Enhancing Connectivity in Vehicular Ad Hoc Networks: A Novel Contention Window-Based Protocol for Overcoming Obstacle-Induced Signal Attenuation

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Abstract: This study delves into how obstacles affect network connections, in Vehicular Ad Hoc Networks (VANETs) which are part of Mobile Ad Hoc Networks (MANETs). VANETs are known for their changing. Intermittently disconnected nodes due to vehicle movements. The research investigates how obstacles like vehicles and roadside structures impact signal transmission and network efficiency. Through simulations and mathematical models, we explore the influence of these obstacles on latency, data throughput and overall connectivity in VANETs. The study emphasizes the importance of factoring in obstacles when designing and optimizing VANET protocols. It also examines how vehicles serving as barriers between transmitters and receivers impact network connectivity and operational performance including latency and throughput. The evaluation is carried out using the DBA MAC protocol. Furthermore, a refined propagation model that considers vehicle height in channel selection is introduced based on CWBP to address the real-world implications of vehicle height on obstacle effects in traffic scenarios. Additionally, a comparative analysis among these protocols is conducted to recommend a protocol, for implementing VANETs.

Keywords: VANET, MAC, DBA-MAC, Routing protocol.

I. INTRODUCTION

A subset of mobile ad hoc networks (MANETs) with an emphasis on vehicle communication are called vehicular ad hoc networks, or VANETs [1]. Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) direct communication is made possible by VANETs, which function without the need for traditional infrastructure as cellular networks do [2, 3]. Whereas V2I networks link cars to roadside infrastructure, such traffic lights and traffic signals, and frequently give the cars internet access, V2V networks enable cars to exchange information directly with one another. Applications for VANETs may be broadly classified into two groups: entertainment and safety. Safety apps help with pre-accident alerts and lane-changing assistance by giving real-time information about traffic conditions, including crashes, congestion, and emergency vehicle warnings. Infotainment applications, on the other hand, offer services related to information and entertainment, including points of interest notifications, media downloads, and internet access [4].

The US Federal Communications Commission (FCC) and other groups have earmarked 75 MHz of the 5.9 GHz band for usage in automobiles, therefore VANET development is getting some support. Since 1992, researchers have been studying Dedicated Short-Range Communication (DSRC). In 2004, the focus moved to the conventional group. The IEEE 802.11p standard, introduced in 2010 outlines data link and physical layer specifications, for settings while the IEEE 1609 standards further define application and network layers.

This study investigates the quick dissemination of messages in VANETs by examining Dynamic Backbone-Assisted MAC (DBA-MAC), an improved cross-layer protocol [1] that enhances message propagation efficiency. The effects of cars on network connection, signal propagation, and overall system performance are investigated in this research. Additionally, a Contention Window Based Protocol (CWBP) based technique was suggested in the study, and it performs better than DBA-MAC.

1.1 Protocols and Standards

Data transfer protocols for VANETs are based on the IEEE 802.11p standard and the IEEE 1609 suite of standards. The data connection layers that let cars to communicate with one other and with infrastructure are the focus of IEEE 802.11p. Meanwhile, security, network services, and multi channel operation are only a few of the higher-level protocols and services outlined by the IEEE 1609 standards. To improve the functionality of VANETs, a hybrid routing protocol known as Dynamic Backbone Assisted MAC (DBA MAC) incorporates on-demand components. Its goal, in comparison to IEEE 802.11 flooding approaches, is to decrease propagation latency and minimise the number of nodes participating in each transmission. This enhancement is achieved by removing backoff periods between transmissions and maximizing the distance between nodes for message forwarding. To further enhance node selection efficiency across VANET protocols utilizing the Contention Window (CW) mechanism a new scheme is proposed. Additionally, a metric known as DEFT (Delay, with Effect of Formation Time) is introduced to combine propagation delay and network formation time offering a assessment of protocol performance compared to current VANET proactive protocols that consider these metrics separately.

This paper's main goal is to increase message dependability and propagation speed in VANETs. The task at hand is examining an improved cross-layer protocol, known as DBA-MAC [1], and suggesting modifications (CWBP) to tackle the distinct difficulties presented by the automotive setting. In order to provide knowledge and resources for improving VANET communication protocols, the research also attempts to simulate and assess the effects of vehicle density, motion, and obstructions on network performance. To decrease propagation latency and boost transmission efficiency, the suggested CWBP system adds a contention window restriction along with a unique relay selection criterion. The method seeks to offer a more accurate and useful solution for real-world VANET settings by adding variables like vehicle height and security distance.

II. LITERATURE REVIEW

The majority of the material that has hitherto been written about VANETs has concentrated on enhancing network performance and communication protocols without taking impediments into account. Research has demonstrated that obstructions have a major impact on the transmission of signals, increasing latency and decreasing throughput [8–16]. For example, studies carried out in urban

and highway settings reveal that structures and other automobiles may significantly reduce and reflect signals, which can impact the overall performance of the network ([8]).

2.1 Factors Affecting Network Connectivity

Several factors influence the connectivity and performance of VANETs:

1. Vehicle Density Impact; When there are vehicles, on the road it can cause traffic jams and signal interference. On the hand having vehicles may result in connectivity issues due to sparse network coverage.

2. Influence of Vehicle Speed; The speed at which vehicles travel affects how long they stay connected. Higher speeds can lead to connections while slower speeds tend to offer stable connectivity.

3. Presence of Obstacles; Physical barriers like buildings and other vehicles can block signal transmission leading to a decline in network performance. Considering how obstacles affect signal propagation is crucial when designing protocols for VANETs.

4. Communication Range Factors; The distance over which vehicles can communicate effectively depends on factors such, as transmission power, antenna properties and environmental conditions. While increasing communication range can enhance network connectivity it may also introduce more interference issues.

2.2 Routing Protocols in VANETs

VANET routing systems are designed to address high mobility and changing topology's challenges. Three different kinds of them might be differentiated [12–14]:

1.   Topology based routing: These protocols rely their routing choices on knowledge of the current network topology, so they are topologically based. Two such are Ad hoc On- Demand Distance Vector (AODV) and Dynamic Source Routing (DSR).

2.   Position-Based Routing: These systems base vehicle positions in determining routing choices. Two such are Greedy Perimeter Coordinator Routing (GPCR) and Greedy Perimeter Stateless Routing (GPSR).

3.   Cluster based routing: Using these systems, vehicles are grouped into clusters under cluster heads in charge of communication both inside and between the clusters. Two such are hierarchical cluster-based routing (HCBR) and cluster-based routing protocol (CBRP).

2.3 Effect of Obstacle in VANET connectivity

Exploring the impact of barriers on network connection in Vehicular Ad Hoc Networks (VANETs) is the focus of our research. Factors like vehicles, buildings and roadside structures have an effect on signal transmission leading to variations in the network's effectiveness and dependability [15, 18]. Our main goal is to analyze the impact of these obstacles, on communication and suggest ways to minimize their consequences.

2.3.1 Obstacle Purposes and Signal Decrease

In vehicular area networks (VANETs), the number of vehicles, the surrounding environment, and the existence of obstructions all affect signal transmission. Under perfect circumstances, free-space models anticipate the pattern of signal transmission. But in practical situations, obstructions obstruct

its propagation, leading to diffraction, scattering, reflection, and attenuation of the signal. The line of sight (LOS) can be blocked by cars and other obstructions between the transmitter (Transmitter) and receiver (Receiver), which will significantly degrade the signal. When there is an obstruction within 100 meters of the transmitter and receiver, experimental research has demonstrated that the Received Signal Strength Indicator (RSSI) can decrease by 7 dB to 20 dB ([18]). The Packet Delivery Ratio (PDR) is directly impacted by this drop in signal intensity, which raises packet loss and reduces communication dependability ([19]). The height of the obstacles plays a crucial role in signal propagation. Research by Boban et al. indicated that taller vehicles, such as vans and trucks, improve the PDR because they are less likely to be obstructed by other vehicles([20-22]). Utilizing tall vehicles as relays can enhance the overall network performance by maintaining better LOS and reducing signal attenuation.

2.3.2 Effects of Obstacles on Network Connectivity

To estimate signal attenuation caused by obstacles, we use diffraction models recommended by the ITU [23]. For scenarios with a single obstacle between the transmitter and receiver, the single knife-edge model is employed. The attenuation due to one obstacle, A_{sk}, is calculated as:

$$A_{sk} = 6.9 + 20 \log_{10}\left(\sqrt{(V - 0.1)^2 + 1} + V - 0.1\right) \tag{1}$$

$$V = \Delta h \sqrt{\frac{2}{\lambda}\left(\frac{1}{d_{TTO}} + \frac{1}{d_{TOR}}\right)} \tag{2}$$

where Δh represents the difference in height between the obstacle and the line-of-sight (LOS) path at the obstacle's status. d_{TTO} and d_{TOR} indicate the gaps from the Transmitter to the top of the obstacle and from the top of the obstacle to the Receiver, respectively [24]. Figure 1 illustrates these parameters.
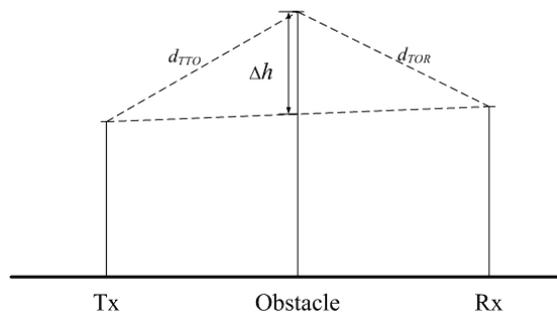

Figure 1 Diffraction model for calculation of parameters [25]

For two obstacles, the double-isolated-edges model is used. This model applies the single knife-edge model sequentially for each obstacle, treating one obstacle as the Transmitter and the other as the Receiver in turn. The total attenuation, A_{di} [26], is given by:

$$A_{di} = A_{sk1} + A_{sk2} + A_c \tag{3}$$

where A_{sk1} and A_{sk2} are the attenuations caused by the first and second obstacles, respectively, and A_c is a correction term calculated as [27]:

$$A_c = 10 \log_{10}\left(\frac{d_{obs2}(d_{TR} - d_{obs1})}{(d_{obs2} - d_{obs1})d_{TR}}\right) \tag{4}$$

For scenarios with three or more obstacles, the Bullington model is adopted. An equivalent obstacle replaces multiple obstacles, determined by the intersection of lines connecting the Transmitter and obstacles, as shown in Figure 2.
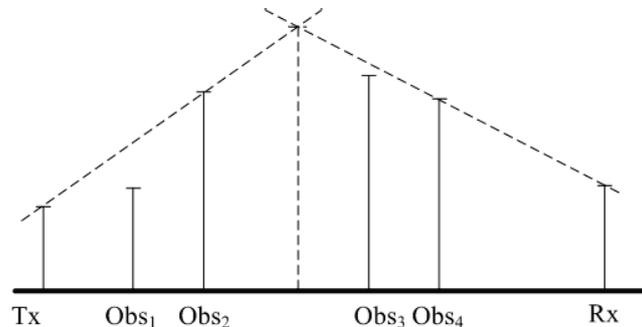

Figure 2. Bullington model used for calculation of three or more obstacles [28]

The above models estimate attenuation by obstacles, while free-space path loss (FSPL) [29] accounts for signal loss due to distance:

$$A_{fs} = 10 \log_{10} \left(\frac{4 \pi c l d_{TR} f_p}{c l} \right)^2 \tag{5}$$

where *cl* is the speed of light (3×10^8 m/s) and *fp* is the carrier frequency of DSRC (5.9 GHz).

2.4 A Proactive Routing Protocol: DBA-MAC

In the DBA-MAC protocol, vehicles equipped with wireless devices are divided into two categories: Backbone Members (BMs) and Normal Members (NMs). This categorization plays a crucial role in the network formation and message forwarding processes, significantly impacting the performance of vehicular communication systems.

2.4.1 Network Formation: BM Selection

When a vehicle does not detect any network within a specific period (5 seconds), it initiates the network formation process by broadcasting a beacon message, thereby claiming itself as a BM. Information such as the transmitter's identification, radio range, and GPS data (including position, direction, and speed) are all part of the beacon message. Vehicles that are in the broadcasting BM's radio range assess if they are qualified to take over as the next BM. The selection is based on a contention-based procedure using the Contention Window (CW) scheme from IEEE 802.11 [30]. Suitable candidates, those maintaining connectivity with the BM and not overtaking it, begin a backoff process. The candidate that completes the backoff first sends a candidature message to the BM and is acknowledged as the next BM, while other candidates suspend their backoff and listen to the channel.

The suitability of candidates is determined by factors such as relative speed and distance to the BM. Candidates predicted to be outside the BM's radio range by the end of the period are excluded to prevent link breakage, which would degrade system performance.

The Suitability Index (SI) is a key metric used to determine the most suitable candidate for BM selection. It is calculated as follows [31]:

$$Si = \frac{\Delta s_i + \Delta v_i t}{RR} \qquad (6)$$

where:

- Δs_i is the qualified distance between candidate i and the BM at the beginning of the period.

- Δvi is the speed gap between candidate iii and the BM.

- t is the updating period of the BM network.

- RR is the radio range of the BM's wireless device.

Candidates following the BM (where $\Delta s_i > 0$) are considered, with approaching candidates having a negative speed gap ($\Delta v_i < 0$) [32]. The CW for each candidate is then adjusted based on their SI:

$$CWi = (1 - \Delta Si/RR)(CWmax - CWmin) + CWmin \qquad (7)$$

Here, $CWmax$ and $CWmin$ [33] are parameters from IEEE 802.11, set to 1023 and 15, respectively. Candidates select a random value within their CW and start a countdown. The first to finish broadcasts a candidature message and is acknowledged by the BM, thereby forming part of the BM network.

2.4.2 Message Transmission by BMs

BMs are pivotal in forwarding messages. Upon receiving a message from an upstream BM, a BM sends an acknowledgment (ACK) after a Short Interframe Space (SIFS) [34] and forwards the message without any backoff, reducing delay significantly compared to the flooding scheme. NMs do not forward messages but keep listening to the channel.

Although BMs primarily forward messages, NMs also play a role when the BM network is disrupted due to mobility changes or channel collisions. When this occurs, NMs forward messages using a contention-based mechanism, which is comparable to the BM selection phase [35]. Both the NMs' distance from the transmitter and the radio range dictate the backoff time:

$$CWi = (CW_{max} - CW_{min}) + CW_{min} \qquad (8)$$

NMs that complete the backoff first forward the message as intermediate nodes.

In proactive protocols for message propagation, specific nodes in the route table, termed as predefined intermediate nodes, handle the transmission of messages. The efficiency of the system, especially in terms of latency, is intricately tied to the route selection within these protocols. Within the context of DBA-MAC, Broadcast Nodes (BMs) are responsible for forwarding messages. The selection of BMs hinges on the suitability of candidates, defined primarily by their distance to the last BM at the end of the network period. Applicants who exceed or lay outside the BM's radio range during the designated period will not be considered. At the conclusion of the term, the candidate who is the furthest away from the BM is considered the most suited. The candidate who is furthest from the BM has the highest chance of winning in the contention process due to this appropriateness criterion [36].
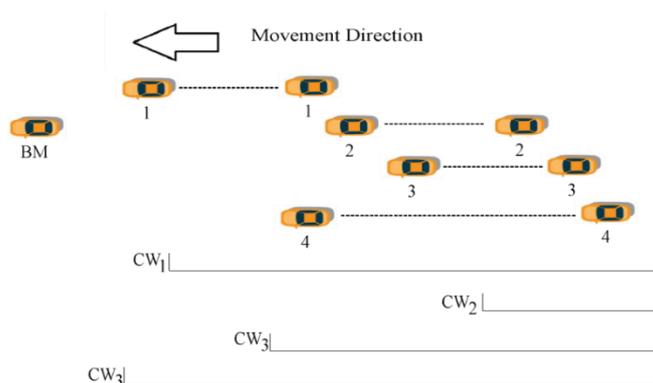
Figure 3: Transmission by BMs

The evaluation standard, in DBA MAC determined by the distance from the BM at the end of the period is important. It has its limitations. It overlooks the candidates starting position at the beginning of the period, which could lead to a reduction in the distance, between neighboring BMs ultimately affecting propagation efficiency negatively. This is illustrated in Figure 3, where candidates are evaluated based on their distance at the end of the period. For instance, candidate 2, despite not having the longest distance at the beginning, might win the contention due to its projected end-of-period distance. This can degrade the performance by reducing the average distance between BMs. Using the initial distance as a suitability criterion also has drawbacks. A candidate might appear suitable at the beginning but could end up closer to the BM at the end, as shown with candidate 4 in Figure 3. This scenario complicates the selection of downstream BMs due to the varying speeds of candidates [38-39]. Candidates leaving the BM have a more stable suitability measure, as their distance from the BM increases consistently over the period.

The analysis of relative distances and their overlaps, illustrated in Figure 4, reveals three primary overlap scenarios: no overlap, partial overlap, and full overlap. Each scenario affects the Suitability Index (SI) ranking differently. In the no overlap scenario, SI ranking remains unchanged, with the candidate having a longer initial distance maintaining a higher SI. Partial overlap scenarios are more complex and are categorized into four groups based on the relative movements of candidates. Depending on whether the distance at the start or the finish is used as the criterion, for instance, the SI ranking varies as one contender approaches while another withdraws.
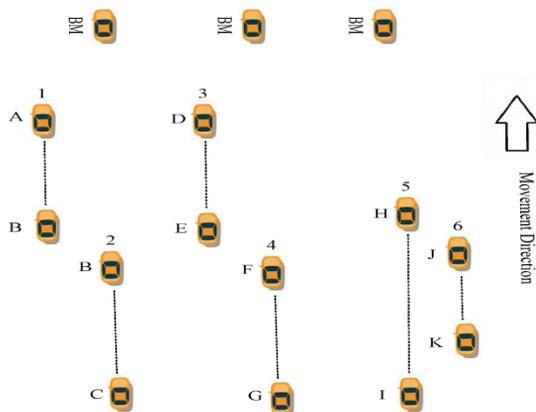

Fig 4 Transmission b/w vehicles

The selection of the Contention Window (CW) is also a factor, in determining the Best Match (BM). The backoff time, which is chosen randomly within the CW range tends to favor candidates with suitability. However, it still allows suitable candidates to win occasionally due to this randomness. This random selection serves as a collision avoidance feature in IEEE 802.11. May lead to average distances, between BMs, affecting system performance. To tackle these issues a solution called the Contention Window Based Protocol (CWBC) scheme is proposed. This scheme restricts the CW selection range based on candidate suitability increasing the chances of selecting the candidate. As shown in Figure 4 the suitable candidate has a CW range ensuring its prompt response. The goal of this scheme is to minimize collisions and better represent candidate suitability.

III. RESEARCH METHODOLOGY

Proposed Contention Window Based Protocol (CWBC) scheme

The suggested approach substitutes the minimum distance at the beginning of the period for the greatest distance at the end as the appropriateness criteria. This method takes into account the candidates' total minimum relative distance, which has a stronger correlation with the ideal BM spacing. Equation 7 defines the Minimum Distance as Criterion (MDC) proposal, which modifies the SI to give preference to candidates who have the longest minimum distance across the time.

The DBA-MAC protocol and its BM selection process are critically dependent on the criteria used for candidate suitability. Adjusting these criteria and constraining the CW selection can significantly impact the efficiency and performance of message propagation in networks. These improvements aim to enhance the average distance between BMs, thus improving overall system performance.

3.1 Network Connectivity

We show roadside network connection to illustrate how automobiles act as impediments reducing signal strength. Instantaneous outcomes are provided by the simulations, applicable to network conditions at any moment due to the statistical nature of vehicle locations. Additionally, we explore how obstacles impact system performance.

3.3 Methodology

Vehicles are randomly distributed on the road, maintaining a predefined minimum distance between consecutive vehicles. Vehicle heights are included to reflect practical scenarios accurately, categorizing vehicles into tall and low types.

In the signal propagation model, only the LOS component is considered. NLOS components, such as reflection and scattering, are neglected as they are not predominant in received signals. The transmitter broadcasts a message, and the link between the Transmitter and the selected receiver is established if the received signal strength exceeds the sensor's threshold.

The network connectivity focuses on direct communication between vehicles within mutual transmission range, excluding communication via intermediate nodes. A Monte Carlo simulation, repeated 100,000 times, provides statistical results by randomly selecting a Transmitter and Receiver from vehicles positioned on an 8-km ring-shaped road.

3.3.1 Configuration

Simulations are conducted at vehicle densities of 40, 80, and 120 vehicles per km. Vehicle heights follow a normal distribution, with parameters listed in Table 1.

Table 1. Paremeters for configuration of CWBP Scheme

Parameter	$P_{Transmitter}$	$Th_{Receiver}$	Fp	Cl
Value	16 dBm	-79.5 dBm	5.9 GHz	3×10^8 m/s

In the QPSK model, the ThReceiver value is somewhat more than the DSRC minimum sensitivity. Up to 240 meters is the limit for transmission distance. Table 2 presents the height distribution of tall and short vehicles.

Table 2. height distribution of tall and short vehicles for CWBP Scheme

Vehicle Type	Tall	Short
Mean Height (m)	3.35	1.5
Std Dev (m)	0.08	0.08

IV. SIMULATION RESULTS

Using a constant tall vehicle ratio of 0.1, we investigate how vehicle density and distance affect the likelihood of connectedness. Figure 5 indicates that as distance increases, the likelihood of connectedness decreases because of more impediments. Connectivity probability is higher at lower vehicle densities because fewer obstacles weaken the signal less significantly. The relationship between Transmitter -Receiver distance and the maximum number of obstacles is detailed in Table 3. The maximum number of obstacles increases with dTR, reducing connection probability.
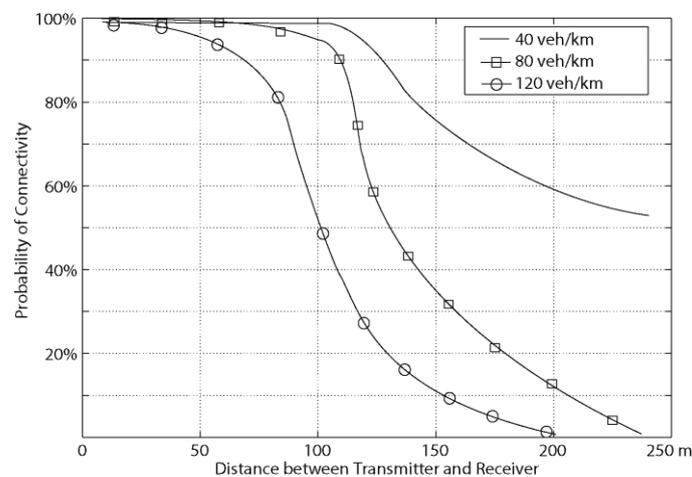

Figure 5 Variation of connectivity probability with distance

Table 3 Relationship between Transmitter-Receiver distance and the maximum number of obstacles

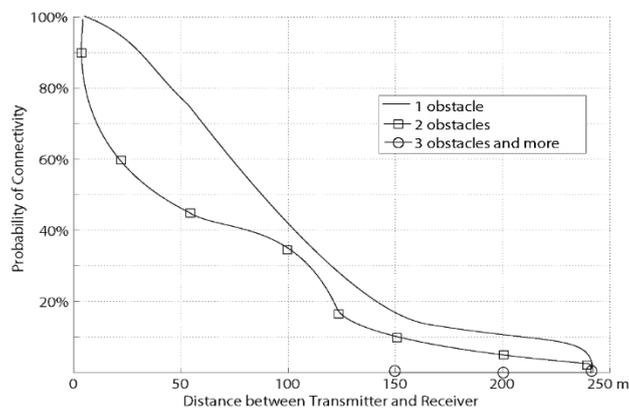| Distance (dTR)	<σ	<2 σ	<3 σ	<4 σ	<5 σ	<6 σ	<7 σ	<8 σ	<9 σ	<10 σ	<11 σ	<12 σ
Max Obstacles (ΔLN=0)	0	0	1	2	3	4	5	6	7	8	9	10
Max Obstacles (ΔLN=1)	0	0	2	2	4	4	6	6	8	8	10	10
Max Obstacles (ΔLN=2)	1	1	2	2	5	5	6	6	9	9	10	10
Max Obstacles (ΔLN=3)	2	2	2	4	4	4	8	8	8	10	10	10

Figure 6 Variation of connectivity probability with distance

Figure 6 illustrates connectivity probability with one and two obstacles. For a single obstacle, connectivity probability shows a step-shaped decrease between 110 and 120 meters due to increased path loss. Beyond 120 meters, the probability stabilizes between 10% and 20%, as low obstacles have less impact on tall Transmitter -Receiver pairs.
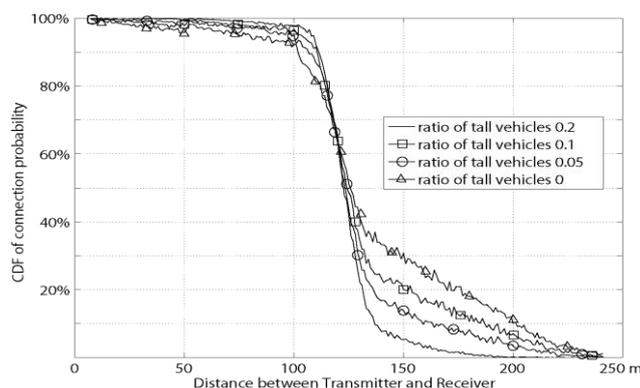
Figure 7 Ratio range divided into three intervals based on connection probability: close distance (0-110 m), middle distance (110-140 m), and far distance (140+ m)

4.1 CONNECTIVITY PROBABILITY AT VARIOUS TALL VEHICLE RATIOS

This section investigates the effects on connectedness probability of varying tall vehicle ratios, with values of 0, 0.05, 0.1, and 0.2, and a vehicle density of 60 per km. Figure 7 displays the range of the ratio, which is separated into three ranges according to the likelihood of the link: close distance (0-110 m), middle distance (110-140 m), and far distance (140+ m). When the distance is short, the signal loss due to distance is minimal. Therefore, the primary factor affecting signal strength at the receiver (Receiver) is the relative height of obstacles compared to the transmitter (Transmitter) and Receiver. Specifically, if the obstacles between the Transmitter and Receiver are taller than both, signal attenuation is more pronounced. This situation is particularly significant when the ratio of tall vehicles (obstacles) is 0.2, resulting in a 12.8% probability of encountering such obstacles. When the ratio of tall vehicles is lower, the frequency of these obstructive combinations decreases, leading to a higher probability of maintaining a connection. If 'no tall' vehicles are present, the signal experiences less attenuation, enhancing connection reliability.

At intermediate distances, increased path loss reduces signal strength, causing it to fall below the receiver's sensitivity threshold and disconnect the link, especially in scenarios involving short Transmitter /Receiver and obstacles. This combination is the most common, leading to a significant drop in connectivity. At greater distances, near the edge of the radio range, path loss is more severe, and obstacles become crucial for network connectivity. The probability of no obstacles is nearly zero, so cases where obstacles cause minimal attenuation—such as tall Transmitter /Receiver with short obstacles or a mix of tall and short Transmitter /Receiver—are important. For a 20% ratio of tall vehicles, the probability of these less obstructive scenarios is 28.8%, higher than the 17.1% probability for a 10% ratio and other scenarios. Thus, a higher ratio of tall vehicles increases connection probability near the radio range's edge. If there are no tall vehicles, any obstacles will significantly attenuate the signal, causing disconnection due to the combined path loss and attenuation.

4.2 The Impact of Barriers on Protocol System Performance

Learn about the Dynamic Backbone-Assisted MAC (DBA-MAC) [16] and its suggested Contention Window Constraint and Minimum Distance (CWBP) here. Problems with BM generation and message transmission are taken into account in the simulation. The results are contrasted with a perfect situation in which every vehicle has an equal chance of receiving the signal within the maximum radio range of

the transmitter. Both Table 4 and Figure 8 show how impediments affect BM selection in DBA-MAC. When candidates with received signal strengths below the Receiver threshold are discarded, the number of eligible candidates falls. This is because of impediments. Table also demonstrates that as the number of barriers increases, candidates farther away are more likely to be disqualified, therefore in reality, eligible candidates are closer to the BM than in an ideal situation.
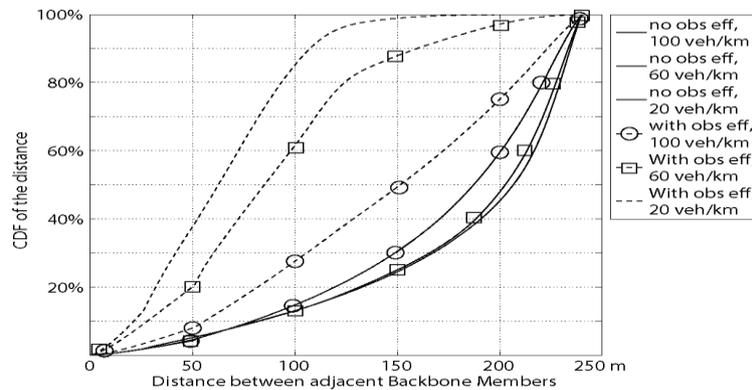

Figure 8 Ratio range divided into three intervals based on connection probability: close distance (0-110 m), middle distance (110-140 m), and far distance (140+ m)

Table 4 In DBA-MAC, the average distance between neighboring BMs both with and without the obstacle effect

Density /km	without obstacles	with obstacles
100	181.92 ± 59.62	63.10 ± 33.73
60	180.21 ± 58.48	90.44 ± 49.07
20	170.41 ± 57.57	146.53 ± 61.90

When compared to DBA-MAC, CWBP's selection performance is much superior (see Figure 8). It is guaranteed that the winning candidate remains the most appropriate even as the number of acceptable candidates diminishes because of the CWBP's intrinsic characteristic that permits the most suitable applicant to react to the BM first. So, even with the obstacle effect, CWBP still outperforms DBA-MAC in BM selection.

When barriers are present, BM selection performance is higher at lower densities, which goes against the ideal scenario. Signal strength is exponentially affected by the number of obstructions between the transmitter and receiver, as seen in Figure 6. Considering barriers, the average distance between adjacent BMs is less at high densities since the average number of cars within a certain range rises as vehicle density does. Longer BM distances at larger densities are the result, according to the CDFs in Figure 9, of both systems, when there are no obstacles: the candidate farthest from the BM has the greatest likelihood of winning the contest. However, obstacles more severely impact propagation at higher densities, bringing suitable candidates closer to the BM. Figure 9 highlights that obstacles significantly affect performance delays, with propagation delays impacted across all densities. Despite this, CWBP still performs better than DBA-MAC.
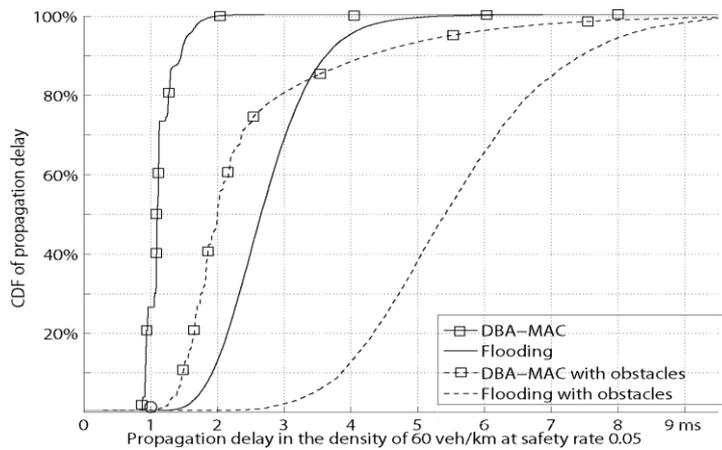
Figure 9 CDFs of propagation delay in density of 60 veh/km at safety rate 0.05

In terms of BM distance, delay performance trends differ when obstacles are considered, aligning with BM selection performance shown in Figure 9. There are more impediments and less connectedness as the quantity of vehicles increases. Delay and retransmission times for DBA-MAC and CWBP are shown in Figures 10 and 11, as well as in Tables 5 and 6, for a range of densities, with and without obstacles. These results demonstrate that CWBP performs better than DBA-MAC in both perfect and obstacle-inclusive situations, which is supported by Figure 10, Table 5, and 6. Performance is better at lower densities with obstacles, opposite to the ideal case where higher density yields better performance.

Table 5 Average delay and retransmission times in DBA-MAC

Density /km	Average delay in DBA-MAC at message rate 0.05			
	without obstacles		with obstacles	
	DBA-MAC	CWBP	DBA-MAC	CWBP
100	181.92 ± 59.62	1.065 ± 0.390	63.10 ± 33.73	2.529 ± 2.508
60	180.21 ± 58.48	1.070 ± 0.360	90.44 ± 49.07	1.821 ± 0.991
20	170.41 ± 57.57	1.096 ± 0.384	146.53 ± 61.90	1.272 ± 0.588

Table 6 Average delay and retransmission times in CWBP Scheme

Density /km	Average retransmission times in the CWBP			
	without obstacles		with obstacles	
	DBA-MAC	CWBP	DBA-MAC	CWBP
100	5.51 ± 0.75	10.47 ± 1.82	6.03 ± 0.83	14.18 ± 2.02
60	5.55 ± 0.74	8.05 ± 1.43	6.04 ± 0.84	10.42 ± 1.85
20	5.77 ± 0.73	6.35 ± 0.87	6.15 ± 0.82	6.94 ± 1.11

Unlike DBA-MAC, where less suitable candidates still have a shot, CWBP gives the highest suitability candidate a better chance of winning the contest to become the next BM. Incorporating barriers does not change CWBP's selection method, hence it maintains its performance advantage over DBA-MAC in these settings.
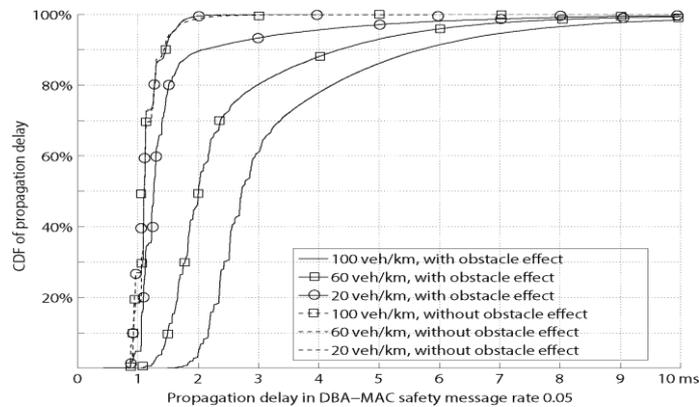

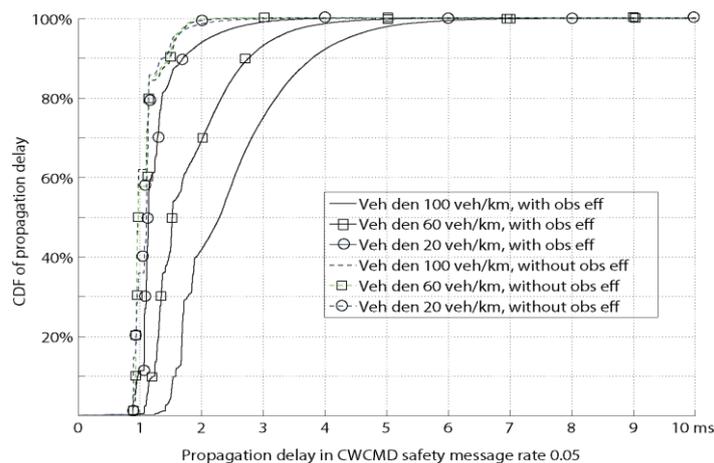**Figure 10 CDFs of propagation delay with varying vehicle speed for DBA-MAC**

Figure 11 CDFs of propagation delay with varying vehicle speed for CWBP Scheme

V.   CONCLUSION

The study findings emphasize the influence of obstacles, like vehicles on signal transmission and network effectiveness in Vehicular Ad Hoc Networks (VANETs). Our analysis indicates that when obstacles obstruct the path between the sender and receiver the signal delay decreases as vehicle density rises, unlike in scenarios where obstacles are not considered. In an obstacle setting higher vehicle densities lead to improved delay performance due to better connectivity. However, when obstacles are taken into account delay performance is better in traffic conditions. This underscores the importance of factoring in obstacle effects when designing protocols and estimating performance for VANETs. The research also reveals that neglecting obstacles can result in inaccuracies in system performance predictions. Therefore, our proposed Contention Window Based Protocol (CWBP) outperforms the Backbone Assisted MAC (DBA MAC) protocol, in scenarios with obstacles. The CWBP not reduces signal delays. Also enhances relay selection efficiency through a unique relay selection criterion and a

contention window restriction. This ensures that the suitable node responds first maintaining performance even when obstacles are present. Our conclusions suggest that future VANET protocol designs should incorporate obstacle modeling to improve the accuracy of performance estimates and enhance communication efficiency, in real world settings. In endeavors it's crucial to enhance obstacle protocols by including a wider range of real-world situations, like urban settings with dense buildings and diverse traffic conditions. Moreover, investigating the use of machine learning methods to anticipate and address the influence of obstacles on VANET performance could lead to enhancements, in communication effectiveness and efficiency.

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