A Cooperative Strategy for Collision Detection and Prevention for Unmanned Ground Vehicles in Military Applications using WSN based VANET

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ABSTRACT
In the recent years, vehicular Ad Hoc Networks have gained tremendous attention of researchers due to various services they provide and likely to be deployed commercially in coming years. VANET enables vehicles to communicate with each other to avoid any critical situation such as vehicle collision, unseen obstacles etc. Safety applications such as collision warning, highway/rail collision avoidance, obstacle detection and avoidance are one of the driving forces behind the deployment of VANETs. Collision detection and prevention is a critical issue to work at as there is an increased rate of collisions between vehicles in fog during night time or zero visibility situations and rescue operations in inconvenient places such as military battlefield, highways. So any strategy that can detect and prevent such collisions to some extend will be beneficial. In this paper, a simple and cooperative strategy for collision detection and prevention for Unmanned Ground Vehicle (UGV) in military battlefield using WSN based VANET is proposed.

Keywords
WSN, VANET, Inter-vehicle communication, Neighbor updates, collision detection, collision prevention, availability.

1. INTRODUCTION
Vehicular Ad Hoc Networks (VANETs) are new paradigm of wireless communication that aims to enable intelligent inter-vehicle communication. The research into this area has started as a result of the immediate need of the Department of Defense (DoD) in the USA for military combat operations in hostile territories [12]. The Federal Communication Commission (FCC) in the US has allocated 75 MHZ of spectrum at 5.9 GHZ frequency for Inter-Vehicle Communication (IVC) and Dedicated Short Range Communication (DSRC) for vehicle to Roadside Communication [2].Various research projects on VANET are going on such as COMCAR, DRIVE, FleetNet, NoW (Network on Wheel), CarTALK2000, CarNet [7]. Being an emerging technology, VANET helps in traffic management during fog time situation or zero visibility situations, vehicle search, rescue operations in inconvenient places [1] and enemy troop movement monitoring in battlefields. Due to the wide variety of services they provide, they are likely to be deployed in military application. The most important and crucial operations in military battlefield are timely detection of an events in a particular area of interest and instant information sharing between unmanned ground vehicle to avoid any unwanted event to occur to increase mission effectiveness [3]. Safety is always the prior concern in every respect. So, safety applications are one of the driving forces behind the deployment of VANETs in military battlefield. Vehicular Ad Hoc Network is a part of Mobile ad Hoc Network (MANET), where every node can move independently within the coverage area and each node can communicate with other nodes in single-hop or multi-hop. The radio used for the communication is Dedicated Short-Range Communication (DSRC) [14]. The rest of the paper is organized as follows: In section II, the need of VANET-WSN integration is discussed. Section III, provides a brief discussion on related work. In section IV, the proposed system model is introduced and in Section V, the working flow of proposed strategy is presented. Section VI, discussed the simulation results. Finally, Section VII explains conclusion on the basis of simulation results presented in sixth section.

1.1 VANET
VANETs are non-infrastructure based network that do not have any central administration for communication between vehicles. With the emerge of wireless technology, nowadays vehicles have become more intelligent to avoid any critical situation [6].VANET enables vehicle-vehicle (V2V) and vehicle-roadside infrastructure (V2I) communication via wireless network. VANET uses moving vehicles as sensor nodes equipped with an On-Board Unit (OBU) and a Roadside Unit (RSUs) to provide ubiquitous connectivity to the moving vehicles on the road to create a mobile network. Each vehicle has two interfaces: IEEE 802.11p Interface for vehicle-vehicle communication and IEEE 802.15.4 Interface for vehicle-roadside sensor node

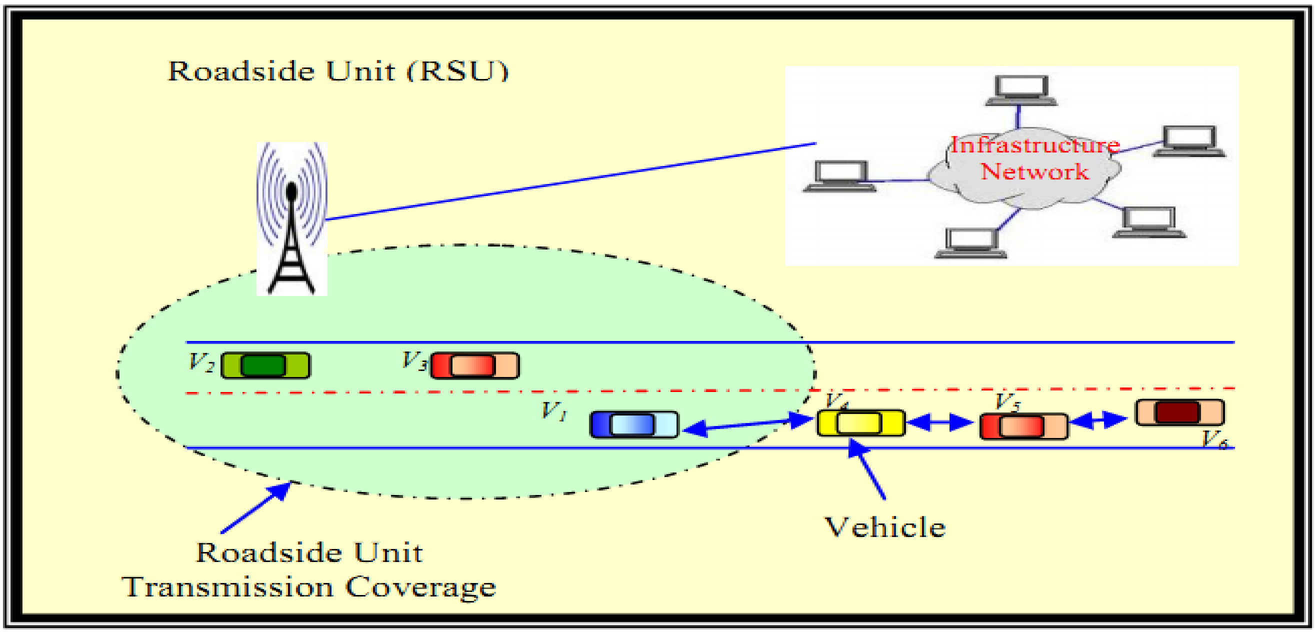

Fig. 1: Vehicular Ad hoc Network architecture [12]

Communication [10]. With On-Board Unit, Vehicles communicate among themselves to avoid collisions. This paper is proposed to implement WSN based VANET in military battlefield at war time to detect and prevent collision between Unmanned ground vehicles (UGVs) or tanks. This paper mainly deals with three issues: neighbor updates, collision detection and prevention and availability of resources.

2. NEED OF VANET-WSN INTEGRATION

As VANET is designed to improve driving safety but VANET does not guarantee timely detection of collision or maintain communication connectivity, when the network density is low such as in rural areas and military battlefield [15]. If VANET is disconnected, the critical information about collision and battlefield conditions cannot be shared timely between vehicles. One solution is to deploy roadside stations but it increases the

Investment cost and lacks of power supply in battlefield. To solve this problem, the integration of VANET with Wireless Sensor network (WSN) to provide timely detection of battlefield condition and communication connectivity is needed [2]. In spite of different features of VANET and WSN, deploying WSN with VANET can help prevent vehicle collision as the WSN node can detect collision on the road and propagates the information within the nearby area. Approaching vehicle will receive the warning message and will change the route accordingly. This is not possible if only VANET is used since the VANET is not connected [2].

2.1 Wireless Sensor Networks

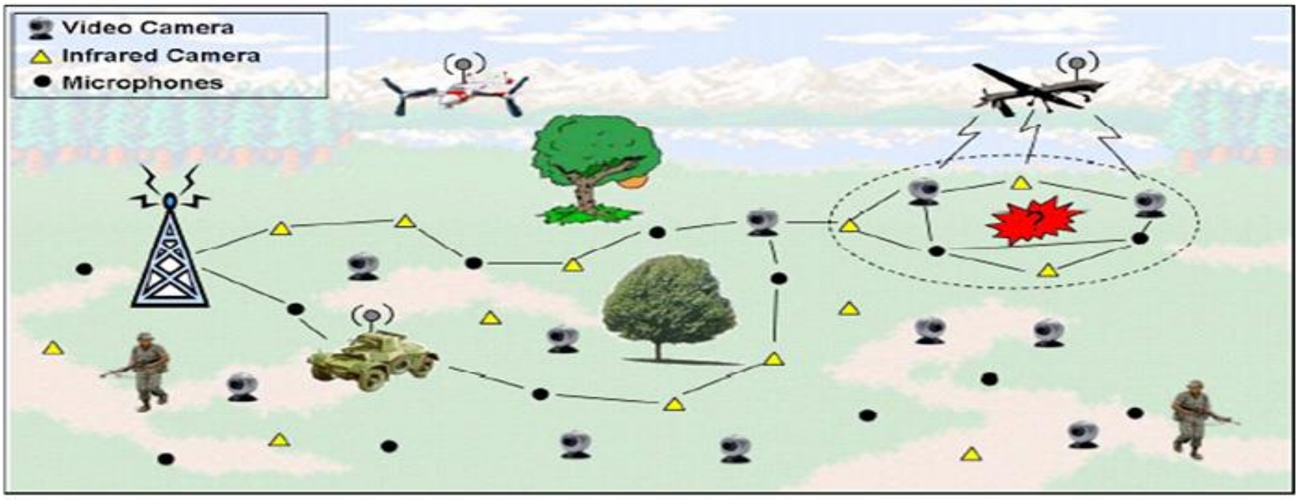

Fig. 2: Representation of Wireless Sensor Network.

Wireless Sensor networks are deployed in resource-constrained and hostile environment such as dense for habitat monitoring and battlefields for enemy troop movement monitoring. A large number of sensor nodes deployed over a geographical area of interest, these tiny sensor nodes are self-organized to form a multi-hop network and relay critical information to a sink node which act as a gateway to a backbone network. The gathered data is analyzed to take appropriate decisions. Sink nodes can not only communicate with source node used to measure roadside traffic conditions, but also communicate with VANET. Sink nodes have a powerful processing capacity, making them possible to be applied in traffic safety and intelligent navigation.

VANET and WSN are ad hoc networks but have different features.

Table 1: Features of VANET and WSN

S.NO.	Parameter	VANET	WSN
1.	Network Access	IEEE 802.11p	IEEE 802.15.4
2.	Routing Protocol	Geocast	ZigBee
3.	Topology	Dynamic	Static
4.	Power Requirement	Not Critical	Critical
5.	Network Connectivity	Changes Frequently	Does not change
6.	Node Deployment	Not Dense	Dense
7.	Node Failure	Rare	More prone to failure
8.	Computational Capability	No Limitation	Limited

3. RELATED WORK

In recent years a lot of research on VANET has been done to identify several issues which need to be resolved for widespread adoption. VANET is designed to improve driving safety. VANET does not guarantee timely detection of collision or maintain communication connectivity when the network density is low i.e. in rural areas.

Ramya Krishnan, T Rajesh [9] **et.al** proposed a model for collision detection. The information such as ID of the vehicle, location of the vehicle, speed of the vehicle, the angle of turn, the stopping distance of the vehicle and the reporting time of the information is exchanged among the neighboring vehicles and then a 2D cone of movement is calculated. This cone of movement predicts collision points for the vehicle. Once the collision is identified, collision avoidance technique is performed. The number of collision points is calculated on the basis of the difference between the number of collision points and the preset value, the force is applied on the breaking system along with the steering system .The Double C-Curve movement is used to keep the vehicle away from colliding with each other. The modified path information (ID of the vehicle, reporting time of the information, current position of the vehicle, future position of the vehicle that causes collision, time of collision, alternate path and previous collision zone area) is added to the information packet sent.

Chung-Ming Huang, Lai Tu, Chih-Hsun Chou [8] **et.al** proposed a relay scheme for Cooperative Collision Warning to reduce the impact of transmission failure caused by shadow fading. An accurate and timely massage may avoid a collision risk. Each vehicle periodically broadcast information about its position, velocity and potential collision target information to its neighbors, on receiving this information from neighboring vehicle, the local vehicle adds it to its neighbor list. On the basis of motion of local vehicle and the received one, the collision detection algorithm calculates the collision risk between two vehicles. Each vehicle besides calculating its own collision risk, it also calculates the collision risk of its neighboring vehicle. If it has detected collision and the neighbor keep quit, it broadcast a relay packet containing information of two vehicles involved in collision but this scheme lacks in several technical challenges such as motion information broadcasting without acknowledgement, secondly a multiple third party vehicles can accomplish the relay task so, to overcome this a coordination method is required to avoid multiple transmission.

In [10**],** a Radar based collision detection technique has been proposed but it has limitation that it can detect collision when the vehicle is in the front or rear. Such system exchanges the information about the position and speed of the vehicle using single-hop WLAN at 360° angle of coverage. It introduces the problem of hidden vehicles, where the transmitter of colliding vehicles is not within the range of each other. This method of collision detection takes more time.

Sandeep Tayal, Malay Ranjan Tripathy [16] **et.al** proposed a vehicular mobility model where different challenges and applications of VANET are evaluated. Several mobility parameters like vehicle speed, vehicular density, vehicular velocity, acceleration/deceleration and human behavior are used to evaluate any VANET design.

Rongyan Xia, Chen Ye, Dongdong Zhang [10] **et.al** designed hybrid architecture to combine the features of VANET and a roadside sensor network for intelligent navigation. They suggested that a vehicle can detect a jam on the road if the speed of the vehicle is lower than a threshold a warning message about traffic jam is send to the nearby WSN sink node. If the density of these messages is higher than a threshold and average speed of vehicle is lower than a threshold, it is predicted that there is a jam. A congested road message is broadcasted to VANET Conversely, if the density is lower than a threshold, sink node broadcast a message which indicates the current road is out of congestion.

ThangaKumar Jeyaprakash, Rajeshwari Mukesh [4] **et.al** discussed that Unmanned Ground Vehicles (UGVs) play an important role in military services .These UGVs share information with each other using V2V communication. An Information Control Unit (ICU) is attached inbuilt with all UGVs to share the information. In this paper authors proposed that the Radar detects an UGV by sending and receiving the reflection pulse from UGV. Each UGV monitors its neighbor nodes. This neighbor node information is displayed in Network Display Unit and IEEE WIMAX 802.16a is used to set up the VANET.

The event data recorder records the information such as fog information to avoid collision during night time, fire control information, and current status of UGV etc. Sensor detects this information and GPS navigates the position of UGV to the neighbored UGVs among the VANET about the status of failed UGV. The damaged UGV will be replaced immediately with the neighbor to provide a protection cover using the information sharing. This information is also used to avoid collision during fog.

4. PROPOSED SYSTEM MODEL

VANET is a type of multi-hop, infrastructure less and most important self-organizing network. Due to its wireless and distributed nature there is a great challenge for system to update the neighbor nodes, how they can access to each other and how they can find their position relative to the target. So, VANET is aimed to combine with WSN in which the client-server architecture is deployed where client is VANET and server is WSN.

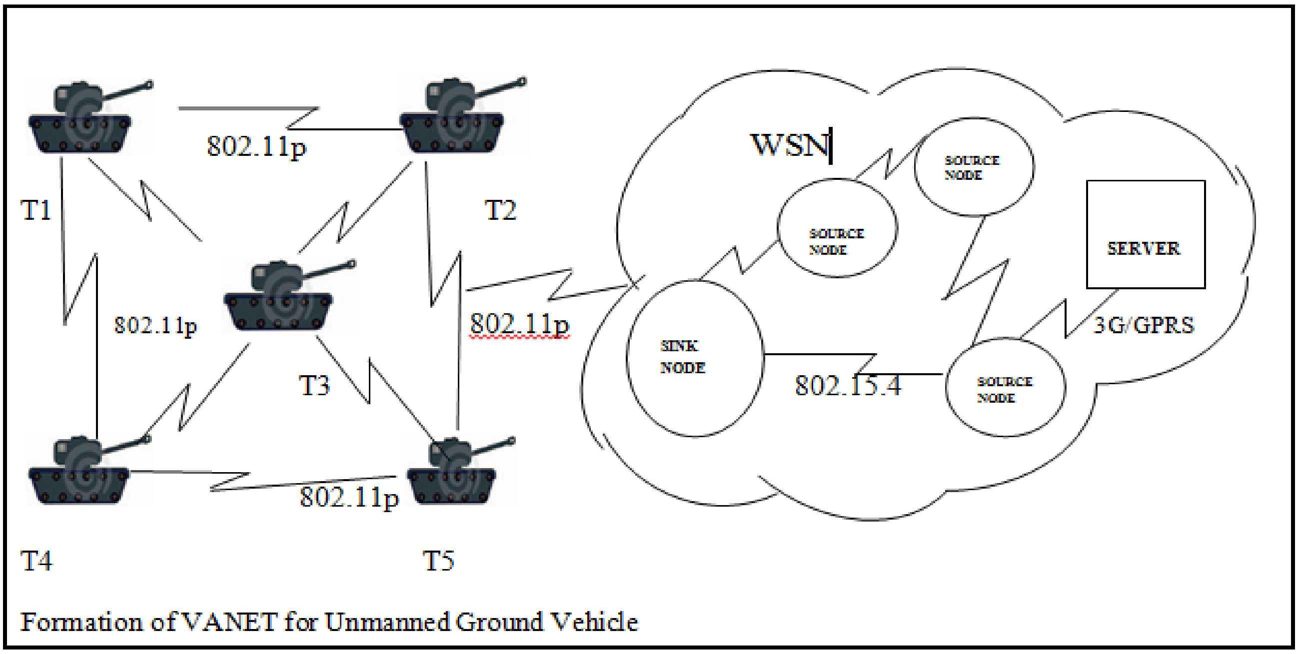

Fig. 3: System Model Representing VANET-WSN Integration

4.1 Target Environment

It is assumed that the target environment has the following characteristics:

- The military tanks or Unmanned Ground Vehicles (UGVs) act as nodes and form a Vehicular Ad Hoc Network. An Information Control Unit (ICU) is attached inbuilt with all UGVs to share the information. The Vehicle-Vehicle (V2V) communication takes place using IEEE 802.11p standard.
- In VANETs, Geocast routing protocol is used to the delivery of information to a group of destination in a network identified by their geographical location [10].
- To setup communication between the moving vehicles like military tanks in this model there must be some neighbor wireless sensor network that captures the information time to time from vehicles and sends updates to the other vehicles in the same zone.
- Communication between the vehicular nodes and WSN server takes place using IEEE 802.15.4 standard.

In fig. 3, When the vehicular Ad Hoc network formed, each tank is activated by entering the parameters such as speed, total distance, remaining distance, no. of grenades on the client side and getting the IP address and port number . After activation, an activation signal is send to the WSN server. It means that all the information is send to the server from the client. Now the tank starts forwarding towards the target, after covering some distance, all the nodes send update information [remaining distance, speed, no. of grenades left, node IP address, node port number] to the server. On receiving this update information from all the nodes, WSN server updates the server side and provides information to all the nodes to find their neighbor nodes, detect collision between nodes, collision prevention, grenades availability update information to protect tank with no grenades left. Now the interaction between WSN server and VANET nodes starts. Initially, a neighbor list is created because all the concepts of collision detection and prevention and availability of resources are based on the concept of neighbor information updates only. When the neighbor list is updated, it gives the information of distance between the tanks from which collision is detected and prevented and also checks the tank with zero grenades. Immediately, the tank with zero grenade stock will be protected by its neighboring tank. To update the neighbor list we use the distance factor that the vehicles which are under the specified neighbor distance range, are the neighbor vehicles and when the vehicles come under the specified range of collision distance, then the vehicles are in collision state. Prevention is done by increasing or decreasing the speed of vehicles according to the situation. The third issue is availability issue, which is one of the important security issues. Vehicular network must be available all the time in military applications. This service requires the entire node to be able to send information at any time. If the network is not available for communication, then VANET becomes useless. Information should be omnipresent and network must be present all the time. Any delay in information broadcasting may lead to biggest disaster. Military applications require right information at right time [14]. In this proposed system model, when any of the tank has left with zero grenade stock. Then from the neighbor information update, the neighbor tank provides protection to the tank that spends all of its mines.

5. WORKING FLOW OF PROPOSED STRATEGY

The main working flow is shown in Figure 4.

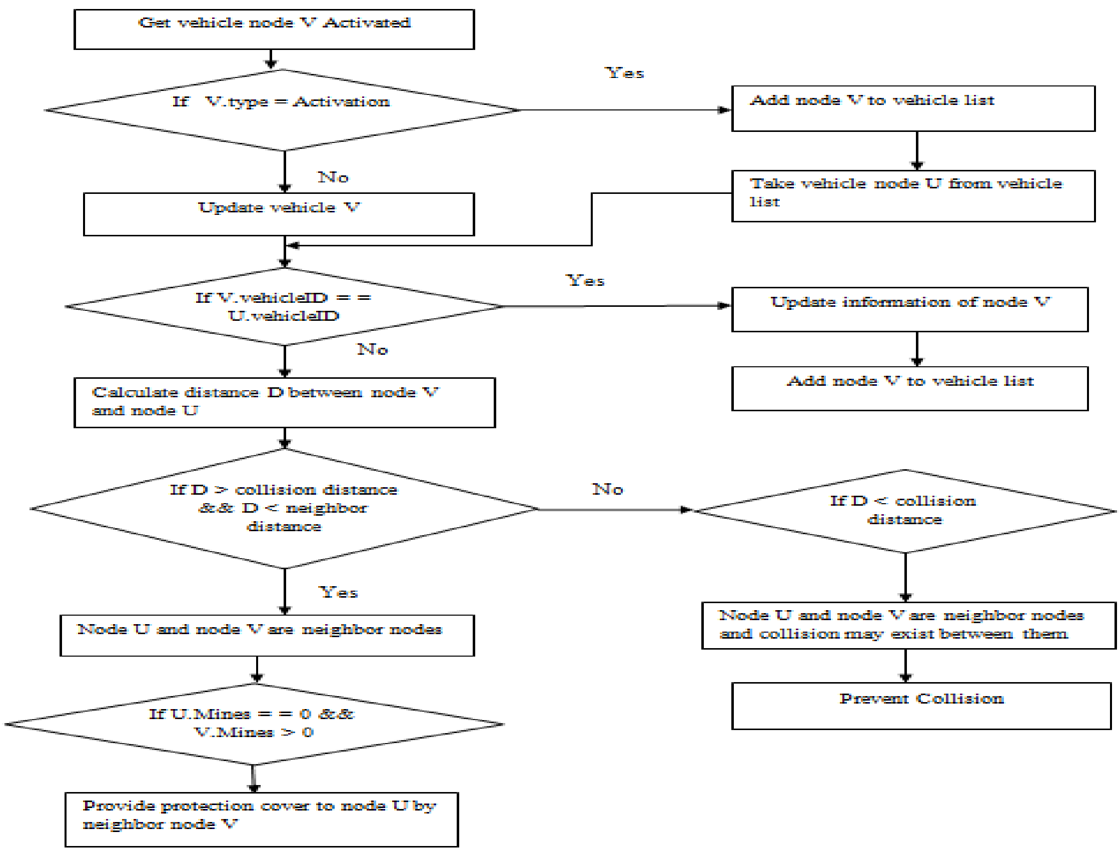

Fig. 4: Flow Level Diagram of Cooperative Collision Detection and Prevention Strategy

5.1 Algorithm

Step-1: Start.
Step-2: Activate vehicle node V.
Step-3: If vehicle node V = Activation then add new node V to vehicle list VL.
Step-4: Else update information of vehicle V in Vehicle list VL.
Step-5: Find neighbor node of vehicle node V
Take another vehicle node U from vehicle list VL.
If (V.VehicleID != U.VehicleID)
D1= TotalDistance – U.remDistance
D2= TotalDistance – V.remDistance
D3= D1- D2
If (D3> CollisionDistance And D3< NeighborDistance)
Vehicle node U is neighbor node of vehicle node V.
Add neighbor node U to neighbor list NL.
Step-6: Else If (D3< CollisionDistance)
vehicle node U is neighbor node of vehicle node V
And Collision may occur between them.
Then go to step 8. to prevent collision.
Step-7: If (U.mines = = 0 And V.mines > 0)
Then provide protection cover to node U by neighbor node V.
Step-8: If (U.remDistance > V.remDistance)
SpeedUp(V)
SpeedDown(U)
Else SpeedUp(U)
SpeedDown(V)
Step-9: Stop.

6. SIMULATION PARAMETERS AND RESULTS

In this section, the results obtained from simulation are presented to evaluate the performance of proposed strategy. To verify the proposed strategy by simulation, a network is designed in which all the nodes behave like a moving vehicle. The performance of proposed strategy is tested in a scenario where number of vehicles move in a specified coverage area using the following parameters as in Table 2.

Table 2: Simulation Parameters

Parameter	Value
Simulation performed	5 times
Number of tanks	N
Total distance from border	10000 m
Collision Distance	10 m
Neighbor Distance	50 m
Tank minimum speed	30 kmph
Tank maximum speed	50 kmph
Available grenades	10 units
Starting distance variation randomly	100 m

The simulation is performed for 5 times for different number of tanks. First, neighbor detection is necessary as it is the highest priority task. All other tasks such as collision detection and prevention, to provide protection cover for tanks running out of mines are based on neighbor information updates. The Table 3 shows the average value of simulation results.

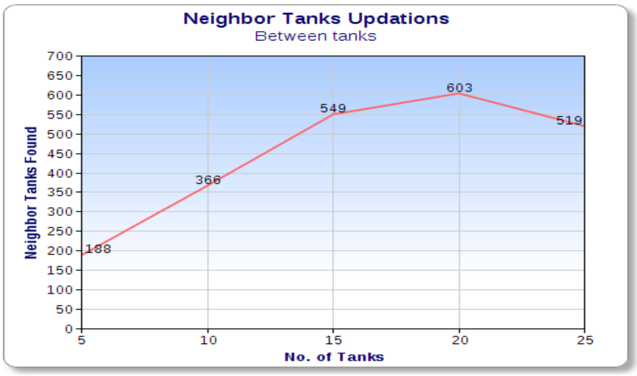

Fig. 5: Neighbor Information Updates

Table 3: Simulation Results

No. of Tanks	Neighbor Tanks Found	Collisions Prevented	Protection Cover Provided by Neighbor Tanks
5	188	55	38
10	366	350	62
15	549	792	217
20	603	1349	118
25	519	1247	87

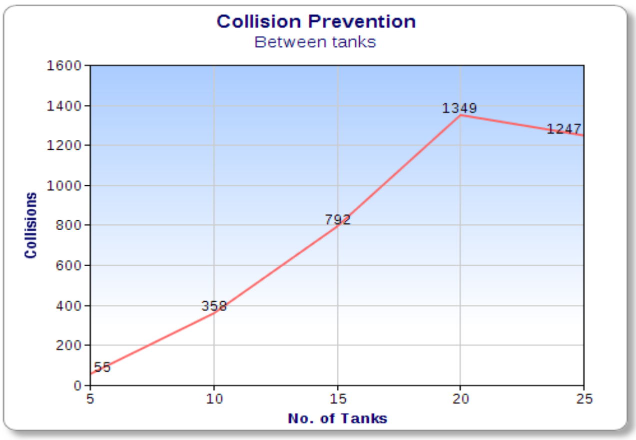

Fig. 6: Number of Collisions Prevented

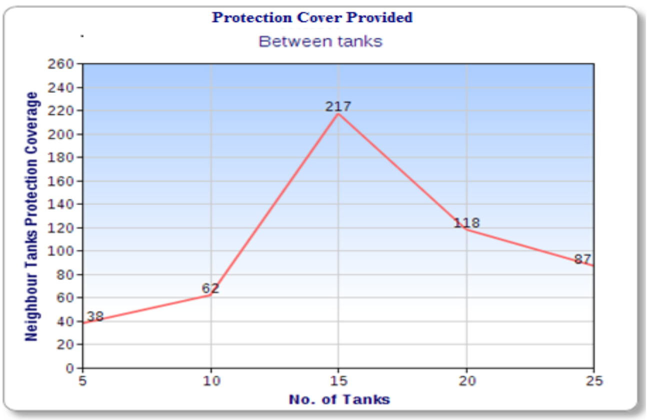

Fig. 7: Protection Cover Provided by Neighbor Tanks

The Above figures give the results of number of collisions detected and prevented by the proposed strategy.

7. CONCLUSION

In this paper, first the need of VANET-WSN integration to improve driving safety and guarantee timely detection and prevention of collision is discussed. Further, the shortcomings of existing methods of collision detection and prevention for VANET are elaborated. The previous methods are not efficient to meet every traffic scenarios. Finally, a simple and cooperative strategy to detect and prevent collision between unmanned ground vehicles using neighbor information updates is presented to overcome the drawbacks of existing works in the literature. The working principle of the strategy has been evaluated through simulation and the obtained results have proven its efficiency.

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