about two weeks [5].

Therefore, we can realize that, in spite of the normal flow of road traffic and due to the impatient nature of human beings, it often leads to road congestions and gridlocks or traffic deadlocks, which are very frustrating for every driver on the road as it is very difficult to resolve this situation manually without proper coordination.

In this paper, we attempt to present certain algorithmic techniques and parameters related to the Traffic Deadlock Resolution System (TDRS) that could help in optimizing the road traffic, which could be made possible by implementing the components of the Internet of Vehicles (IoV) to a majority of the vehicles on the road today.

Revised Manuscript Received on July 10, 2019.

Arpit Roy, Amity Institute of Information Technology, Amity University, Noida, India.
Ruchika Bathla, Amity Institute of Information Technology, Amity University, Noida, India.
Sonia Saini, Amity Institute of Information Technology, Amity University, Noida, India.

II. ANALYZING COMMON TRAFFIC PROBLEMS

Some of the most common problems involving traffic are Traffic Congestions, including Gridlocks, which severely impact the efficiency in the flow of traffic. Traffic Congestions or Gridlocks occur when there isn't any space for any of the vehicles to move forward because each of the vehicles are blocking each other, as illustrated in Fig. 2. We can easily notice that the vehicles are in a state of complete deadlock, and none of the vehicles are able to move forward.

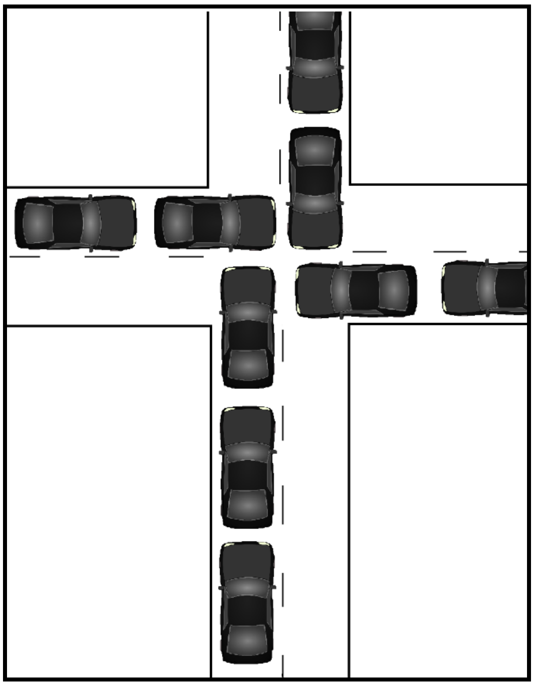

Fig. 2: A typical traffic deadlock

The most reasonable and logical way to resolve this deadlock would be for each of the vehicles to move back a certain amount of distance and allow each one of them to pass through the newly created space in a systematic manner. This should be followed by a properly controlled flow of traffic which would ensure the avoidance of any future states of deadlocks. In theory, the manual resolution of these kinds of deadlocks wouldn't be an issue, but higher the complexity of the deadlock, the harder it is for the vehicles to come out of that deadlock. This is because, ultimately, the vehicles are controlled solely by human drivers, who are inept at coordinating efficiently with other nearby and far off human drivers, to quickly analyze the complexity of the gridlock situation and resolve it using efficient methodical resolution approaches (especially in the case where there is a huge build-up of traffic around the deadlock).

This brings us to the entry of computing technologies, which have a significant amount of computing resources to quickly analyze, resolve and optimize traffic congestions including various states of deadlocks. This gives us plenty of motivation to integrate various technologies within the vehicles to give rise to the Internet of Vehicles (IoV), and eventually solve real world problems.

III. TECHNOLOGY REVIEW

One of the most significant technology involved in the Internet of Vehicles is the Vehicular Ad-hoc NETwork (VANET). VANET is basically a subclass of MANET (Mobile Ad-hoc NETwork) that enables exchange of data among automobiles and roadside infrastructure with the help of Wireless LAN Technologies (WLAN) with an intention of providing effective and safe means of transportation. The vehicles that are a part of the VANET are intelligent mobile nodes that are capable of exchanging data with its neighbors and other vehicles in the network. VANETs are considered to be more challenging than MANETs due to the high mobility of nodes and frequent topological changes [6].

To be able to efficiently exchange traffic information, VANETs make use of certain routing protocols, one of which is the AODV Protocol (Ad-hoc On-Demand Vector Routing Protocol) presented in [7], [8] and [9]. The challenge however is to figure out an efficient way to significantly diminish the delays associated with the exchange of information from the different vehicular nodes on the network [10].

There are basically three broad categories of communication types in a VANET [11], which are better illustrated in Fig. 3:

A. V2V (Vehicle-to-Vehicle) Communication

This enables the communication between different vehicles directly, within a certain range, without the need of any roadside infrastructure.

B. V2I (Vehicle-to-Infrastructure) Communication

This enables the communication between different vehicles to the roadside infrastructure, within a certain range.

C. I2I (Infrastructure-to-Infrastructure) Communication

This enables the communication between various roadside infrastructures, within a certain range, without the involvement of any vehicles.

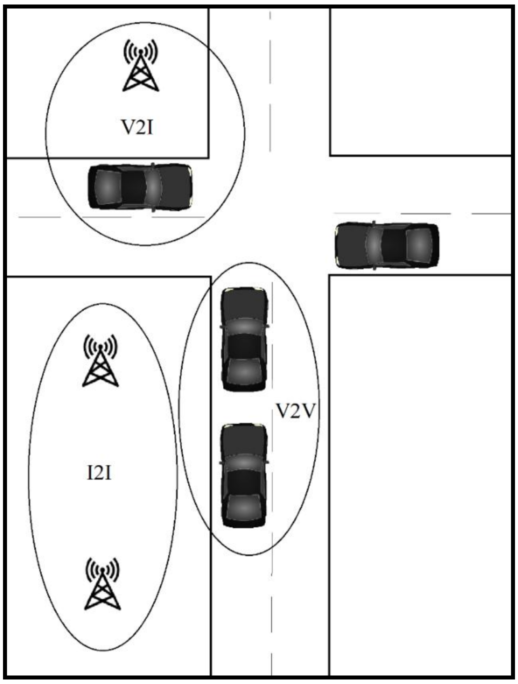

Fig. 3: VANET Communication Types

Note: Nowadays, there are two more emerging types of VANET communications, which are, V2C (Vehicle to Cloud) and V2X (Vehicle to Everything). V2C allows communication between the vehicles and the cloud platform, whereas V2X aims towards connecting vehicles to every possible thing in its surrounding.

Another major technology that could help towards the implementation of Traffic Deadlock Resolution System is the Ultrasound Range Finder, which could be implemented using HC-SR04 Module and an Arduino (or a similar technology that's capable of being reasonably scaled) [12]. This technology along with other promising technologies, such as a combination of RADAR and LIDAR, would allow the system to detect and measure the distance of any objects in front of the sensors, and the results would immensely help towards the efficient working of TDRS.

IV. PROPOSED METHODOLOGY

Having sufficiently discussed about the common traffic problems and involved technologies in brief, we may proceed to understand the model which will aid in the resolution of traffic congestions and certain states of intersection gridlocks. There are two phases involved in the functioning of TDRS:

A. Deadlock Detection Phase

This phase involves the consistent monitoring and accurate detection of a situation which fully qualifies as a state of deadlock, where two or more vehicles are unable to move forward due to blocking each other's paths. The Necessary and Sufficient Conditions for Deadlock Detection are:

1. Vehicles are in an Idle State.
2. The "Hello Packet" returns to its Originating Vehicle.

The way the Deadlock Detection is supposed to work is that, whenever a vehicle is in the running condition and has been in the idle state for more than 30 seconds, it would send out a "Hello Packet" originating from its front facing transmitter and would be received by an omnidirectional receiver of the vehicle in front of the sender. Each Hello Packet would have two major components attached to it, namely, a source vehicle identification in its header to identify which vehicle generated that Hello Packet, and a Time-to-Live (TTL) counter of a certain value, which will determine how long the Hello Packet would stay active in the network. The TTL value also helps to avoid flooding of the VANET with outdated Hello Packets by discarding them after the TTL value eventually reaches the zero value. Transmission and retransmission of Hello Packets would have a range of roughly 3.5 meters, which is slightly more than the average width of road lanes. This is to ensure the best usability of the Hello Packets, which is to detect deadlocks, and if there already exists a distance of more than 3.5 meters, there is a very high possibility of the absence of any deadlock. Note must be taken that, transmissions of Hello Packets must be done unidirectionally and its receptions must be done omnidirectionally. This process is better illustrated in Fig. 4.

The Deadlock Detection Algorithm (DDA) is better illustrated in Fig. 5. It basically starts of by checking the state of the vehicle, whether it is in a state of motion or in a state of idleness, which is an important factor in identifying the detection of a deadlock. It is because, if the vehicle is already in motion, then there is absolutely no question of any possible deadlock situations. This is why the state of the vehicle is checked multiple times within the DDA for ensuring that the vehicle is indeed in the idle state.

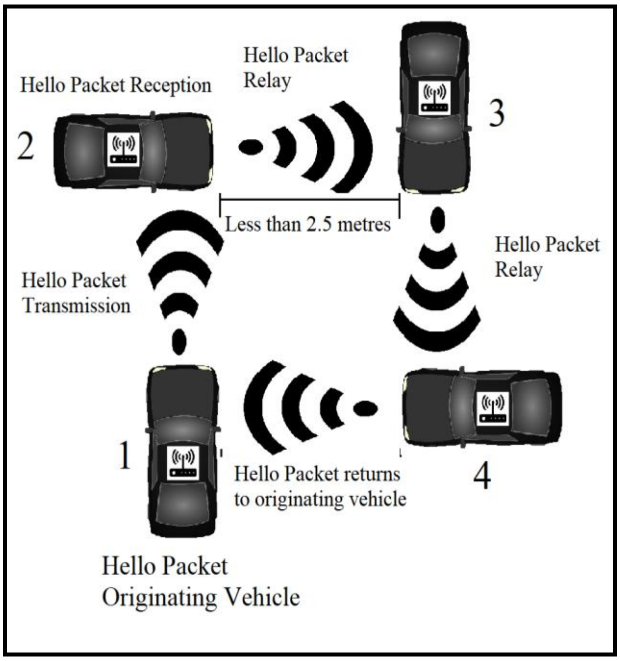

Fig. 4: Deadlock Detection Process

Once the vehicle is deemed to be in a state of idleness, it initiates a 30 seconds timer, called the "Idle Timer", which allows some time to resolve any minor deadlocks, if any, on its own. As soon as the Idle Timer expires, it first resets the Idle Timer, after which the vehicle sends out a Hello Packet to its immediate neighbouring vehicle in front of it, if any. In case, no object or vehicle is found within the range of 3.5 meters, then it is certain that there is no presence of deadlock.

After transmission of the Hello Packet, it initiates the Hello Timer, during which the vehicle would be in the Waiting State until the Hello Timer expires. During the Waiting State, the vehicles would wait for the return of its original Hello Packet generated by it. In case the Hello Packet does not return to the originating vehicles before the Hello Timer expires, it would send out another Hello Packet and reset the current Hello Timer. At any point in time, during the Waiting State, if the vehicle comes in the state of motion by the driver's ability to manually override the TDRS process, it would immediately terminate the ongoing DDA process. This is because, if the vehicle is in motion, it is confirmed that the deadlock no longer exists and there would be no need to keep the TDRS process running. But if the Hello Packet returns during the Waiting State, it would be confirmed that there indeed exists a state of deadlock. This would immediately end the Deadlock Detection Phase and initiate the Deadlock Resolution Phase.

The roles of other vehicles, that are a part of the same deadlock, are to run the same DDA process on their respective systems, along with continuous monitoring and forwarding of Hello Packets received from other vehicles, as illustrated in Fig. 6. If a vehicle receives a Foreign Hello Packet (the packets that are sent by other vehicles), the receiver must simply pass it on to the next available vehicle within 3.5 meters, using its front facing transmitter.

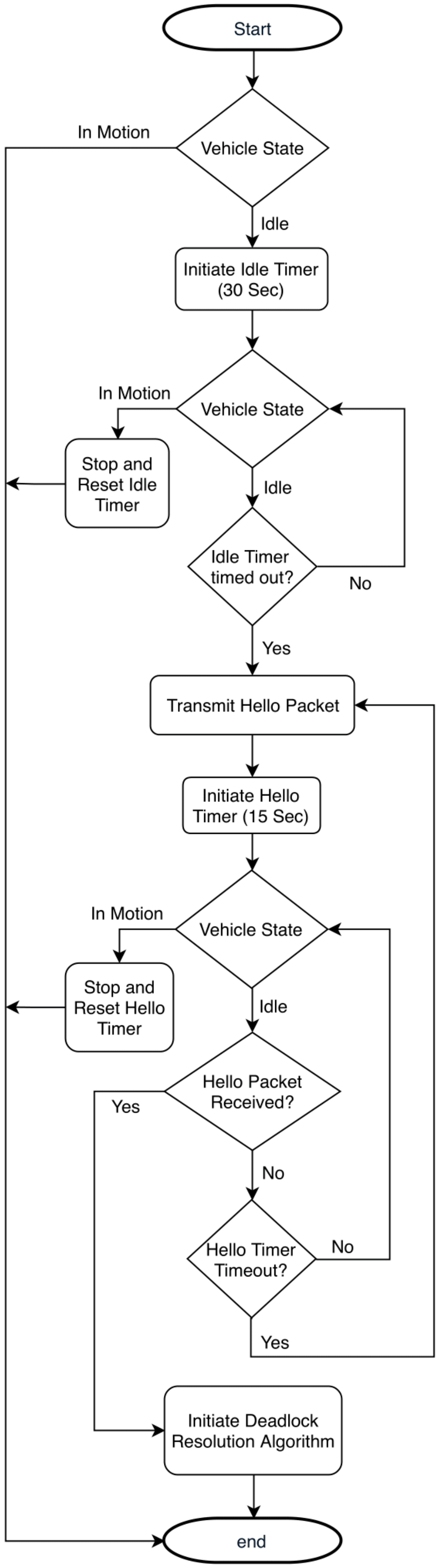

Fig. 5: Deadlock Detection Algorithm (DDA) Flow Chart

The pseudocode for the DDA (Fig. 5) is as follows:

```
IF vehicle is in the idle state
   INITIATE Idle Timer of 30 seconds
ELSE
   END
UNTIL Hello Timer is equal to zero
   IF vehicle is in motion
      STOP and RESET Idle Timer
      END
UNTIL Hello Packet received
   TRANSMIT Hello Packet
   INITIATE Hello Timer of 15 seconds
   UNTIL Hello Timer is equal to zero
      IF vehicle is in motion
         STOP and RESET Hello Timer
         END
      IF Hello Packet received
         INITIATE DRA
         END
```

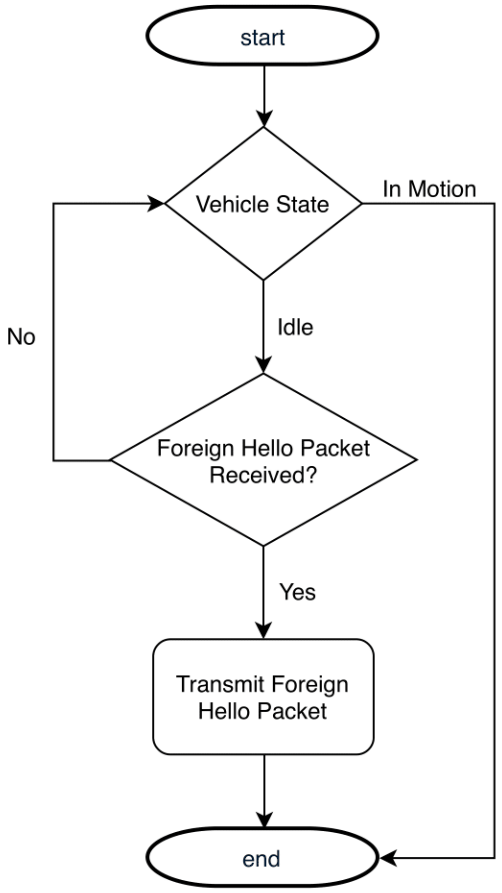

Fig. 6: Foreign Hello Packet Transmission Flow Chart

The pseudocode for the Foreign Hello Packet Transmission Flow Chart (Fig. 6) is as follows:

```
IF vehicle is in the idle state
   IF Foreign Hello Packet received
      TRANSMIT Foreign Hello Packet
END
```

B. Deadlock Resolution Phase

This phase involves the execution of the Deadlock Resolution Algorithm (DRA) to resolve the current state of deadlock and help resume normal uninterrupted flow of traffic. The basic objective of this phase is to resolve the deadlock by creating a sufficient amount of space at the point of deadlock, so as to allow the vehicles to pass with a proper flow. This is achieved by moving each of the queued vehicles back by at least 3.5 meters, which is the average width of a road lane, and it would allow for the passing of other vehicles through this newly created space. Without the help of automated systems and communication protocols, it would be a daunting task for the drivers to resolve this on their own, especially when there are long queues of vehicles surrounding the deadlock.

Once it is confirmed that there indeed exists a condition of deadlock (as determined by the DDA process), the Deadlock Resolution Algorithm is hence initiated. This algorithm makes use of something known as the Deadlock Resolution System Control Token (DRS Control Token), which helps to keep track of the vehicles that must perform the indicated processes outlined in the DRA Flow Chart (Fig. 7).

The vehicle which initiates the DRA will have the DRS Control Token by default, and vehicles have the capability of passing this token to other vehicles that are part of the VANET. The point to be noted here is that, a vehicle may pass on the DRS Control Token to another vehicle if and only if they both satisfy the conditions, viz., both vehicles must be a part of the same queue and should be facing the same direction. The DRS Control Token helps determine which DRS Vehicle (a vehicle participating in the TDRS Process) in the queue must move back a certain amount of distance, without colliding with any DRS/Non-DRS Vehicles or intruding objects, thus avoiding any inadvertent collisions that may potentially happen during the execution of the DRA. The processes involved in the DRA are better illustrated in Fig. 7.

The Deadlock Resolution Algorithm starts off by scanning for objects behind the vehicle within a range of 3.5 metres. The purpose of this process is to figure out whether there is any object or another vehicle behind, in which case, it would not be able to move back because the object or another vehicle is blocking the path of the vehicle possessing the DRS Control Token. Hence, if another vehicle that is a participant of the current TDRS process (DRS Vehicle), is discovered within a range of 3.5 meters, the DRS Control Token gets passed on to the vehicle behind, in hopes that there would be space behind that vehicle for it to move back. In case there is a long queue of cars, the DRS Control Token keeps getting passed on to the trailing vehicles, until it finds a vehicle in the queue which has at least 3.5 metres of distance behind it.

In the likelihood of an unfortunate scenario, that the queue of vehicles is blocked by a certain intruding object or a vehicle that is not a part of the VANET, the DRA would simply be terminated and would rely on the successful execution of the DRA on one of the other queues of vehicles involved in the deadlock to create that space for traffic flow.

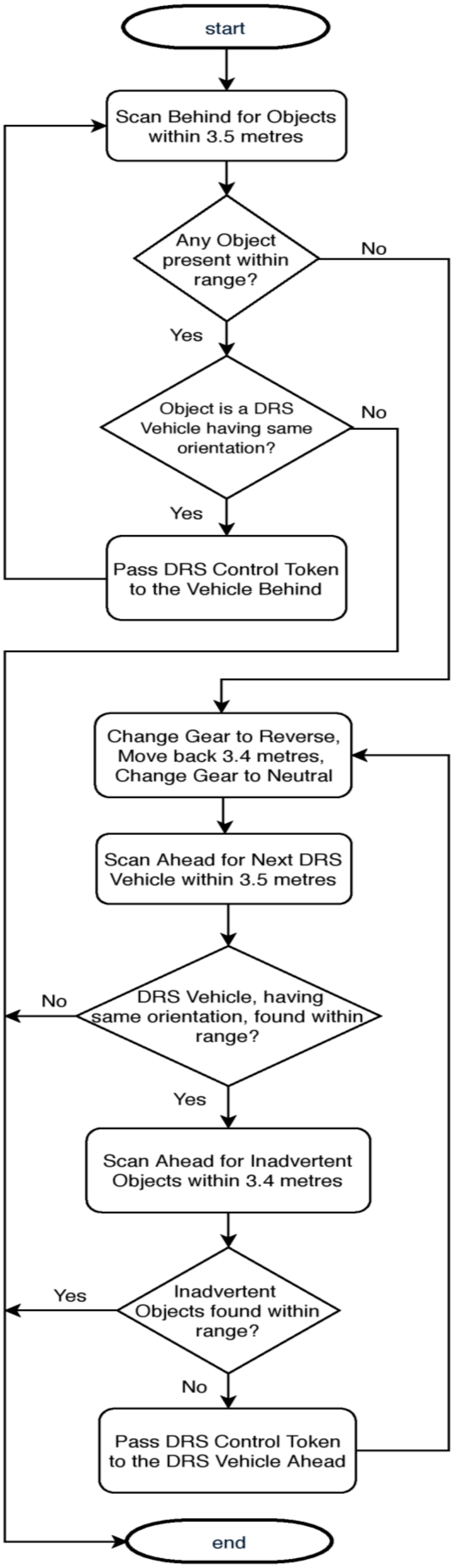

Fig. 7: Deadlock Resolution Algorithm (DRA) Flow Chart

In the likelihood of a fortunate scenario, where a vehicle in the queue is encountered having more than 3.5 metres of space behind it, the vehicle would switch to reverse gear and move back 3.4 metres. The differential 0.1 metre of distance is used as a buffer to avoid any kind of close contact with possible intruding objects or a vehicle directly behind.

This is followed by changing the gear back to neutral and scanning of objects within 3.5 metres ahead of the vehicle to search for another DRS Vehicle, if present. If a DRS Vehicle is found within the mentioned range, it then scans ahead for any inadvertent objects, within 3.4 metres, that may potentially be intruding the queue. In case no inadvertent objects are found within the range, it simply passes on the DRS Control Token to the vehicle in the front, which is again followed by the process of moving back 3.4 metres.

The entire process continues until a DRS Vehicle is encountered having no objects or vehicles within a range of 3.5 metres, and would result in the termination of the DRA, thus completing the Deadlock Resolution Phase, hence marking the successful execution of the entire Traffic Deadlock Resolution System.

The pseudocode for the DRA (Fig. 7) is as follows:

```
UNTIL no objects exist within 3.5m behind
   SCAN BEHIND for objects within 3.5m
   IF object present within 3.5m
      IF object is a DRS Vehicle
      AND has same orientation
         PASS DRS Control Token behind
      ELSE
         END
CHANGE gear to Reverse
MOVE BACK 3.4m
CHANGE gear to Neutral
SCAN AHEAD for DRS Vehicle within 3.5m
SCAN AHEAD for objects within 3.4m
WHILE DRS Vehicle found within 3.5m having
same orientation AND absence of any
inadvertent objects within 3.4m
   PASS DRS Control Token ahead
   CHANGE gear to Reverse
   MOVE BACK 3.4m
   CHANGE gear to Neutral
   SCAN AHEAD for DRS Vehicle within 3.5m
   SCAN AHEAD for objects within 3.4m
END
```

V. DISCUSSIONS

The ever-increasing surge of road traffic complexities drastically raise the possible occurrences of traffic deadlocks which become quite tedious for human beings to resolve on their own without any technological intervention. Thus, the TDRS system greatly increases the efficiency by which traffic deadlocks can be resolved, which ultimately helps towards the reduction of pollution as well as save a great deal of time and other valuable resources such as fuel, vehicle life, etc.

The execution of the above proposed methodology leads to the working of the following three primary functions:

- Constant monitoring of traffic deadlock situations.
- Accurate detection of traffic deadlock situations.
- Methodical resolution of traffic deadlock situations.

Before the design of the associated algorithms, it was found that, in a typical traffic deadlock situation, the backmost vehicle in the associated queue, was deemed to be the cause of hindrance for resolving the deadlock as it blocked the movement of all the vehicles in front of it. Therefore, the Deadlock Resolution Algorithm, as illustrated in Fig. 7, aims to locate the backmost vehicle of the respective queues involved in the deadlock and safely move the entire queue of vehicles backward in order to create a sufficient gap in the front where all the queues converge to create the deadlock. This newly created gap in the front of the queue resolves the traffic deadlock as it now allows the safe passage of vehicle from the adjacent queues.

Moreover, this paper talks about the detection and resolution of a traffic deadlock, but not about its avoidance. Once a particular traffic deadlock is resolved, certain measures must be employed in order to maintain a consistent flow of traffic and avoid possible future traffic deadlocks.

Last but not the least, considering the rapid growth of the technological advancements around us, there is a lot of room for improvement and optimization of TDRS, and hence has a great scope in the future, especially considering the rise in road traffic complexities and its negative consequences associated with it.

VI. CHALLENGES OF TDRS

Although the TDRS system primarily aims at efficiently alleviating road traffic congestions with automated resolution of deadlocks, there still exists certain challenges that may render the TDRS system ineffective.

One such challenge involves the situation where there could be possible interference of living or non-living things affecting the queue of vehicles that are part of the TDRS process. For instance, it is very common in India to witness heavy domestic animals, such as cows, buffalos, etc., to wander on the roads, and may interfere with the DDA and DRA algorithms. Also, TDRS would be incapable at times when a certain vehicle, involved in the deadlock, breaks down and doesn’t respond to any system generated signals or inputs given by its driver. The efficiency of TDRS would also be hampered if the queue of vehicles were to be on a curved road, and hence, possible solutions would have to be developed in order to curb this challenge.

Other major challenges that are associated with TDRS are the privacy and security vulnerabilities, which may enable a majority of the threats to jeopardize the entire system. Since the entire system is invariably based on VANETs, therefore all relevant security challenges of a VANET would be applicable to TDRS as well. An extensive survey, research and in-depth analysis about current security implementation on VANETs have recently been done in [13] and [14], the studies of which would greatly aid towards the development of strong security implementations of TDRS.

Last but not the least, there could be possible challenges regarding the large-scale deployment of TDRS to new and existing vehicles, because the working of TDRS totally depends on the existence of a reliable IoV infrastructure, the deployment of which is still at its infancy. Different strategies must be adopted for accommodating the deployment of VANET and related IoV Technologies, to new as well as old vehicles. Moreover, many questions arise regarding the possibility of new traffic rules which would have to be in compliance with the local governing bodies along with the acceptance of this technology by the local government.

There could be more potential challenges involved with TDRS and further research needs to be done to compensate them as far as possible.

VII. CONCLUSION

Thus far, we have analyzed the current situation of the ever increasing traffic complexities that are happening all around the world today, and we have also realized the need for integrating vehicular technology to help alleviate the problems related to the poor management of the flow of traffic.

The Traffic Deadlock Resolution System, which entirely works on the VANET system, offers two distinct phases, namely, Deadlock Detection Phase and Deadlock Resolution Phase. This leads to the execution of the three primary functions which are Monitoring, Detection and Resolution of various traffic deadlock situations, thus helping towards the efficient resolution of traffic deadlocks and ultimately help in resolving the traffic congestions on the road. Apart from this, certain challenges to the system have been acknowledged and determined that further research needs to be done to alleviate such challenges to make TDRS much more efficient and effective.

In the end, we conclude that the entire TDRS system is based on the collective cooperation of all the adjacent vehicles and would be highly effective if and only if all the vehicles, involved in the deadlock, are a part of the VANET. That being said, TDRS would be highly effective only following the deployment of this technology to the majority of vehicles on the road today.

REFERENCES

1. "Global car sales 1990-2018", Statista, 2019 [Online]. Available: https://www.statista.com/statistics/200002/international-car-sales-since-1990
2. Saurabh Sharma, "Smart solution to traffic: The grey's way", Techie Scoops, March 17, 2017. [Online]. Available: https://techiescoops.com/smart-solution-to-traffic-2
3. Toni Petrinić, "Longitudinal Spacing Control of Vehicles in a Platoon for Stable and Increased Traffic Flow", IEEE International Conference on Control Applications (CCA), October 3-5, 2012. Dubrovnik, Croatia. DOI: 10.1109/CCA.2012.6402468.
4. He Dan and Wang Qian, "Monster traffic jam ... again", China Daily, September 4, 2010 [Online]. Available: http://www.chinadaily.com.cn/cndy/2010-09/04/content_11255653.htm
5. Peter Foster, "Chinese drivers stuck in the longest traffic jam", The Telegraph, August 24, 2010 [Online]. Available: https://www.telegraph.co.uk/news/worldnews/asia/china/7961325/Chinese-drivers-stuck-in-the-longest-traffic-jam.html
6. Divya Chadha and Reena, "Vehicular Ad hoc Network (VANETs): A Review", International Journal of Innovative Research in Computer and Communication Engineering, Vol. 3, Issue 3, March 2015.
7. C. E. Perkins and E. M. Royer, "Ad-hoc On-Demand Distance Vector Routing", Second IEEE Workshop on Mobile Computing Systems and Applications, 1999, pp. 90–100.
8. J. Härri, F. Filali, and C. Bonnet, "Performance comparison of AODV and OLSR in VANETs urban environments under realistic mobility patterns", 5th IFIP Mediterranean Ad-Hoc Networking Workshop, Lipari, Italy, June 14-17, 2006.
9. M. Gerla, L. Kleinrock, "Vehicular networks and the future of the mobile internet", The International Journal of Computer and Telecommunications Networking, Vol. 55, Issue 2, February 2011, pp. 457-469, DOI: 10.1016/j.comnet.2010.10.015
10. Sabih ur Rehman, M. Arif Khan, Tanveer A. Zia and Lihong Zheng, "Vehicular Ad-Hoc Networks (VANETs) - An Overview and Challenges", Journal of Wireless Networking and Communications, Vol. 3, Issue 3, 2013, pp. 29-38, DOI: 10.5923/j.jwnc.20130303.02
11. Pallavi Agarwal and Neha Bhardwaj, "A Review on Trust Model in Vehicular Ad Hoc Network", International Journal of Grid and Distributed Computing Vol. 9, No. 4, 2016, pp.325-334
12. Scott, "How to Set Up an Ultrasonic Range Finder on an Arduino", 2015 [Online]. Available: http://www.circuitbasics.com/how-to-set-up-an-ultrasonic-range-finder-on-an-arduino
13. Aljawharah Alnasser, Hongjian Sun, Jing Jiang, "Cyber Security Challenges and Solutions for V2X Communications: A Survey", Computer Networks, Vol. 151, 14 March 2019, pp. 52-67, [Online]. Available: https://doi.org/10.1016/j.comnet.2018.12.018
14. Irshad Ahmed Sumra, P. Sellappan, Azween Abdullah and Ahmad Ali, "Security issues and Challenges in MANET-VANET-FANET: A Survey", EAI Endorsed Transactions on Energy Web and Information Technology, Vol. 5, Issue 17, April 2018, DOI: 10.4108/eai.10-4-2018.155884

AUTHOR'S PROFILE

Arpit Roy is an IT professional in the field of computer networking and is a Cisco Certified Networking Associate (CCNA). He has completed his B.Sc. (IT) in 2019 from Amity Institute of Information Technology, Amity University, Noida. He has also served as the President of Networking Club during his final year of graduation at Amity University, Noida. During his graduation, he was presented with the award of "Best in Leadership Qualities" from Amity University, Noida. His areas of research include Computer Networking, Internet of Things, Cloud Computing and Cyber Security.

Ruchika Bathla is pursuing Ph.D. (Information Technology) from Amity University, Noida, Uttar Pradesh. She is working as Assistant Professor in Amity Institute of Information Technology, Amity University, Noida. She has done MCA & B.Sc. (Computer Science) from Kurukshetra University. She has more than 14 years of teaching experience. She has published several research papers in various National & International conferences. Her research areas include Recommender Systems, Machine Learning, Data Mining and Big Data Analytics.

Sonia Saini is pursuing Ph.D. (Computer Science and Engineering) from Birla Institute of Technology (BIT), Mesra, Ranchi, India. She is working as Assistant Professor in Amity Institute of Information Technology, Amity University, Noida. She has done M. Tech. (IT) from Punjabi University, Patiala and M. Phil. (Computer Science) from Madurai Kamaraja University, Madurai. She has more than 16 years of teaching experience. She has published several research papers in various international conferences & journals. Her research areas include Data Mining, Big Data Analytics, and Healthcare Analytics.