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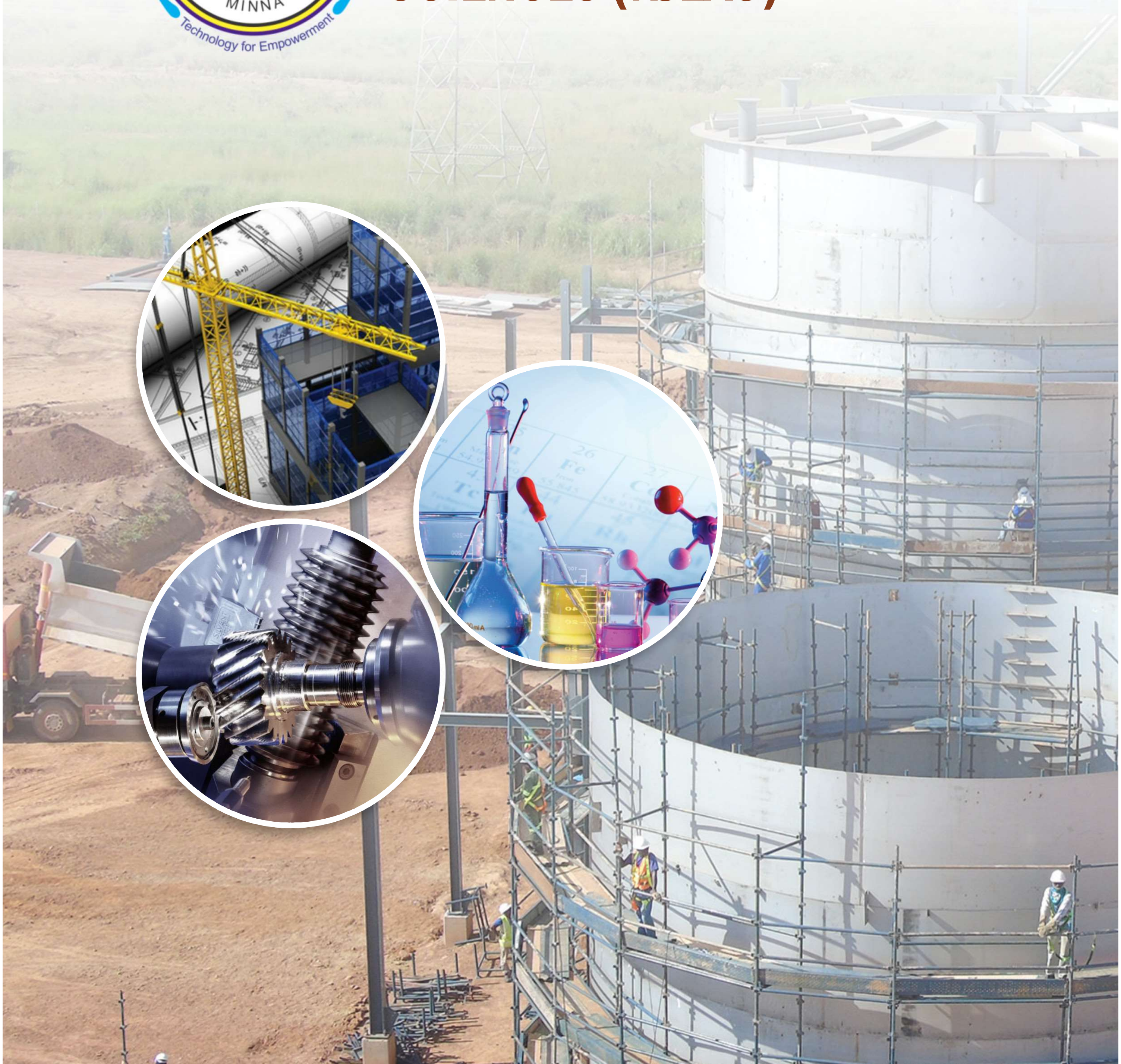

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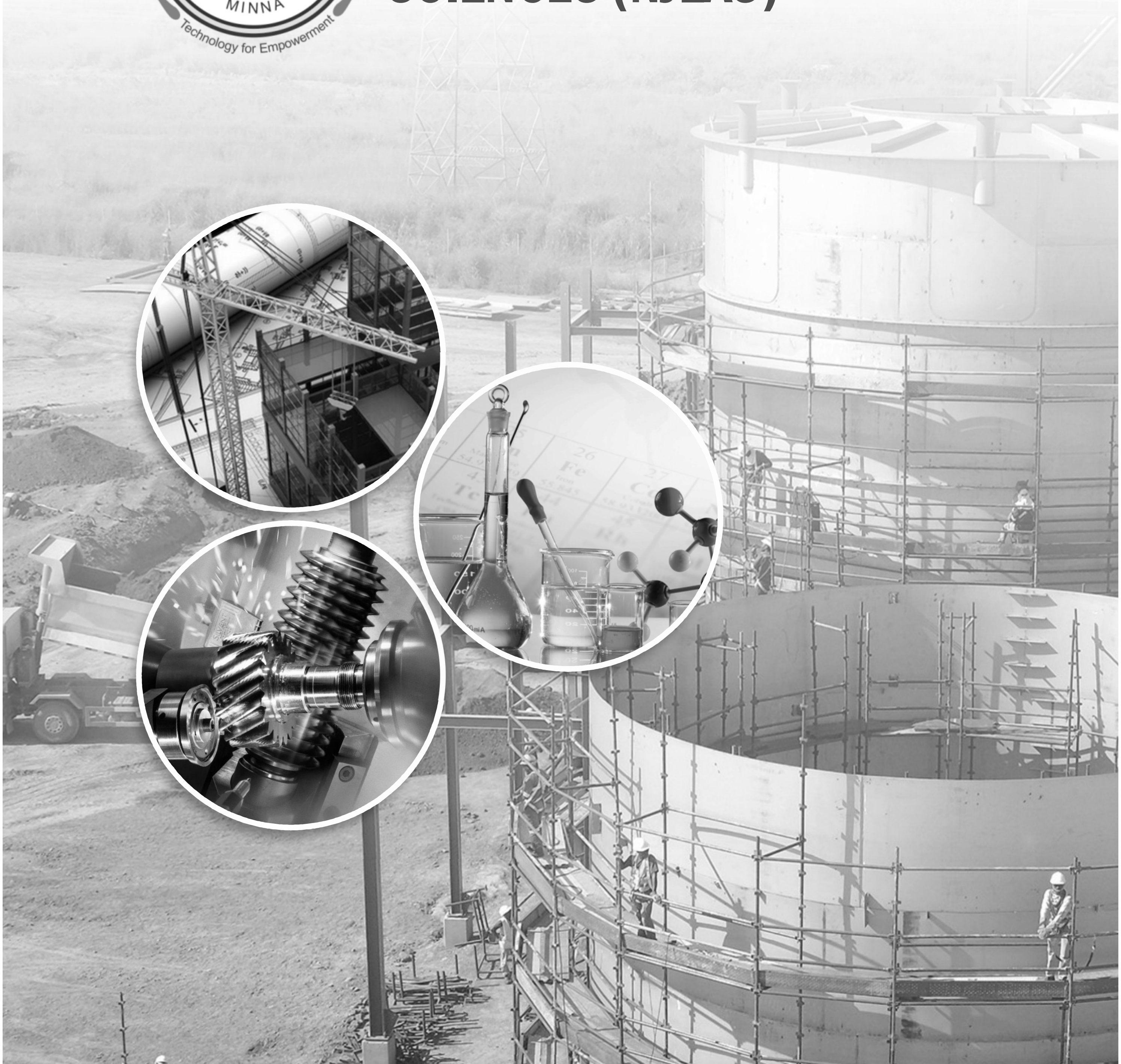

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TABLE OF CONTENTS

PACKET DELIVERY RATIO (PDR) OF AN ENHANCED WEIGHT BASED CLUSTER HEAD SELECTION ALGORITHM FOR ROUTING IN VEHICULAR ADHOC NETWORKS (VANETs)

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Abstract

Packet delivery ratio is the ratio of packet sent to packet received. It is one of the most important reasons why clusters are formed in the first place. In weight-based cluster head selection algorithm, the cluster head is selected based on the aggregate weights of the vehicles. Because of frequent topology changes in VANETs routing is a serious problem. In this work, an enhanced cluster head selection algorithm for routing has been proposed in which cluster head is selected based on aggregate weights of the vehicle. The algorithm was simulated on MATLAB for 40, 50, 60 and 70 nodes with a 0%, 11.4%, 26% and 28% improvement respectively in terms of packet delivery ratio (PDR) compared to the existing weight-based cluster head selection scheme. In evaluating the algorithm for 40, 50, 60 and 70 nodes, the average packet delivery ratio as sensor radius increased was 0.62, 0.57, 0.63 and 0.61 respectively.

Keywords: clustering, VANETs, weight, cluster head, v2i, v2v.

INTRODUCTION

Vehicular adhoc networks (VANETs) remains one of the disruptive technologies of the fourth industrial revolution. Vanets are a type of Mobile Adhoc Networks (MANETs) (Bhatia *et al.,* 2020), which are networks that are not permanently tied to existing infrastructure but are constituted by nodes forwarding packets among themselves (Karthikeyana & Usha, 2021). This makes it easy for small devices to communicate at close range (Grace *et al.,* 2020; Guo *et al.,* 2020). One of the fastest-growing research areas in the field of communication engineering is adhoc networks. Adhoc networks are temporary networks, they do not require a central entity coordinating them; instead, the communicating nodes are able to use tailored techniques to control communication among themselves. Vehicular adhoc networks (VANETs) are a category of mobile adhoc networks (MANETs), and are typically nodes on wheels, with mobility (Manoj and Charanjeet, 2019). Vehicular communications have emerged as an important application of wireless technology. Vehicular communication networks are an interconnection of vehicles to achieve autonomous driving. Vehicular Adhoc Networks (VANETs) could be Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Network (V2N), Vehicle-to-Devices (V2D) and generally, Vehicle-to-Everything (V2X) (Grace *et al.*, 2020).

In recent times, a trend in hybrid connectivity is fast emerging as seen in vehicle-to-vehicle-to-infrastructure (V2V2I) (Fuqiang and Lianhai, 2010). This implies that vehicles are not only communicating among themselves, or communicating with cellular towers but they communicate among themselves and with network infrastructure also referred to as road side unit (RSU) (Aljeri and Boukerche, 2017).Communication with network infrastructure allows vehicular clients access remote services(Emara *et al.* 2018; Huang*et* *al.,* 2020). Considering the limited capabilities of vehicles in terms of storage and processing, it is imperative that VANETS should be equipped with higher storage and processing capabilities. Alternatively, provisions are being made for storage and computation at the edge of the infrastructure (Wang*et al*., 2018; Wang *et al.,* 2020; Zhou*et al*., 2018). Fig. 1 shows the inter-vehicular communication and a vehicle to infrastructure connection. Inter-vehicular communication is made possible via direct short-range communication (DSRC), while V2I communication is made possible by wireless access in vehicular environment (WAVE) which consists of 802.11p protocol among several other protocols. (Nkoko & Kogeda*,* 2013; Zhou *et al.,* 2018)

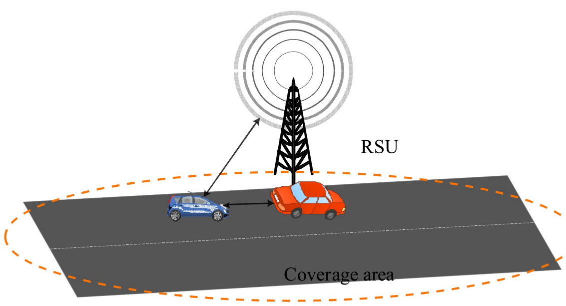

Fig. 1: Vehicle to Vehicle to Infrastructure Communication

Communication is possible in V2V networks using sensors. The Onboard Unit (OBU) is a network of sensors which are always in constant communication with other sensor nodes (Raza *et al.*, 2019; Storck and Duarte-Figueiredo, 2019). The VANETs perform such functions as vehicle diagnostics services, location information reporting, and communication with other vehicles and infrastructure, provision of safety information and monitoring for road users, information and entertainment (infotainment), traffic management and internet connectivity. Busari *et al.* (2019) proposed a generalized hybrid beam forming technique for connectivity in vehicular communication using massive Multiple Input Multiple Output (MIMO). A new parameter known as sub-array spacing was introduced. Varying this parameter, brings about different sub-array configuration and by extension, variations in system performance.

Clustering algorithms in VANETs group vehicles in each spatial location based on certain properties such as speed, direction of travel and lane identification (id). Clusters are managed by cluster heads, other vehicles within the vicinity of the cluster head assumes the status of cluster members. Packet transmission and reception from or to any member is done through cluster heads. The cluster head therefore serves as routers as in traditional computer networks. The cluster head forwards packets to RSUs within the vicinity of the cluster. A vehicle that must be chosen as cluster head must meet certain criteria. Several protocols are available in literature and major emphasis of these protocols is optimal cluster head selection which will reduce packet delay, maximize throughput and also reduce packet loss. Several challenges have been witnessed in the area of vehicular communications. One of such is cluster head selection in cluster-based communication (Duan *et al;* 2016, Ren *et al;* 2021).

Clustering has emerged as a means of disseminating information, in clustering in vehicular communications, vehicles are either cluster heads (CH) or cluster members. cluster heads are chosen on the basis of balanced parameters and enhanced functionality (Grace *et al*., 2020; Waleed *et al*., 2020), such parameters include speed, direction of travel, driver behaviour, inter-nodal distance and communication range. It is desired that a cluster have good stability, high efficiency, and reduced frequency of cluster head selection. Without loss of generality, cluster heads must have good ranking to be chosen as cluster heads. Cluster heads are required to coordinate inter cluster and intra cluster communication.

The IEEE 802.11p standard is a proposed standard which is meant to enable Wireless Access in Vehicular Environment (WAVE). The standard specifies operation in the 5.9 GHz frequency band. WAVE is composed of IEEE 802.11p and IEEE 1609.x. The IEEE 802.11p controls the physical layer and the medium access layer (PHY/MAC) while the IEEE 1609.x provides specifications for the control of upper layers. In the 1609.x family, IEEE 1609.3 specifies standards for transport and network layers. The 1609.4 documents specify standards for multi – channel operation. It is widely accepted in literature that in multi – channel operation, a WAVE system makes use of a single common control channel (CCH) and a number of service channels (SCHs) (Hu & Lee, 2022).

One of the major challenges of clustered communication in vanets is routing (Manoj & Charanjeet, 2019). Because of the frequent topology changes in VANETs, clustering is important because it helps to segment the network thereby reducing packet loss due to collision. This makes it important that efficient routing techniques be developed to cater for the rapid changes observed. The enhanced weight-based cluster head selection algorithm is a technique which selects cluster heads based on suitability index which is determined by the aggregate weight of all vehicles within the cluster. The algorithm also employs dynamic cluster sizing in improving packet delivery ratio when packets are routed from cluster heads to cluster members, since as vehicular traffic rises from low to moderate, network performance indicators such as packet delivery ratio is also affected. With this kind of algorithm, the network remains in optimum state even as vehicular traffic increases.

RESEARCH QUESTIONS

This work seeks to answer the following research questions.

1. How can weight-based cluster head selection techniques be improved to accommodate frequent topology changes?
2. What is the sensor radius within which packet delivery ratio does not deteriorate?
3. What should be done to keep packet delivery ratio from deteriorating as traffic volume increases?

REVIEW OF RELATED WORKS

The concept of packet delivery of cluster heads is gaining more attention in VANETs. The purpose of clustering is to segment communicating nodes according to certain features. Clustering in VANETs is quite complex due to frequent topology changes, hence several factors have to be considered when clustering in VANETs. Cluster stability besides cluster head selection becomes a thing of interest as well. Cluster stability is dependent on certain constraints and it is when stable clusters are formed that efficient routing can be achieved (Yassine & Salah, 2019).

In the work of Waleed *et al.*, (2020), an optimized node clustering algorithm in vanets was developed by using meta-heuristic algorithms. This algorithm used parameters such as node's direction, communication link capacity, network area, node density and transmission range. The algorithm is based on the grasshopper optimization algorithm (GOA) and mathematically modeled the swarming behaviour of grasshoppers. However, this algorithm is more suitable in high traffic areas. Ghassan, (2021) proposed an intelligent cluster optimization algorithm based on whale optimization algorithm for vanets. In this framework, an intelligent clustering approach was used to optimize the routing of packets in the vanets. The algorithm mimicked the behaviour of whales. This algorithm is however complex and several analyses are required to compute the performance metrics. Nivedita and Soumitra (2014), Ftaimi and Mazri (2020), surveyed the various cluster head selection techniques based on fuzzy logic, neural network and genetic algorithm. This work did not consider other algorithms apart from machine learning techniques. Cluster head selection routing algorithms should be implemented even without machine learning techniques. In Karthikeyana and Usha (2021), an adaptive clustering algorithm for stable communication in vanet was proposed. This algorithm combined weight based and neuro-fuzzy prediction by developing a static zone-based clustering and a k time zone base clustering, static time zones does not take to cognizance the frequent topology changes in VANETs. The scheme of Xiaoyu *et al.*, (2016) introduced a software defined networking (SDN) programmable network structure as an enabling platform to apply intelligence and control in 5G-vanet HetNet. The SDN controller has a global view of the HetNet so as to be able to execute clustering only when needed. The dual cluster design also guarantees seamless end-user data access especially when there is cluster head service disruption.

Mohammed *et al.* (2017) proposed a center-based stable evolving clustering algorithm with grid partitioning and extended mobility features for VANETs. This article proposes a Vehicle-to-Infrastructure (V2I) based clustering framework in vanet using a modified evolving clustering algorithm with adoption of the concept of the grid in vanet clustering for the first time. It has developed a novel traffic generator that includes in addition to driving behaviour, a novel lane changes probabilistic model. It proposes grid partitioning for the road environment before doing clustering, which makes it suitable for high density highways. It also proposes an extended mobility feature that combines in addition to relative position and velocity of vehicles, a relative acceleration which makes the clustering more dynamically aware of higher moments when mobility variables can be added. The algorithm is more suitable for cases where mobility is low and traffic density is high, it is not suitable for high mobility road traffic, this is because it employs grid partitioning.

Grace *et al.* (2020) proposed a vanet clustering based on weighted trusted cluster head selection, this proposed technique proposed a new clustering protocol with a unique cluster head selection process while still retaining the features of vanet clustering. The cluster head selection in this protocol is based on the weighted formula. The algorithm does not allow for dynamic cluster adjustment hence, packet delivery ratio deteriorates with increase in vehicles in a linear fashion.

In Sharma *et al.*, (2022) a weight-based based clustering technique was proposed by using a rhombus shaped network with an average speed and degree of suitability of each vehicle to determine the cluster head among a group of vehicles. The work used a transmission range of 150 – 200 meters for vehicles to be in a cluster. This work like that of Tambuwal *et al*., (2019) and Iskandarani, (2022), opined that the speed of vehicles is assumed to have a normal distribution. Iskandarani, (2022) further compared aodv to dsr routing protocols in clustered communication. It is however interesting to ascertain the behaviour of cluster head routing with varying node density. This will help in understand the tolerance that can be associated with cluster based communication in vanets.

According to Tambuwal *et al*., (2019), in "Enhanced weight-based clustering algorithm to provide reliable delivery for VANET safety applications", the weight associated to each parameter is based on its importance and relevance in the vehicles' mobility. The work also did not only carry out cluster head selection, it went ahead to select a backup cluster head which assumes the position of the cluster head in the event of link failure or incumbent cluster head exiting the cluster. The problem with this is that there needs to be a new selection process if this happens to cluster head and the back-up cluster head. A mechanism by which every vehicle is indexed based on its weighted value and can assume leadership in the event of cluster head and back up failure is more scalable as it will reduce the overhead involved in frequent cluster head selection.

In the work of Bijalwan *et al*., (2022), A Self-Adaptable Angular Based K-Medoid Clustering Scheme (SAACS) for Dynamic VANETs was proposed. This work seeks to reduce the overhead incurred during clustering by estimating the road length and transmission range. This action also reduced network delay. The cluster head is selected based novel performance metrics called cosine-based node uncoupling frequency that is used to find the most suitable node irrespective of their current network statistics. The scheme uses similarity value to determine the suitability of a vehicle to be in a cluster. The parameters of interest in the scheme are direction, relative speed and proximity. The scheme also chose the vehicle with the highest wait as the cluster however, in the event of link failure of the cluster head, the cluster member closest to the centroid is chosen as cluster member. This does not take cognizance of the weight. Another drawback of this scheme is that re-clustering process is initiated in the case of unstable clustering thus incurring another overhead. Alternate solutions to unstable clustering should be sought without placing much constraints on the network resources. Similarly, Saleem *et al;* (2021) proposed a deep-learning based dynamic stable cluster head selection in vanets. This scheme also used a weighted formula to determine the cluster head based on four parameters namely, befit factor, community neighborhood, eccentricity, and trust, the stability of the cluster head depends on the vehicle's speed, distance, velocity, and change in acceleration. Kalman filter was used to determine the accurate location of any given vehicle at any time. The major issue with this work is the computational complexity of the various machine learning models required to arrive at a stable cluster head.

Several machine learning and AI models have been used in this sphere of research. Machine learning models remains predominant within the research arena. The proposed algorithm therefore carries out weight-based cluster head selection algorithm by using K-means clustering algorithm and:

i. factoring in the dynamic cluster resizing of the network as vehicles continues to increase in a low to medium vehicular network for the purpose of retaining good packet delivery ratio as vehicular traffic increases.
ii. Indexing the vehicles so that the next vehicle with the highest weight assumes the leadership of the cluster.

METHODOLOGY AND NETWORK MODEL

The clustered network is built on a bidirectional road with a moderate traffic where vehicles share broadcast messages with vehicles in their clusters and communicate with other clusters through the cluster head which is chosen based on certain parameters. Vehicles within the same cluster are referred to as neighbours and their neighbourliness is governed by the condition:

$\sum_{j=1}^{k} d(i,j,k) \leq R_{max}$ (1) (Sharma *et al.*, 2022).

where *i, j* and *k* coordinates of the vehicle.

The following assumptions are made:

1. The vehicles are equipped with GPS which enables them to know their location relative to their trajectory.
2. The traffic density is moderate. The average velocity of the cluster is dependent on the specification of the group of vehicles.
3. The vehicles are equipped with 802.11p interface for direct short range communication, Vehicle-to-Vehicle (V2V) and wireless interface for (V2I) communication.
4. The first vehicle to send hello messages is chosen as the cluster center. The cluster center is the vehicle around which the cluster is created.

The vehicles are clustered based on their velocities using K-means clustering. Vehicles with velocities within the vicinity of the mean velocity can constitute a cluster. The cluster boundary is specified by the distance of other vehicles from the cluster center.

The vehicles that come together to form a cluster send hello messages to vehicles within its transmission range R_{max}. Vehicles within that range that reply to the hello messages sent and do not belong to any cluster, begin cluster formation by k-means clustering while those belonging to a cluster will ignore the hello message received. The flowchart for this work is presented in Fig. 2.

When the cluster head is selected, a simple flooding technique is then used in broadcast protocols to send packets to all the vehicles within a cluster.

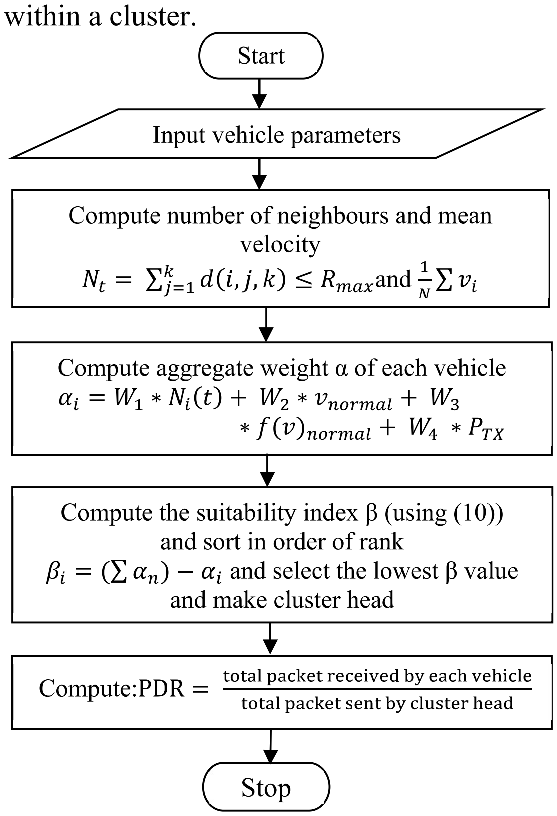

Fig. 2: Flowchart for the proposed work.

CLUSTERING PROCEDURE

i. Initialize speed, direction, transmission power, and position
ii. Check for available clusters from hello messages received
iii. If there are more than one clusters,
iv. {
v. choose most suitable cluster and join
vi. }
vii. Else,
viii. Initiate cluster formation
ix. Compare speed of vehicles within range
x. Compute average speed and pdf
xi. Cluster vehicles by k-means clustering
xii. Begin cluster head selection
xiii. compute weight
xiv. compute suitability index
xv. Select cluster head
xvi. Send broadcasts
xvii. Perform analysis
xviii. End

CLUSTER HEAD SELECTION PARAMETERS

Mean Speed

In this work, the speed of the vehicles is assumed to have a Gauss/Random distribution as widely stated in literature. This is because vehicles on a lane only have low, moderate, and high speed. The probability density function (pdf) is expressed as:

$$f(v) = \frac{1}{\sigma\sqrt{2\pi}}\, e^{\left[-\frac{1}{2}\left(\frac{(x_v - \mu_v)^2}{\sigma^2}\right)\right]} \qquad \sigma > 0 \qquad (2)$$

where μ, σ, x_v and μ_v are the mean, standard deviation, velocity of vehicle *x* and mean velocity respectively while $\frac{1}{\sigma\sqrt{2\pi}}$ is a constant factor that makes the area under the normal distribution curve equal to 1.

$$D_{a,b} = \sqrt{(X_b - X_a)^2 + (Y_b - Y_a)^2} \leq R_{max} \quad \text{(Sharma et al., 2022)} \qquad (3)$$

The mean velocity $\mu_v = \frac{1}{N}\sum_j^m v_i$ or

$$\mu_v = \sum_{j=1}^m \frac{\Delta d}{\Delta t}$$

And the normalized velocity is expressed as:

$$v_n = \frac{x_v - \mu_v}{\sigma} \qquad (4)$$

Mean Distance

By using the Euclidean distance, the mean distance between the nodes say a and b is given by:

$$\mu_d = \frac{\sum_{j=1}^m D_{a,b}}{N(t)} \qquad (5)$$

$$d_{normal} = \frac{x_p - \mu_d}{\sigma_d} \qquad (6)$$

where x_p, μ_d and σ_d are position of vehicle *x*, mean standard deviation of the distance.

Weight Computation

The suitability value of a vehicle is computed based on the weighted value assigned to each of the parameters discussed. Each node computes its mean distance μ_d using (5). The values W_1, W_2, W_3 and W_4 are chosen based on how critical the parameters are in the network. Hence higher weights are assigned to number of neighbours and transmission power.

The aggregate weight of each vehicle is computed as follows:

$$\alpha_i = W_1 * N_i(t) + W_2 * v_{normal} + W_3 * f(v)_{normal} + W_4 * P_{TX} \qquad (7)$$

Subject to:

$$W_1 + W_2 + W_3 + W_4 = 1 \qquad (8)$$

where: W_1=0.3, W_2=0.2, W_3=0.2, W_4=0.3 and W_1, W_2, W_3 and W_4 are the weights associated with each parameter.

P_{TX} = transmission power of the vehicle

α_i = the weight of each vehicle i

To be able to form a table of suitability value in ranking order, a vehicle computes its rank on the table by the (10)

$$\beta_i = (\sum \alpha_n) - \alpha_i \qquad (9)$$

β_i = suitability index of vehicle i

The smaller the value of β, the better the position of the vehicle in the ranking. Vehicles with smaller suitability values have good chances of appearing at the top of the table while vehicles with high suitability values do not have a good chance of appearing at the top of the suitability value table.

Packet Delivery Ratio

The packet delivery ratio (PDR) is the ratio of total packet received by each node to the total number of packets sent by the cluster head. It is expressed as:

$$PDR = \frac{\text{total packet received}}{\text{total packet sent}}$$

(10) (Sharma *et al*, 2022)

Table 1: Simulation Parametrs

Parameter	Value
Number of Lanes	2
Length of Road	4km
Packet Size	500 bytes
Number of Vehicles	40, 50, 60, 70
Sensor Radius (m)	0, 50, 100, 150, 200, 250, 300, 350
Cluster Size	Variable
Number of Clusters	Variable

SIMULATION AND RESULTS

The simulation was carried on MATLAB. To validate this algorithm, the enhanced weight-based clustering algorithm was benchmarked with the existing weight based cluster head selection algorithm in terms of their packet delivery ratios for 40, 50, 60 and 70 nodes. This is because this work is simulated for a moderate traffic size as can be seen from the assumptions. Fig. 3 shows that there is no difference in performance (0%) in terms of packet delivery ratio (PDR) for 40 nodes. This suggests that at lower number of nodes, cluster head selection techniques will behave averagely the same, this can be attributed to the clear line of sight and reduced travel distance of packets within the cluster. The pdr is uniform with low sensor radius between 50-100 meters, it however begins to experience packet drop between 100 to 200 meters justifying the Sharma *et al*., (2022) position of having a transmission range between 150 – 200 meters. Beyond 200 meters, the relationship between pdr and sensor radius becomes non-linear. It is hence technically correct to limit the transmission radius of vehicles to 150-200 meters.

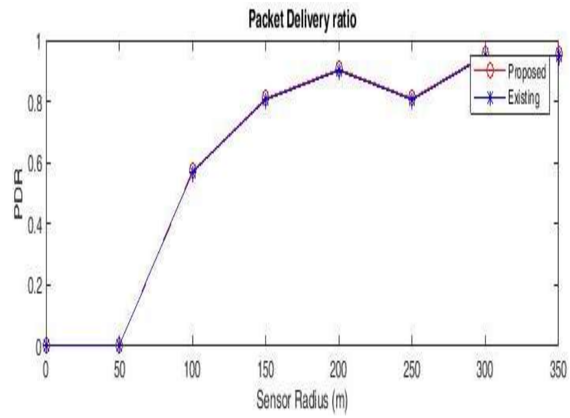

Fig. 3 Packet delivery ratio for 40 nodes

From Fig. 4 as the number of nodes increase, there is a dynamic adjustment in cluster size. This keeps the packet delivery ratio from falling off with respect to sensor radius. Hence packet delivery ratio will improve despite the increase in nodes. It is however observed that packet delivery ratio decreases as the number of nodes increase as seen in Figs. 3 and 4. As the sensor radius increases for all number of nodes, there are different sensor radius beyond which the packet delivery ratio flattens and fails to improve. Hence in comparison with the existing scheme, there is an 11.4 percent improvement in the packet delivery ratio as observed in figure 3. Number of nodes and sensor radius is linear, and changes occur at 100 meters, 150 meters, 200 and 250 meters because of the cluster re-sizing as against re-clustering as proposed in Bijalwan *et al.*, (2022). This eliminates time wasted in re-clustering when clusters become unstable. It thus emphasizes the general opinion of this work that smaller clusters will help in keeping packet delivery ratio high.

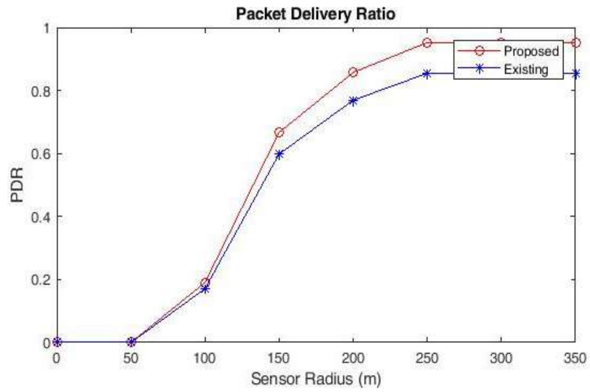

Fig. 4 Packet delivery ratio for 50 nodes

As the number of the number of nodes continues to increase, the proposed algorithm continues to outperform the fixed cluster head selection technique. For 60 nodes, 26% improvement was observed, and this is caused by the dynamic adjustment that comes with increase in nodes in this algorithm. However, beyond 200m, the packet delivery ratio becomes constant as observed in Fig. 5 It is observed that the linearity of pdr with sensor radius has improved in the proposed technique compared to the existing and the percentage difference has increased further justifying that at higher nodes, only smaller cluster sizes will keep pdr. Although it is clear that for this number of nodes, this technique becomes non-linear at 155 meters as against the 150 meters of the existing technique.

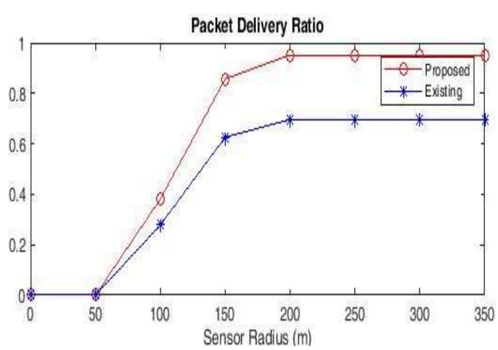

Fig. 5 packet delivery ratio for 60 nodes

In Fig. 6 it is further observed that for the moderate traffic which is being considered, given the sensor radius from 0 to 350 meters, packet delivery ratio begins to rise from below 50m, this is because the vehicles are closer within the clusters, however, there was approximately 0% difference between the proposed scheme and the existing scheme and this means that both algorithms are alike at lower sensor radius in terms of packet delivery ratio and this suggests that small sensor radius has higher packet delivery ratio. Overall, there was a 28.5% improvement at 70 nodes. Having too many nodes implies having many clusters. When this happens, packet delivery ratio is hugely affected as seen in the Fig. 5

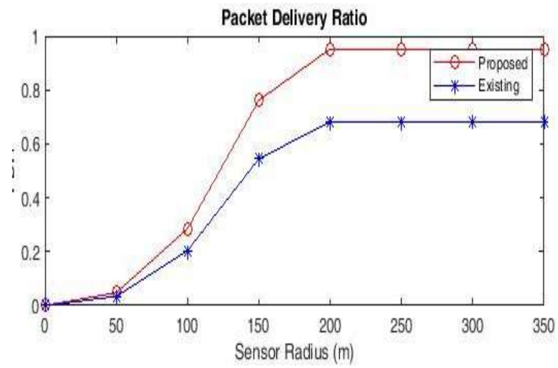

Fig. 6 packet delivery ratio for 70 nodes

The enhanced weight-based cluster head selection algorithm was evaluated alone for 40, 50, 60 and 70 nodes as shown in Fig. 7 It is observed that the average packet delivery ratio for 40, 50, 60 and 70 nodes are 0.62, 0.57, 0.63 and 0.61 respectively, this once again validates the fact that packet delivery ratio improves with dynamic cluster adjustment. It is observed here that at 70 nodes, packet delivery ratio is higher than that of 50 nodes. At 60, the cluster sizes become reduced leading to the formation of smaller but more number of clusters. The reduced cluster sizes then cause pdr to improve for 60 nodes but at 70 nodes the pdr drops to 0.61 making this scheme suitable for small traffic volume. Higher traffic volume will require more modifications.

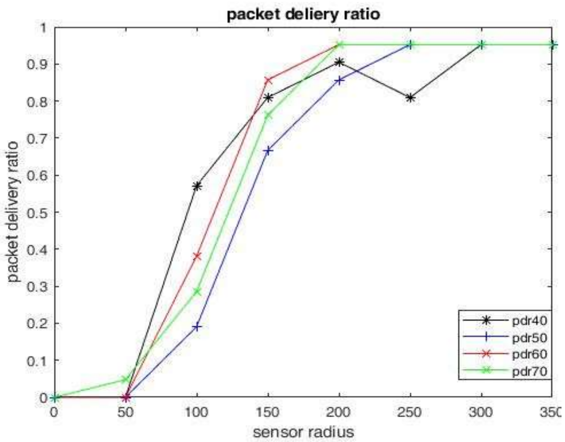

Fig. 7 comparison of packet delivery ratio for different number of nodes at different sensor radius

CONCLUSION/LIMITATION

In this paper, the authors have been able to analyze packet delivery ratio by using the enhanced weight-based cluster head selection algorithm, we also have been able to demonstrate that the proposed algorithm is a significant improvement against the existing weight-based cluster head selection technique. Dynamic cluster head selection helps in resizing clusters to keep packet delivery ratio from deteriorating beyond acceptable limits. This produced an average packet delivery ratio of 0.62, 0.57, 0.63 and 0.61 for 40, 50, 60 and 70 nodes respectively. This algorithm needs to be improved upon if it must serve for vehicles at higher velocities. In future works, we shall analyze cluster head selection delay and end to end delay in enhanced weight-based clustering algorithm. This work is constrained to moderate traffic size of 40, 50, 60 and 70 nodes making this model is most suitable for low to medium traffic because it assumes a normal distribution.

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