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Research Article

Army Ants inspired Swarm Intelligence and Stigmergy based approach for QoS Routing in VANETs

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Abstract

Vehicular Ad hoc Networks (VANETs) are the network of vehicles, well known as VANETs, a prominent research domain among the researchers and academicians due to its significant applications in Mobile Ad hoc Networks. Attaining the Quality of Services (QoS) in real-time routing is a crucial challenge in the VANETs research. In this paper we have proposed a Swarm intelligence and Stigmergy based approach inspired by the life of army ants. The simulation is implemented using NS-2.35 and SUMO to analyse the performance metrics like Packet delivery ratio, end-to-end delay, throughput and control overheads. Our simulation results outperforms in terms of Packet delivery ratio throughput and lesser delay.

Keywords: VANETs, Ant Colony optimization, Swarm Intelligence, QoS in VANETs, QoS Routing Protocol.

1 Introduction

The network consists of moving vehicle nodes in a dense/sparse traffic on an urban or a city traffic scenario, where each vehicle node is associated with sensors that enables communication among the vehicles (V-V) and roadside infrastructures (V-I), real-time monitoring of the traffic flow, emergency message broadcasts, data transfer, entertainment and infotainment applications, etc. Even though the characteristics of MANETs and VANETs are very similar, VANETs are distinct from the MANETs because of their subsequent topology changes as a response to the changes in mobility, distance, location, speed of moving vehicle and the type of communication device associated with the vehicle node [1]. VANETs have to make spontaneous decisions according to the changes in the network of vehicles where abundant vehicle nodes may join or leave the network inappropriately [2]. Abrupt changes in VANETs behavior should not degrade the performance and instead it must provide reliable service to all the available nodes and roadside infrastructures without compromising the Quality of Services (QoS). Several attempts are made by the researchers to address the implementation of VANETs routing protocol, but the challenge to fulfil the QoS requirements are still miserable.

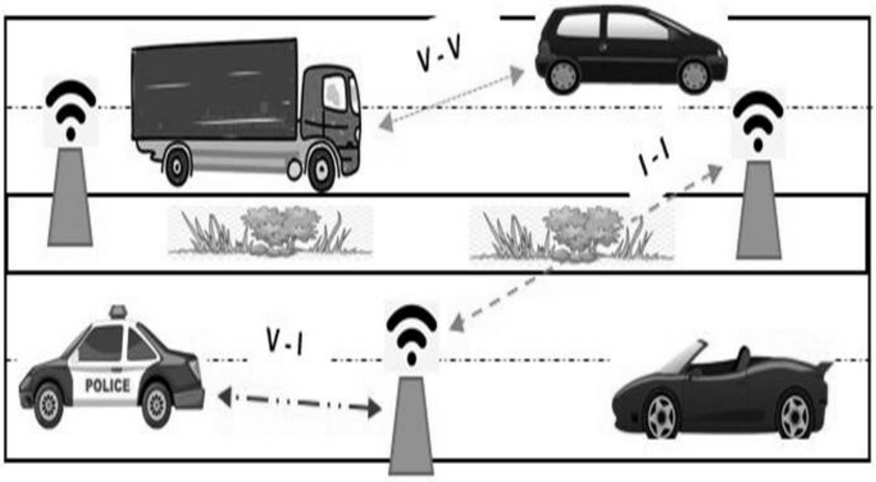

Fig. 1. V-V, V-I Communication

1.1 Motivation to the research work

It is believed that the nature has the capability to provide solution for almost all the computational problems, especially in networking by implementation of swarm intelligence (SI) [3].

Ant Colony Optimization (ACO): A probabilistic optimization technique utilized by the colony of ants to discover the shortest route to the location of food, with the assistance of pheromone trails and communication among ants. [4]

Bee Colony Optimization (BCO): A meta-heuristic optimization technique used by the honey bees to randomly find out the food source and intimate the inmates in the hive for nectar, availability, quantity, quality and its location through coordinated communication. [5]

Particle Swarm Optimization (PCO): An iterative meta-heuristic optimization technique based on birds in its flocks, which were considered as particles, attempts to find better solutions through the social behavior of particles. [6]

Bacterial Foraging Optimization (BFO): A population based optimization technique that explores and exploits the space over its foraging behavior through bacterial chemotaxis. [7]

Whale Optimization (WO): An optimization algorithm based on foraging strategy of humpback whales by bubble-net feeding and encircling methods. [8]

To analyze the performance of VANETs, the routing protocols must be optimal and satisfy the Quality of Service (QoS) requirements. Hence, this paper presents the review on works by researchers related to the implementation of nature-inspired Swarm intelligence in Section 2, followed by the proposed work in section 3, simulation and performance analysis by comparing its performance with the other protocols in section 4. Finally, section 5 describes the conclusion and the future work.

2. Related Work

As a solution to the VANETs routing problems, Ouahmani et al. [4] proposed a bio-inspired model to establish the cooperative and collaborative control routing among the moving vehicle nodes (or ants) using Ant Colony optimization (ACO). ACO, a population based SLS (stochastic local search) model that uses the pheromone traces to establish communication among the vehicles (ants). The concentration of pheromones decides the direction and time of the trace deposited by its smell or taste at certain period, during foraging or path discovery process. Similar scenario is considered in VANETs using V-ant algorithm to trace vehicle movement information to the path discovery process to desired destination and upon successful reach of destination, the complete path is cached for further communication, gave better throughput and reduced end-to-end delay when compared with performance of other protocols. Lagraa, Nasreddine et al. [5] Proposed a fuzzy-based, bio-inspired QoS compliant routing approach for VANETs using ABC (Artificial Bee Colony) optimization. Fully-logic was used to pick out the feasible path in terms of cost also, satisfying the QoS metrics. The performance was better in terms of PDR and delay despite of its control overheads.

L. T. Jung et al. [9] proposed a QoS routing scheme based on Bee communication to discover the best route to food source from the beehive. The mobile agents (Smart, Route and Onboard Agents) forages from the base station or beehives aggregates the required information and relay them back to the base. The performance was better in terms of throughput and reduced packet loss. Kaviarasan, R et al. [10] implemented gray wolf optimization algorithm (WOA) to handle the obstacles faced during direct communication among moving vehicle nodes through Non-Line of sight (NLOS) communication. The work promises less latency and increased detection rate during communication. Harrabi, Samira et al. [11] proposed a swarm intelligence based routing protocol to determine the optimal route using particle swarm optimization (PSO) to improve QoS. The work generated less overhead and low packet loss in terms of performance.

3. Proposed Work

3.1 Army Ants and their Colony Optimization

According to Myrmecologists, Army Ants are an ideal ant's species from Eciton burchellii family better known for their predating behavior with their extremely long mandibles while foraging and preying to transport food for their colony [12]. The colony usually has Queen which lays eggs and manages entire colonial activities, male ants only meant for reproductive process and a large group of over 200000 blind female foragers or worker ants who works for the colony to build/repair the nest, forage for food and protect from intruders. Army ants deploys swarm intelligence through pheromones and stigmergy. Pheromones are chemical traces, available over 10-20 types, evaporates with respect to time, are secreted by sternal glands in head, thorax, gaster or legs of army ants, which are used for collective and distributed food search by the population of army ants. Forward foragers leaves the deposits of pheromone traces along the path they travel, which helps the followers leaving the colony, to decide on direction based on its concentration by its smell/ taste sensed through its antenna. Foragers senses the pheromones, makes decision and leave traces. The backward foragers leave more concentrated pheromone traces on the way back to their colony, as these assists in reaching the confirmed destination to food to conduct swarm raids. Stigmergy is an approach for indirect communication among the population. Lifecycle of army ants exists either in stationary phase where queen overlays egg, colony stays in fixed location and nomadic phase where entire colony is on move along with queens in order to prey and feed to growing larvae.

3.2 The Model

In our proposed AASISQ (Army Ants inspired Swarm Intelligence and Stigmergy assisted QoS Routing) protocol, swarm intelligence using Ant Colony Optimization (ACO) assisted with Stigmergy approach to have coordinated communication among the population of available moving vehicle nodes. Army ants are considered because of its foraging behavior in which the ants preys whatever comes in its way to reach its destination. The network consists of Source node SVN and Destination vehicle node DVN, intermediate vehicle nodes and the Road-side Units at road intersection and also across the road path acting as intermediates in the absence of intermediate vehicle nodes. Each vehicle node is assumed to have installed with a GPS device for tracking its location and calculating the distance covered and both vehicle nodes, RSUs are assigned a unique identification number.

There are two variations of routing tables maintained, where the moving vehicle nodes maintains table with node id's of neighbor vehicles, its distance using GPS location, relative speed, the timestamp to decide the pheromone threshold value as mentioned in table 1(a) and RSUs maintains table with node id's of neighbor vehicles, its distance using GPS location, type of intermediate node (vehicle node/RSU), relative speed, the timestamp, hop count and calculated pheromone value as in table 1(b).

Table 1(a). Routing table at Vehicle nodes

Node ids	Distance d	Speed	Timestamp

Table 1(b). Routing table at RSU's

Node ids	Distance d	Intermediate type	Speed	Time stamp	Hop count	Pheromone Value (CP(n)

Forward Foraging for Path discovery: Before any transmission, the source vehicle node SVN checks for existing route information from the neighbor RSUs or vehicle nodes, to reach the destination node DVN. If available, establish communication and starts transmitting data. If route to DVN is not available, create an Onward Forager Army Ant (OFA), broadcast or multicast to the available neighbor or RSU's in its communication range. The neighbor nodes are chosen based on the probability of pheromone concentration amount $CP(n)$ (latest routing data) at intermediate node or RSU n1 and Euclidian distance 'd' between the current node i and neighbor vehicle node n1 among k set of neighbor nodes using the formula [13], [14].

$$CP(\mathrm{n}) = \frac{p(n)*d(i,n)}{\sum_{k=1}^{n} pk} \qquad \text{--- (1)}$$

Where $p(n)$ is the pheromone amount at node n, $d(i,n)$ is the Euclidian distance and $\sum_{k=1}^{n} pk$ is the aggregate of pheromone of all neighbor nodes among k set of nodes.

The pheromone amount is estimated based on the latest routing information updated at intermediate node with respect to time stamp. The protocol utilizes the Euclidian distance among the nodes or intermediates with an attempt to use simple shortest path routing to attain QoS with high throughput and less delay. In familiar cases, RSU intermediates are assumed to have better pheromone concentration because of its stationary behavior. In the absence of RSUs in cases like rural environments, the ongoing vehicle nodes will acts as intermediates and will carry information to the next available RSU and/or a vehicle node in its range, whichever is the nearest. The OFA will have information like time stamp of its creation, source address, destination address, Ant sequence number, threshold time value (T_{th}) and stack of pheromone traces on intermediate node type whether it is a moving vehicle node or stationary RSU, intermediate node id, hop count, speed and position with its time stamp.

The Algorithm for AASISQ protocol

Input: All nodes (including intermediate vehicle nodes and stationary RSUs) maintaining neighbor table and the pheromone table

Neighbor table - list of neighbors and Euclidian distance from current node to respective neighbor node

Pheromone table- routing information to all reachable nodes with time stamp of when it was updated

Output: High concentrated pheromone values with confirmed route information from Source vehicle node SVN to Destination vehicle node DVN

Forward Foraging for Path discovery

At SVN, before any transmission, check for existing route information from the neighbor RSUs or vehicle nodes in its range, to reach the destination node DVN

If available,

Establish communication and starts transmitting data

Else

Create an Onward Forager Army Ant (OFA),

Broadcast or multicast OFA to available neighbors or RSU's in its communication range.

Next neighbors are calculated using the formula --- (1)

End if

OFA at intermediate nodes and on reaching at DVN: On arriving at the intermediate neighbor RSU or vehicle node, check (sense pheromone) for the available route to destination and if available adopt it (make decision). Else, exhibit the behavior of Foraging ants by leaving the pheromone traces at the intermediate nodes and start multicast or broadcast to its neighbors. When the OFA reaches the DVN,

DVN checks and compare the time stamp value with the threshold time value (T_{th}) to calculate the delay. If time stamp value is lesser the threshold time value (T_{th}), convert the OFA as BFA (Backward Forager Army Ant). If time stamp is greater the threshold time value (T_{th}), kill OFA. The BFA will have information like source address, destination address, Ant sequence number and stack of recorded pheromone traces on intermediate node type, intermediate node id, hop count, speed and updated position of vehicle nodes.

OFA at intermediate nodes

On arriving at the intermediate neighbor RSU or vehicle node

  If pheromone information available (sense pheromone)

    Adopt it (make decision)

  Else

    Exhibit behavior of foraging ants (leaving pheromone traces)

    Find the next intermediate nodes and start multicast or broadcast to its neighbors, until DVN found

  End if

OFA on reaching at DVN

If time stamp value of OFA < threshold time value (T_{th})

  Convert OFA as BFA (Backward Forager Army Ant)

Else

  Kill OFA

End if

Backward Foraging and Route maintenance: The generated BFA at DVN is broadcasted or multi-casted to the neighbor RSUs or vehicle nodes in the desired path back to SVN. The intermediate nodes receives (senses) the BFA, and validates (make decision) the received information with the existing information and update the new information through the stack of pheromone traces which increases the concentration in its routing table. The distinct behavior of Backward Foragers Army Ants is to release more concentrated pheromone routing traces while returning to its nest (Source) and following a disciplined lane to reach the destination. Hence, with the updated information, inactive vehicle nodes are deleted (evaporated) and high concentrated pheromone deposited (leave traces) at intermediate nodes.

When the SVN receives the BFA Army ant, validates the sequence numbers and initiates the data transmission to DVN. In this model, the pheromones are deposited at both neighbor RSUs and vehicle nodes. Still, as the RSUs are stationary, pheromone traces are always available at RSUs.

Backward Foraging and Route maintenance

Multicast or broadcast BFA to its neighbors, until SVN found

At each intermediate node, compare pheromone of BFA and OFA

If pheromone of BFA is highly concentrated,

Update /append confirmed route information to pheromone table and evaporate (delete) old pheromone deposits (inactive links) with particular id

End if

BFA on reaching at SVN

Validates the sequence numbers

Update pheromone table

Initiate the data transmission to DVN

4. Performance Evaluation

VANET Simulation models evaluates performance, predicts information through available data and makes decision based on these information. These models utilizes mobility models and mobility trajectory traces to analyse the vehicles node's moving patterns, location, velocity, variation in acceleration etc. Familiar mobility models for VANETs are random waypoint model, reference point group mobility model, freeway mobility model and Manhattan mobility model that are popularly used by the researchers.

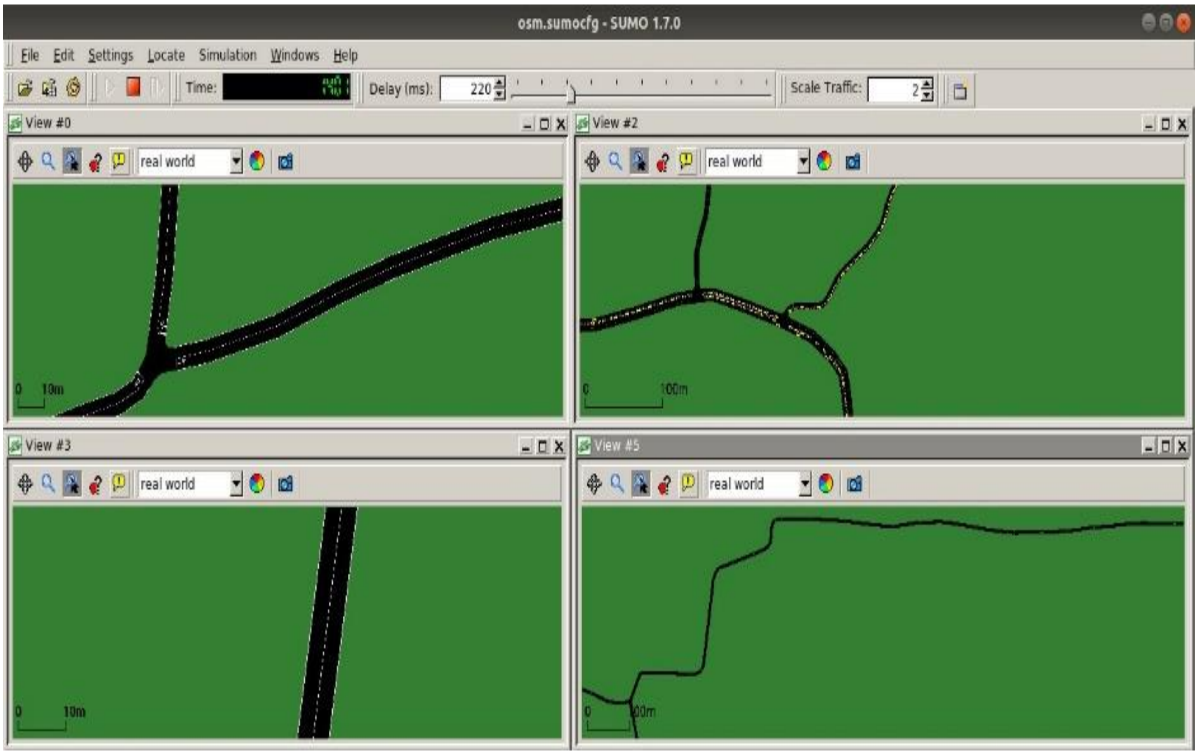

Fig. 2. AASISQ simulation in SUMO

In our proposed work, the simulation is experimented with NS-2.35, a discrete-event simulator for creating nodes, device and to implement the AASISQ protocol in an urban scenario [15]. SUMO in association with Open Street Map is used for simulating mobility of the vehicle nodes in a real-time urban scenario.

Table 2. Simulation Parameters

Parameter type	Value
Network Simulator	NS-2.35
Routing Protocol	AASISQ
Simulation Time	100s
Simulation Area	1000*1000m
Number of Nodes	50
MAC Protocol	IEEE 802.11
Channel Type	Wireless Channel
Antenna Type	Omni directional Antenna

End-to-End Delay:

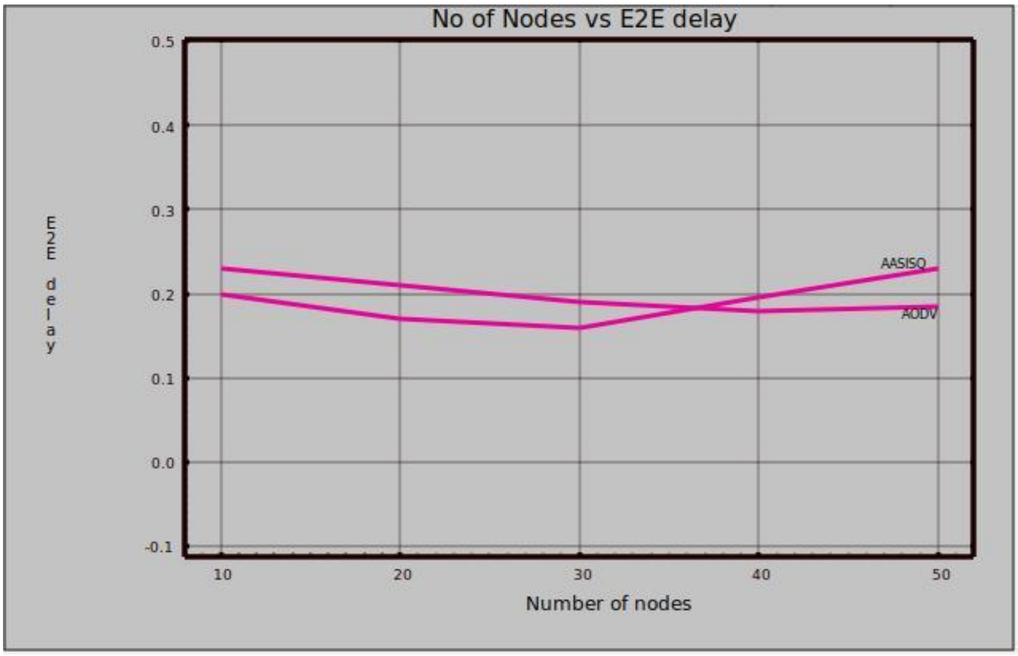

Fig. 3. No. of nodes vs E2E dalay

End-to-End delay is calculated as the ‘Number of links b/w nodes *(Transmission Delay + propagation delay + processing delay+ queuing delay)’.

Packet-delivery-ratio:

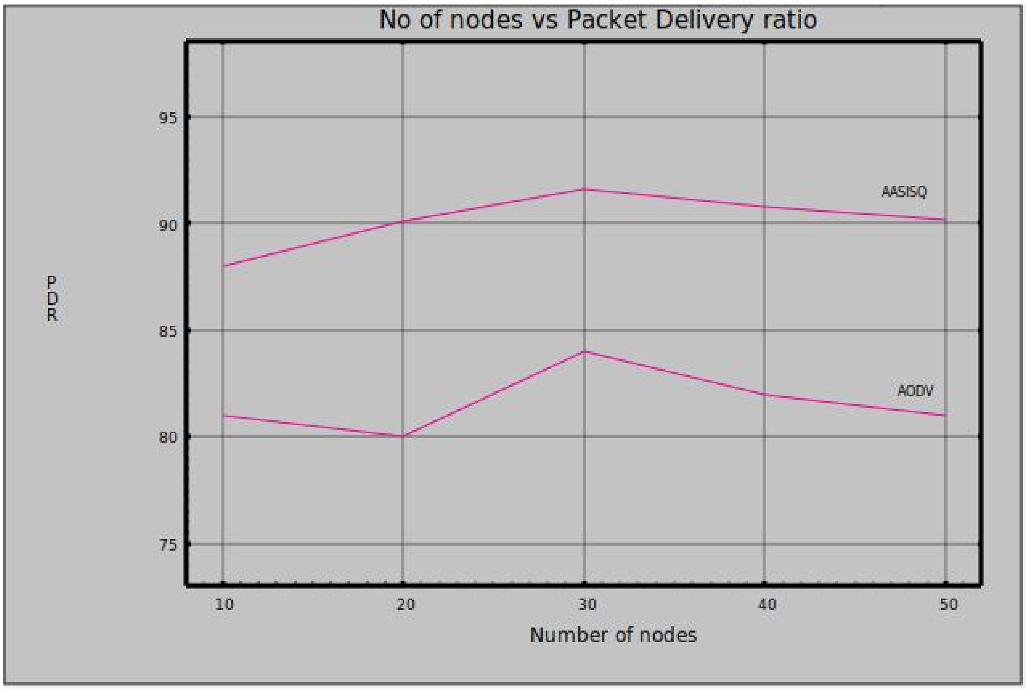

Fig. 4. No. of nodes vs Packet Delivery ratio

Packet Delivery ratio is calculated on the ‘Number of packets delivered/ Number of packets transmitted Number of packets delivered/ Number of packets transmitted’.

Control overhead is nothing but the ‘Number of control messages generated for route discovery and route maintenance’.

Throughput:

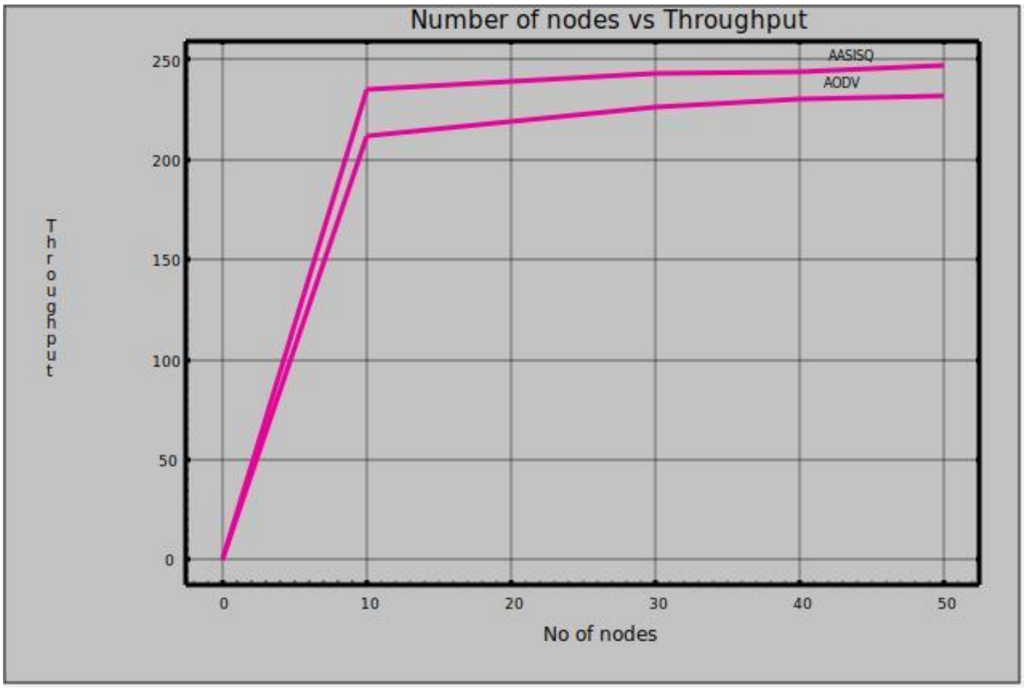

Fig. 5. No. of nodes vs Throughput

Throughput is calculated as the Number of packets delivered per unit time.

In all the simulation scenarios, the number of nodes considered was 50 vehicle nodes. The performance metrics from Fig. 3, 4, 5 shows AASISQ protocol is preferable than AODV protocol in terms of packet delivery ratio, throughput and end-to-end delay. As the routing overheads are directly related to the number of nodes, when the number of vehicle nodes increases, the overheads also increases.

4 Conclusion

In this paper, nature inspired techniques for solving the computional networks issues are studied and it motivated us to implement the Army Ants inspired Swarm Intelligence and Stigmergy based approach for QoS Routing in VANETs. The SUMO is used as the realtime traffic generator and OpenStreetMap is used to capture the local map and simulate traffic scenario in SUMO. Mobility file generated using SUMO is exported to NS2 to analyse the realtime traffic. The simulation results of the proposed protocol is compared with the performance of AODV protocol, which shows better formance in terms of throughput and lesser delay by achieving QoS, eventhough the rate of control overheads are high. As a future work, the performance of the AASISQ protocol will be compared with other protocols with a view to impart the other QoS parameters without conceding overheads.

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