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ORIGINAL RESEARCH

Salp swarm bio inspired algorithm for detecting non line of sight vehicles in VANETs

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Abstract Vehicular adhoc networks is one of the tangible applications of MANETs which is designed to facilitate road safety application in a messy road environment. The sharing of location information between the vehicles plays a vital role in avoiding fatal accidents. The communication is established via direct communication for transmitting emergency messages between the vehicles. But the presence of interference and obstacles makes the localization of vehicles an intricate chore. Though the presence of intelligent transport system makes VANETs a wiser network it has failed in localizing the vehicles which is in non line of sight (NLOS) region. This paper aims in proposing a Salp swarm bio inspired algorithm for effective localization of the vehicular nodes which is in the NLOS region by utilizing the properties of meta-heuristic approach. The simulation results have proved that it has improved the emergency message delivery rate, neighborhood awareness and minimized latency when compared against the existing works.

Keywords Vehicular adhoc networks · Intelligent transport system · Salp swarm · Non line of sight · Meta-heuristic

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1 Introduction

The usage of car in this decade has been increased greatly in 2019 around 75 million new cars has been sold as per the world statistical report. As per the data's of World Health Organization (WHO) approximately 1.35 million people die in a year due to the road traffic crashes. Drivers are more susceptible in traffic as they must be aware of the maps in close proximity while driving [1]. The unawareness of the maps by the driver will result in deadly road accidents.

To design a secure and ease driving atmosphere and to support more vehicular applications the VANET networks were introduced [2, 3]. The most desirable application of VANET is the safety related application [4]. For supporting the safety related applications such as broadcasting emergency messages dedicated short range communication (DSRC) is used. The DSRC collects the information of the vehicles like their speed, the direction in which the vehicles moves and geographical coordinates of the vehicles [5]. The emergency messages must reach the neighboring vehicles within stipulated time in the networks in order to avoid traffic accidents.

In the road intersection scenarios the received signal strength is found to be degraded due to presence of either the static obstacles like huge trees and buildings which is present in the road side or due to dynamic obstacles like large vehicles like truck. This disrupt in the communication channel creates non line of sight (NLOS) situation, the vehicles may not be aware of the location information of the approaching vehicle as the broadcasted emergency message will be delayed or dropped due to the presence of obstacles [6, 7]. Figure 1a depicts the scenarios of line of sight where the two vehicles where in direct line of sight and where able to disseminate the emergency messages.

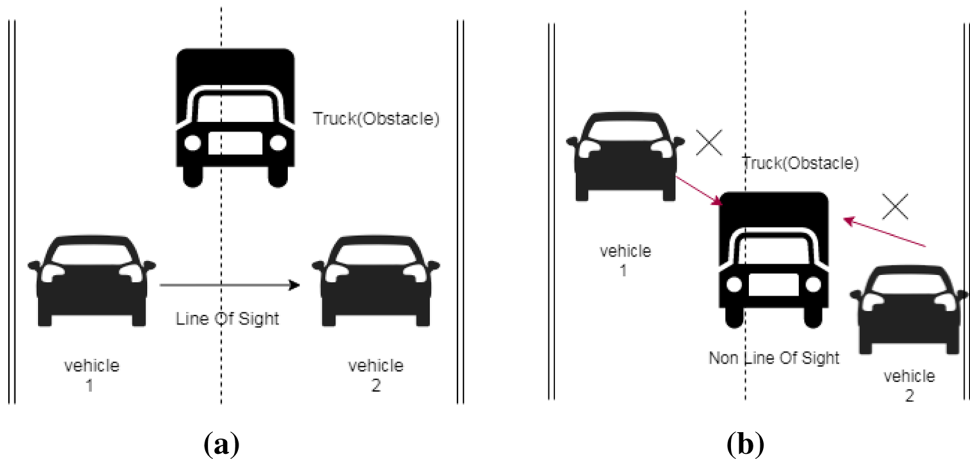

Fig. 1 **a** Line of sight situation 1, **b** non line of sight situation

Figure 1b depicts the NLOS situation where vehicles where obstructed by truck (obstacle). So the emergency messages between the vehicles cannot be transmitted and it leads to an NLOS situation.

The vehicular adhoc network utilizes multiple transmitters and receivers for transmitting the emergency messages between the vehicles [8]. The VANETs uses IEEE 802.11p standards to avoid packet collision. But packet lost during transmission is found to be comparatively high. The CSMA made use of repetitive transmission method for relaying the lost packets. But the emergency message cannot be transmitted within the bound time period.

Network coding (NC) was used to improve the message retransmission but it is found to have a drawback it doesn't consider the lifetime of the packet [9, 10]. The NC works on NLOS but only on a highway scenario but not on other types scenarios like road intersection where NLOS has occurred. This paper provides a key contribution namely Salp swarm bio inspired algorithm (SASBA) in node localization for all scenarios. This algorithm is designed mainly based on the bio inspiration of Salps behaviour which belongs to the Salpide family [11]. It resembles similar to that of the jelly fish in terms of resemblance and locomotion. It exhibits swarming behavior. Salps forms a group called Salp chain in deep seas. This formation achieves the best movement using rapid harmonized changing and foraging. The Salp formation has two classes one is leader and remaining are followers. The leader helps in identifying the food and the followers will follow the leader's movement. Based on this inspiration the SASBA is used for localizing the vehicles which is in NLOS regions.

The major highlights of this paper includes: (1) Salp swarm algorithm helps in better localization of the vehicular node by using exploration and exploitation phenomena which is said to be an added advantage. (2) This proposed approach is not range based approach which helps aids in narrow down of the position of the vehicles as the vehicles tend to change its position frequently. (3) The Salp swarm algorithm is found to have an increased emergency message delivery rate, neighbourhood awareness rate and minimized latency which helps to deliver the emergency message to the drivers to take correct decisions and collision can be avoided.

The rest of the paper is organized as follows: Sect. 2 reviews about the literature review their pros and cons and the need of the proposed work. Section 3 briefs about the working principle of Salp swarm bio inspired algorithm. Section 4 discusses about the simulation environment and results observed after deployment. Section 5 concludes the work followed by future directions.

2 Related work

This section is going to discuss about the methods used by the researchers to localize the nodes and their merits and demerits.

Initially, Sastry et al. designed a secure light weight protocol [12] termed as Echo based protocol. It has an added advantage that it doesn't makes use of any cryptographic methods nor any type of time related synchronization methods thus it can be adapted in building low cost devices. This protocol helps in localizing the in region verification of about 80–90% position of the legitimate location claims.

Capkun et al. proposed a multilateral verifiable mechanism [13] it uses minimum three base stations to identify the position of the node. The multi-lateration identifies the position of the node with the help of three reference points generated. The distance is measured from three reference points to identify the position of the legitimate node. The major drawback of this approach is that it incurs high computation overhead by using three reference nodes.

Secure localization algorithm [14] was proposed by Anjum et al. it makes uses of nonce mechanism. The source node initially generates nonce packets at different power levels. These packets are transmitted by three reference nodes which are within the communication range. The nonce packet reaches the node which location has to be localized. The nodes receive the nonce and retransmit back to the generated node. Thus the anchor nodes help in effective identifying the distance between the reference node and the NLOS. This mechanism is found to be effective only if the nodes are dynamic and in the close proximity range.

Abumansoor and Boukerche [15] designed multihop location verification protocol (MLVP) which helps in verifying the vehicle which are been directly connected when the direct communication between the vehicle is not feasible. The neighboring vehicle helps in verifying the location of the vehicle and transmits the information to the requested verifier. When direct communication fails in retrieving the information of vehicle the MLVP is triggered and updates the neighborhood list of the vehicles. This mechanism has an added advantage that it provides data integrity of the information exchanged between the neighborhood nodes. The major con of this approach is that it assumes that at least one vehicle must be in direct communication of the verifier which is practically not feasible all the times.

Broadcasting emergency messages to the emergency vehicles in the stipulated time becomes a tedious task under congested environment, so Alodadi et al. designed an cooperative volunteer protocol based NLOS mechanism for effective detecting the NLOS using anchor nodes by adapting the concept of context aware approach which is been embedded in the onboard units which helps in analyzing the position of the desired vehicles by interacting between them and thus making suitable decision by avoiding accidents [16]. This mechanism has improved packet delivery ratio, channel utilization rate and increased neighborhood awareness. It is suitable in road way scenarios like highway and in road intersection.

The Antenna's has been used by Ren et al. [17] for verifying the position of the vehicle using the verification algorithm which computes the comparative position of the vehicles with respect to the neighboring vehicles. The vehicle makes use of group bit vectors and updates the information regarding its neighbors.

Filtering approach is been used by Yan et al. [18] to identify the position and verify its integrity using box counting approach on a grid plane. By analyzing the gathered information and plotting it over a grid. The grid which has the largest amount of information is selected and it is used for computing the position of the desired vehicle.

A sequential Monte Carlo scheme-based NLOS node localization scheme was proposed by Wang et al. [19] based on the merits of weighted Monte Carlo positioning process. This sequential Monte Carlo scheme exploited information pertaining to location broadcasted by the neighbouring vehicular nodes that are within the distance of two-hops. It used a minimized mean bounding box size which is shrinked to the maximum percentage of 87%, thereby reducing the scope of identifying the NLOS nodes in the vehicular network. This sequential Monte Carlo scheme was identified to be potent over the Distance Vector-Hop algorithm, since it shrinks the estimation of candidate locations with a ensured enhancement in sampling efficiency of 95%. It was also confirmed to maintain reduced communication and computation overhead with maximum accuracy under localization.

An orbit-based distributed NLOS node localization scheme was proposed by Fujita et al. [20] for exploiting the merits of connectivity constraints derived from the knowledge acquired by the maximum coverage vehicular nodes. This orbit-based localization scheme used the idea of connectivity graphs for potential exchange of information related to each vehicular node's range of communication.

From the related works it is analyzed that the position of the vehicles is which is identified during NLOS situations [21] is found to have drawbacks like high computational overhead, fixed number of anchor nodes is used to identify the position of the vehicle, hardware specific methods has been adopted which is cost effective and during the searching process in identifying the position of the vehicle it may get struck into local optima. So to improve the neighborhood awareness, channel utilization rate and minimizing the latency and to avoid the drawbacks faced in the literature, Meta Heuristic approach must be used in identifying the position of the vehicle.

3 Proposed bio inspired approach for NLOS identification

The meta-heuristic approach makes use of the exploration and exploitation intelligently. The exploration is used to identify the search space and exploitation is used to intensify the potential area of search. The Meta heuristic approach can be deployed to identify the position of the NLOS mainly due to the factor that it doesn't get struck into specific area of search space and it has some added advantage that it is not problem specific and it solves NP-complete problems [22]. Figure 2 portrays about different types of swarm under the meta heuristic approach.

Salp resembles as that of the jelly fishes because of their transparent body and it belongs to the family of Salpidae

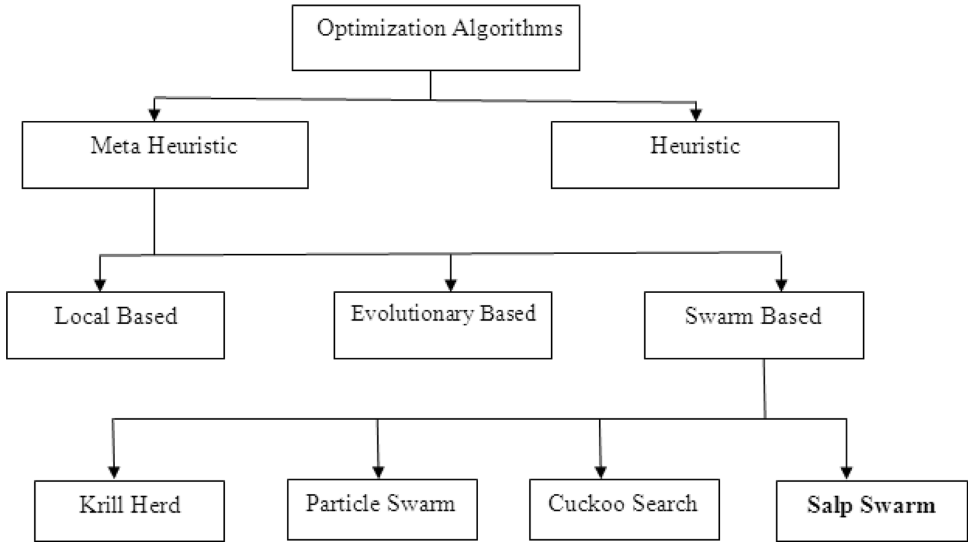

Fig. 2 Different types of meta heuristic approach based on swarm methodologies

[23]. Their locomotion is done by pumping the water as a result it moves forward. The biological researchers face a major hindrance in accessing them in the ocean and it is also very difficult to keep Salps under laboratory environments. The Salps exhibit the behavior of swarm called as Salp chain. Marine researchers believe that the swarm behavior is mainly exhibited for better locomotion [24]. This Salp swarm model is the inspiration behind in designing an effective node localization algorithm. Figure 3 depicts Salp swarm model. In Salp swarm models there will be two terms called leader Salp and follower Salp. The leader Salp helps in identifying the food source and all the other Salps i.e. follower will move in the direction of the leader. This model is found to have a problem that the global optimal for the solution is unknown [25].

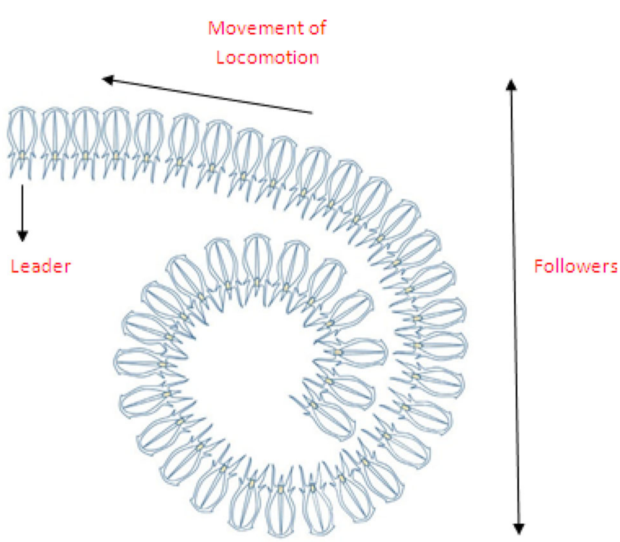

Fig. 3 Salp swarm model

It is therefore assumed that the best feasible solution achieved so far is the global optimal solution and the food source is chased in that direction by the Salp chain. The food source is updated during the process of optimization during exploration phase and exploiting the more the search space. So the Salp chain will move more towards the global optima during the iteration process.

The major highlights of the Salp swarm are namely;

- The Salp swarm algorithm provides the best solution in identifying the food source and it will get lost even the complete Salp chain weakens.
- The Salp swarm algorithm updates the position of the leader with respect to the food source (NLOS node). The leader Salp explores and exploits the search space which improves the neighborhood awareness rate with respect to the NLOS node.
- The Salp algorithm updates the position of the followers which is done by the leader Salp.
- The Salp algorithm during the course of iteration in identifying the position of the NLOS node first explores the search space and then exploits it.
- The Salp algorithm doesn't get stagnated into local optima.

Here the food source is the NLOS node which is to be identified by the leader Salp in the chain.

3.1 Salp swarm bio inspired algorithm (SASBA)

This algorithm is mainly designed based on the inspiration of existing swarm optimization algorithms like bees, ants and fishes which is used for solving optimization issues. This mathematical approach is mainly designed to identify the position of the NLOS nodes in the VANET environment. The NLOS situation might occur as result of partial

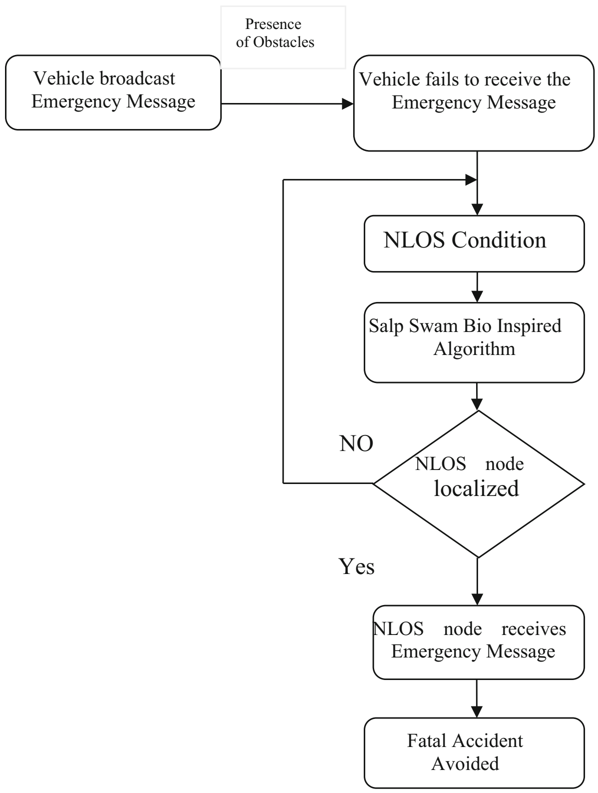

Fig. 4 Architectural view of NLOS detection

or complete obstruction in the path of propagation of signals. The obstruction can be a static obstacle like trees or tall buildings present in the road side which is obstructing direct communication or it can be a dynamic obstacle like trucks and large vehicle obstructing the communication of emergency message to be disseminated to the emergency vehicles which is approaching.

The emergency messages have to be reached to the destined vehicle within stipulated time. If the emergency messages are not delivered in the stipulated time drivers may take wrong conclusion resulting in fatal accidents. So in VANET environment at most care must be taken in disseminating the emergency messages and identifying the position of the NLOS nodes.

To design a mathematical Salp chain, the population is categorized into two namely leader and followers [26]. The leader is the front portion of the Salp chain and remaining Salps are considered as followers. The leader helps in identifying the position of the NLOS node. The followers are considered as the neighboring nodes. The Salps positioned in an m dimensional search space where 'm' is the variable for the given problem. The position of the scalps is represented in a matrix 'a'. It is assumed generally that the NLOS node named 'n' is in the search space of the swarm target. The fitness of each Salp is calculated to identify the Salp with best fitness in order to select the leader and the leader position is updated using Eq. 1.

The position of the leader is updated using Eq. 1

$$a_j^1 = \begin{cases} n_j + c_1 + \left(ubd_j - lbd_j\right)c_2 + lbd_j, c_3 \geq 0 \\ n_j - c_1 + \left(ubd_j - lbd_j\right)c_2 + lbd_j, c_3 \geq 0 \end{cases} \tag{1}$$

where a_j^1 denotes the position of the leader in the jth dimension and n_j denotes the position of the NLOS nodes in the jth dimension, ubd_j indicates the upper bound of the jth dimension lbd_j denotes lower bound of the jth dimension in the network and c_1, c_2 and c_3 denotes the random numbers.

The c_1 random number helps in balancing helps in balancing the exploration and exploitation which is defined in the Eq. 2. From the Eq. 1 it is quite evident that the leader only updates the position of the NLOS node:

$$c_1 = 2e^{-\left(\frac{4l}{L}\right)^2}. \tag{2}$$

So, L denotes the maximum number of iterations and l denotes the current iteration of the search process in identifying the position of the NLOS. The variables c_2 and c_3 are random numbers which will take the value in the range between 0 to 1.

Next the followers position i.e. the neighboring vehicles position has to be updated that is done using the Eq. 3:

$$a_j^i = 1/2at^2 + v_0t \tag{3}$$

where a_j^i shows the position of the ith follower in the jth dimension and the variable t denotes the time period and v_0 denotes the initial speed of the vehicle.

Where the value of $a = v_{final}/v_0$ and $v = x - x_0/t$. In optimization generally the iteration is denoted by time. So discrepancy between the iteration is represented by 1. Assuming that $v_0 = 0$. So this equation is represented as

$$a_j^i = \frac{1}{2}\left(a_j^i + a_j^{i-1}\right) \tag{4}$$

where $i \geq 2$ and a_j^i denotes the position of the ith follower of the Salp in the jth dimension.

Algorithm for Salp Swarm Bio inspired Algorithm (SASBA)

1. Initialize the population of Salp population a_i where i will take the values from i=1to n considering the upper bound and lower bound
2. While end condition is not met
3. Calculate the fitness for each Salp to identify the leader
4. F= the leader of the swarm
5. Update the c1 by Equation 2
6. For each Salp a_i
7. If (i==1)
8. Update the position of leading Salp (anchor node) by Equation 1
9. Else
10. Update the follower position(neighbor nodes) by Equation 4
11. End
12. End
13. Verify the position of the scalps based on upper and lower bound
14. End
15. Return F

The position of the NLOS nodes is identified with the help of leader Salp and improving the neighboring hood awareness rate with follower nodes.

Algorithm for NLOS localization using Salp Swarm

1. Initialize the NLOS nodes N_L , Anchor nodes M_A are in range of transmission.
2. Anchor nodes within the range of communication is considered as localized
3. The coordinates of the NLOS nodes are considered as (a, b) and D_n is the distance between the NLOS node and the Anchor node using Equation 5.

$$D_n = \sqrt{(a - a_i)^2 - (b - b_i)^2} \quad (5)$$

4. The error which occurred during localization while estimating the distance between the Anchor node and the unknown NLOS node as nodes tend move in the network is calculated using the function as shown in Equation 6.

$$f(a, b) = \min(\sum_{i=1}^{M_A}(\sqrt{(a - a_i)^2 - (b - b_i)^2)}^2) \quad (6)$$

5. The mean square error is been calculated between the coordinates of the actual (a_i,b_i) and the estimated node (m_i,n_i) coordinates of the NLOS node is determined using Equation 7.

$$E_D = \frac{1}{N_D} \sum_{i=1}^{D}(\sqrt{(a_i - m_i)^2 - (b_i - n_i)^2)} \quad (7)$$

Where N_D is the NLOS node

6. The Salp algorithm is used for localizing the NLOS nodes is evaluated between E_D and N_D
7. The NLOS position is been identified and localized if not the above steps has to be followed for localization of the targeted node.

In Fig. 4, it depicts the overall view of NLOS detection. When the emergency message is broadcasted between the vehicles the presence of obstacles will create NLOS situation where the intended vehicles fails in receiving the emergency messages. The position of the NLOS node has to be identified with the help of Salp Swarm optimization mechanism and the emergency message has to be broadcasted to the NLOS node in order to avoid fatal accidents. As in emergency situations the vehicles have very limited time period and the delay in the emergency messages will make the driver taking wrong conclusions resulting in loss of life.

In Fig. 5. It depicts about the workflow of the Salp algorithm in selecting the leader and followers node based on the fitness function used and the how the position of the Salps are been updated with the help of lower and upper bound. The Salp swarm algorithm which helps in identifying the position of the NLOS node and it is been disseminated to the intended vehicle with the help of leader and follower Salps.

4 Simulation results and analysis of the proposed SASBA scheme

SASBA is studied using the network simulator named EstiNet 8.1 that integrates data and management planes of IEEE 802.11p and EstiNet modular framework [27]. EstiNet 8.1 is the commercial type of NCTUns network emulator and a simulator, which possess a predominant number of registered users from 165 countries [28]. The performance of SASBA is implemented in the network

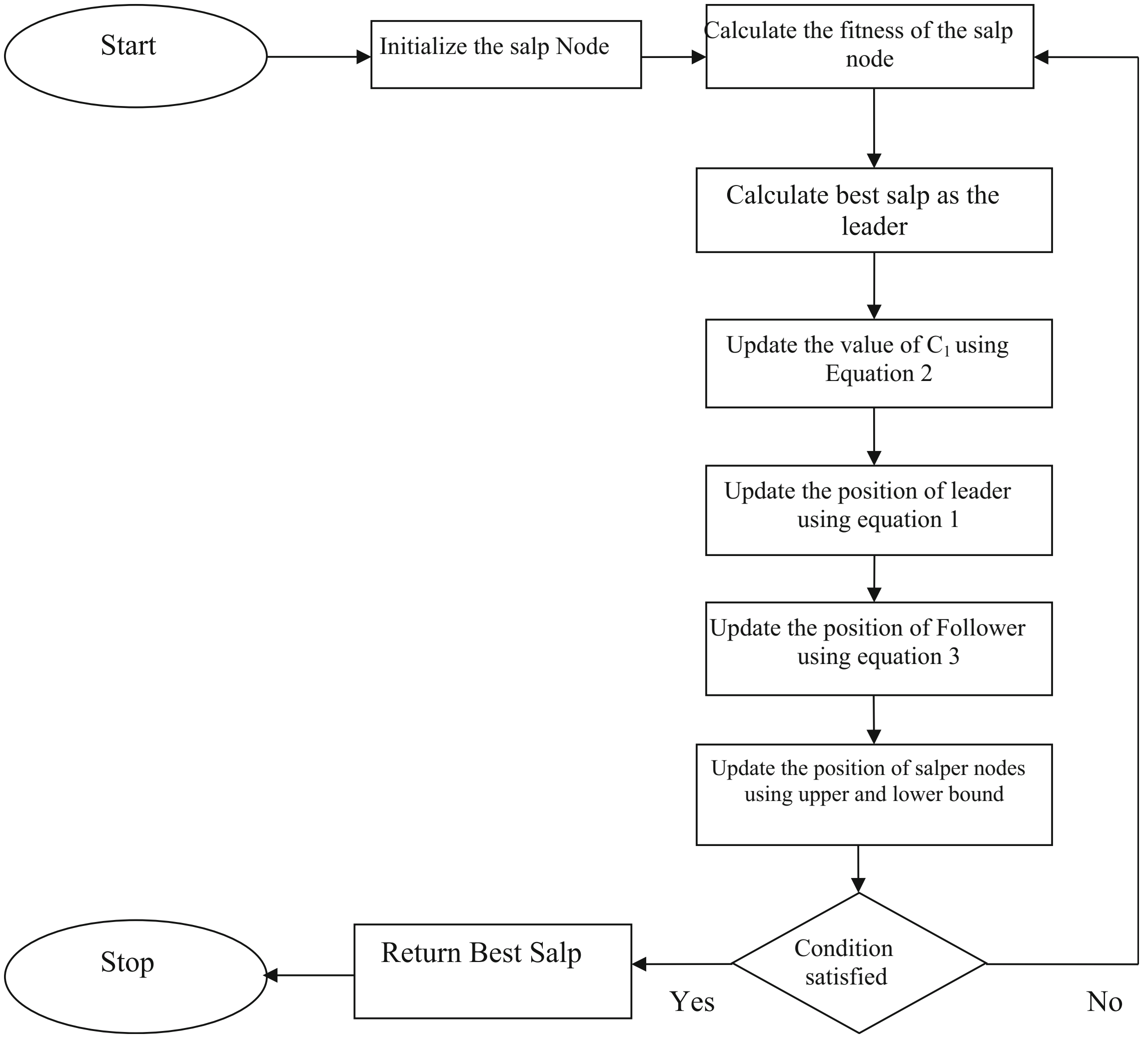

Fig. 5 Working illustration of Salp swarm algorithm

environment that consists of a maximum of 200 vehicular nodes uniformly distributed around the terrain area of 2000 m × 2000 m. In addition, the simulation parameter and its associated values used in the investigation of SASBA are portrayed in Table 1.

Table 1 Simulation parameters and values of SASBA

The parameters used for simulation	Values
Area of simulation	2000 m × 2000 m
Time of simulation	300 s
Range of transmission	250 m
Bandwidth used	12 Mbps
Maximum speed of vehicles	40 and 80 m/h
Size of warning messages	512 Bytes
Type of traffic	Constant bit rate (CBR)
Type of MAC protocol	IEEE 802.11p
Maximum number of vehicles	200
Type of mobility generator	Open street map

Initially, the potential of SASBA is studied based on rate of Emergency message delivery, neighbourhood awareness rate and latency under different number of vehicular density and number of anchors.

Figure 6. portrays the Emergency message delivery rate of SASBA when examined under different number of vehicles in the network is found to be predominant by 34, 29 and 23% when compared to SLA-NLOS, CVP-NLOS and MLVP-NLOS NLOS detection methods. The emergency message delivery is found to be crucial parameter to avoid the collision between the vehicles during the emergency and non emergency situations. The Salp Swarm algorithms using the merits of swarm intelligence approach were to deliver the emergency message within the stipulated time period. The SASBA method is found to have improved localization rate of 34% when compared to the mechanism SLA, CVP and MLVP.

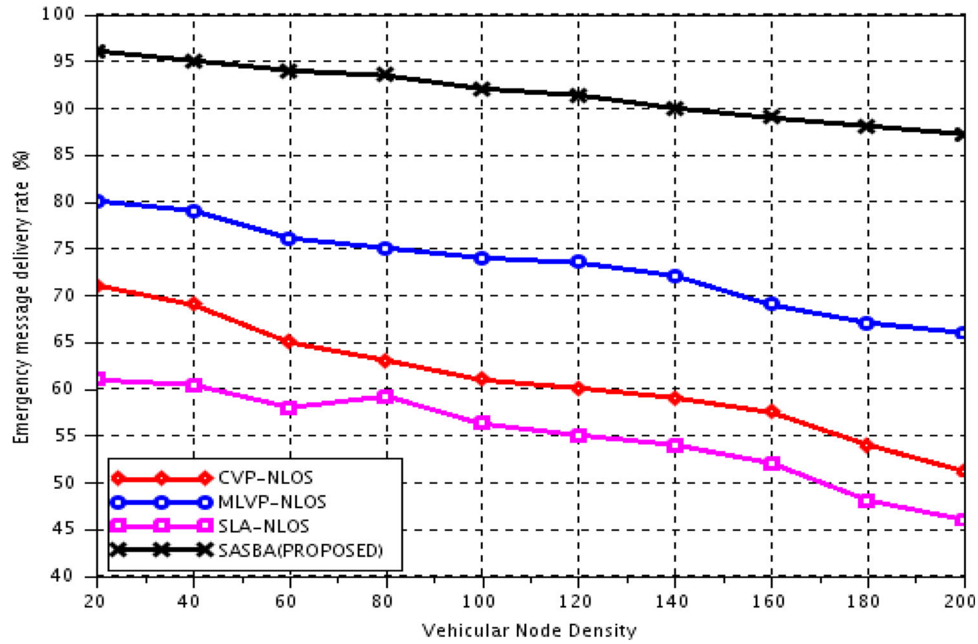

Fig. 6 SASBA emergency message delivery rate

Figure 7 portrays the neighborhood awareness rate of SASBA when examined under different number of vehicles in the network is found to be predominant by 35, 32 and 26% when compared to SLA-NLOS, CVP-NLOS and MLVP-NLOS NLOS detection methods. The neighbourhood awareness factor helps the nodes in the network to be aware about the neighboring nodes positions which will be helpful in transmitting the emergency message to the targeted nodes. The proposed SASBA method being a meta-heuristic approach it improvises the NLOS detection rate far better when compared against the bench marks chosen for evaluation. In Fig. 8 depicts the performance of SASBA is against CVP-NLOS, MLVP-NLOS and SLA-NLOS and is found to be minimize the latency which occur during emergency message delivery. The latency observed in delivering the emergency message using SASBA is found to be minimized by 29, 26 and 21% to MLVP-NLOS, CVP-NLOS and SLA-NLOS.

Figure 9 reveals the performance of SASBA based on the emergency message delivery rate under varied number of anchoring nodes. The emergency message delivery rate is highly influenced based on the rising number anchor nodes as the distance between the NLOS node and anchor node is normalized highly when compared to the existing

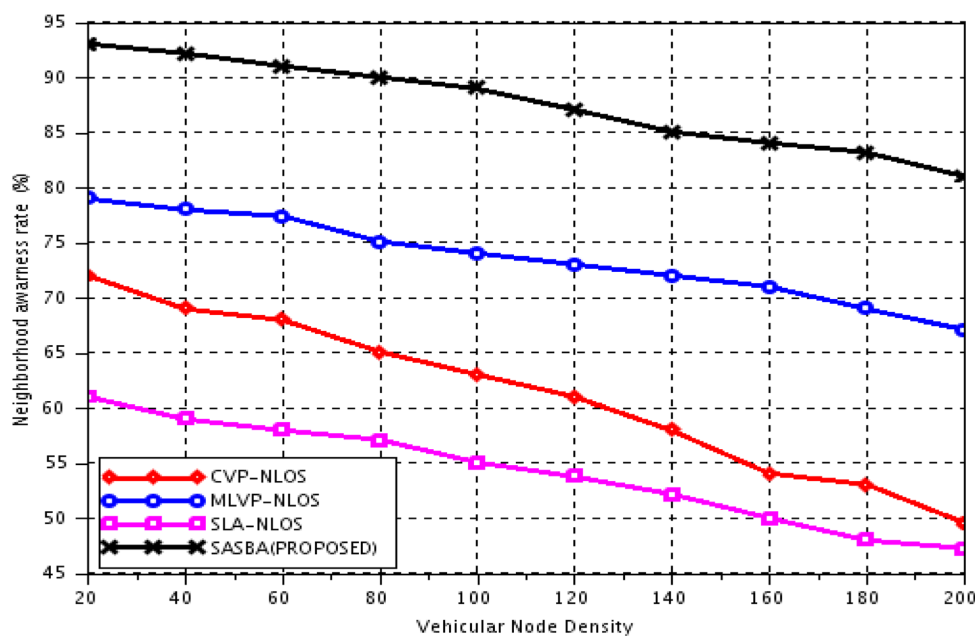

Fig. 7 SASBA neighborhood awareness rate

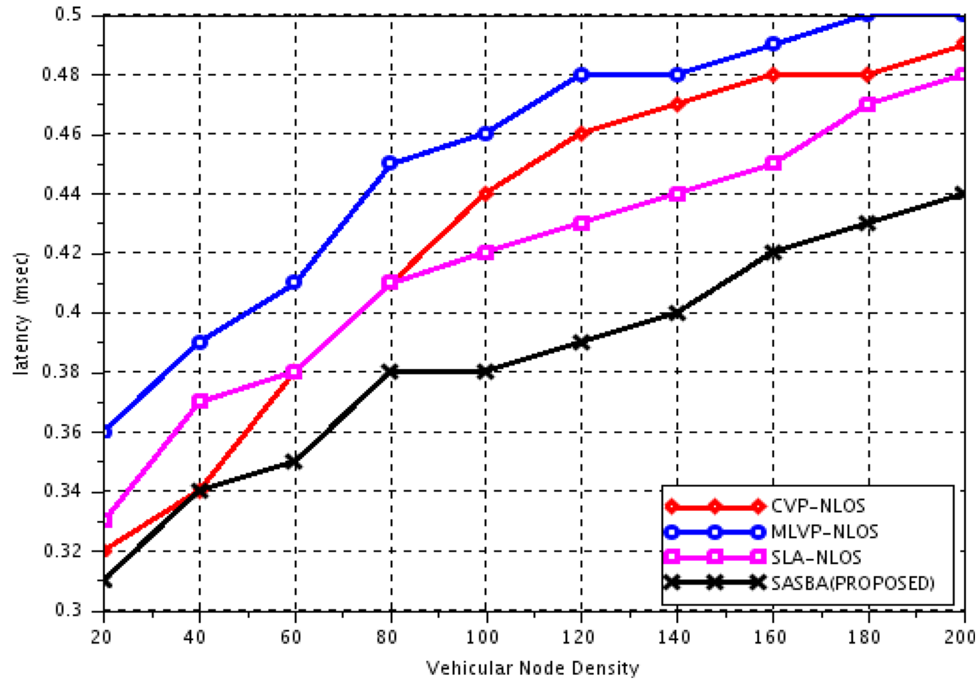

Fig. 8 SASBA latency against vehicular node density

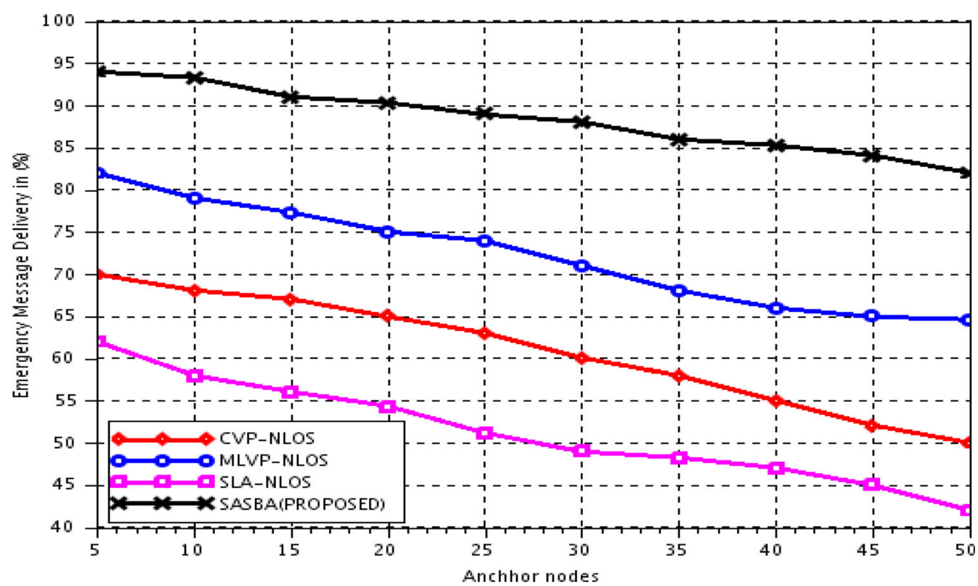

Fig. 9 SASBA emergency message delivery based on anchor nodes

works The emergency message delivery rate of SASBA is found to be superior by 29, 26 and 21% better to SLA-NLOS, CVP-NLOS and MLVP-NLOS. In Fig. 10 the performance of SASBA based on neighborhood awareness rate under varied number of anchor nodes. The neighborhood awareness rate is found to be improved by under increasing number of volunteer nodes as the distance between the NLOS and volunteer nodes is considerably reduced because of the increased number of anchor nodes. The SASBA is improved by 28, 24 and 22% when compared with SLA-NLOS, CVP-NLOS and MLVP-NLOS.

In Fig. 11 it depicts the performance of SASBA has outperformed the methods CVP-NLOS, SLA-NLOS and MLVP-NLOS by minimizing the delay which occurs in broadcasting emergency message packets. The SASBA is found to be superior in minimizing the delay by 31, 26 and 24% compared to MLVP-NLOS, CVP-NLOS and SLA-NLOS. The presence of delay will increase the arrival time of the emergency packet, as a result the delayed arrival of packet leads to wrong conclusion of the drivers resulting in accidents. The SASBA aids in better localization utilizing the meta heuristic approaches with minimum delay compared to it bench mark chosen.

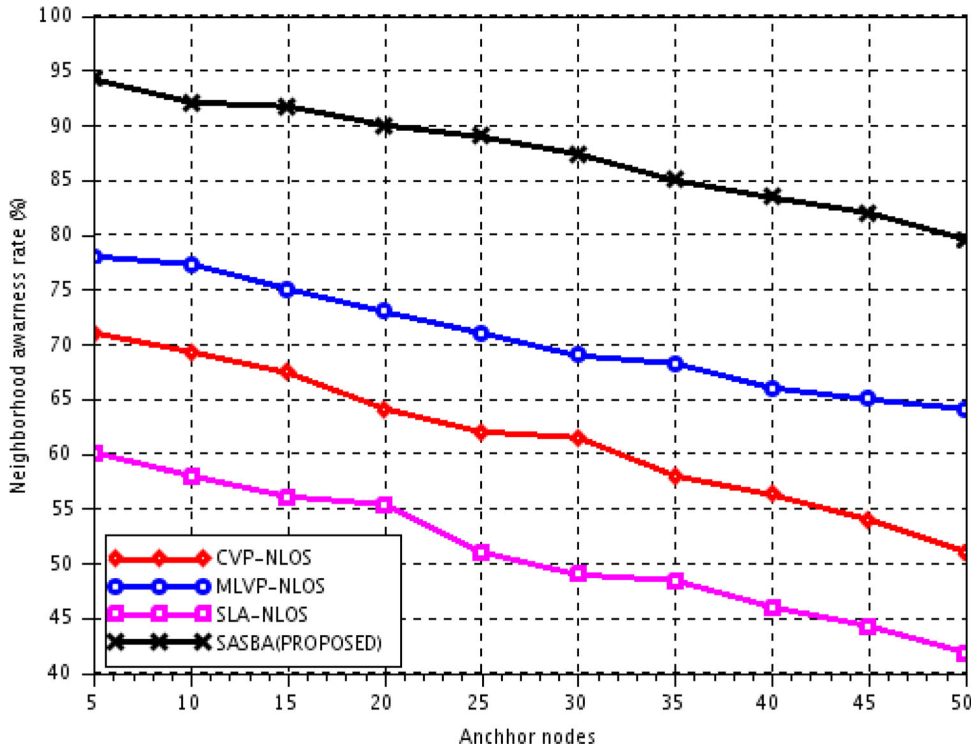

Fig. 10 SASBA neighborhood awareness rate based on anchor nodes

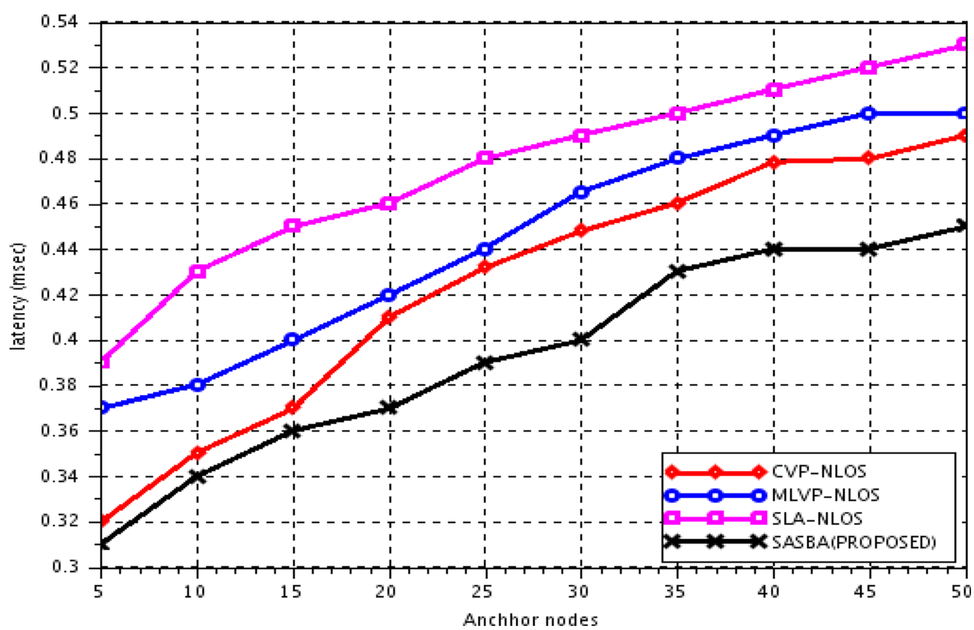

Fig. 11 SASBA based on anchor nodes

In Fig. 12 portrays how SASBA helps in better localization against MLVP-NLOS, CVP-NLOS, SLA-NLOS in increasing number of vehicular nodes. The proposed SASBA helps in better localization even in the presence of increased volunteer nodes because of the overhead is been minimized by the SASBA which is proven from the results. The NLOS detection rate is found to be improved by 7, 11 and 13% when compared to its baseline MLVP, CVP-NLOS, SLA-NLOS. In Fig. 13 it elevates the performance of SASBA over MLVP-NLOS, CVP-NLOS, SLA-NLOS when evaluated against vehicular density of the network. The latency is found to be minimized predominately for the SASBA because of the controlled exploitation in identifying the NLOS node. The latency of the proposed SASBA is found to be minimized by 4.7, 8 and 11% when compared to the bench mark chosen.

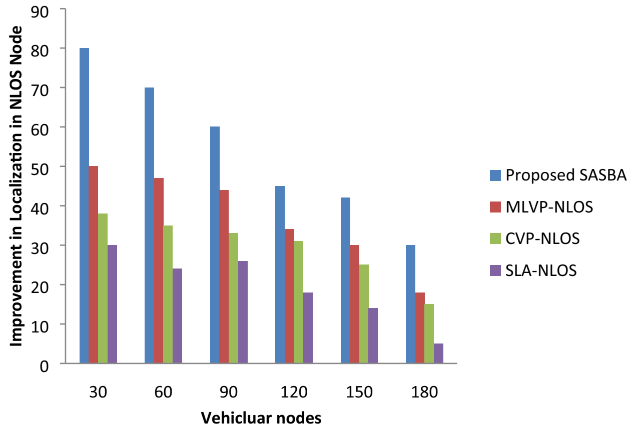

Fig. 12 Localization rate against vehicular nodes

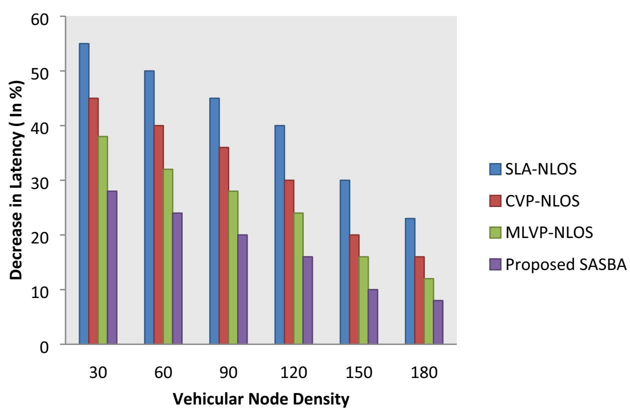

Fig. 13 Latency against vehicular node density

5 Conclusion and future enhancement

The SASBA has been proposed to improve the NLOS detection rate in VANETs as to enhance the features of road safety applications by improving the dissemination of emergency message packets to the destined vehicles within the stipulated time period. The emergency messages have to be delivered to vehicles even if the nodes are in NLOS situation as it involves human lives. The SASBA methods helps in localizing the position of the NLOS and also the emergency message delivery rate and neighborhood awareness rate is found to be improved when varied against vehicular node density and also under increased number of anchor nodes which is observed from the results. As a plan of future direction the SASBA can be used in wireless sensor networks for the purpose of localization and other bio inspired algorithms like ant colony optimization and bacterial foraging can be used in vehicular adhoc networks for the purpose of localization and their merits and demerits can be analyzed.

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