TELKOMNIKA Telecommunication, Computing, Electronics and Control
Vol. 18, No. 1, February 2020, pp. 57~71
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v18i1.13565

The performance of the vehicular communication-clustering process

Omar Daoud[1], Ahlam Damati[2], Qadri Hamarsheh[3]
[1,3]Department of Communications and Electronics Engineering, Faculty of Engineering and Technology, Philadelphia University, Jordan
[2]Department of Electrical Engineering, Faculty of Engineering and Technology, Philadelphia University, Jordan

Article Info

Article history:

Received Jul 11, 2019
Revised Oct 3, 2019
Accepted Oct 22, 2019

Keywords:

Clustering Algorithm
Energy Efficiency
IoV
UWB-MB-OFDM
V2V

ABSTRACT

For the new wireless systems and beyond, the intelligent transportation system is considered as one of the main features that could be covered in the new research topics. Furthermore, both high-speed data transmission and data processing play a crucial role for these generations. Our work covers two main propositions in order to attain an improvement in such intelligent systems performance. A clustering algorithm is proposed and presented for grouping mobile nodes based on their speeds with some modified head assignments processes. This will be combined with a parallel-processing technique that enhances the QoS. Mainly, this work concerns enhancing the V2V data transmission and the processing speed. Thus, a wavelet processing stage has been imposed to optimize the transmitted power phenomenon. In order to check the validity of such proposition, five main efficiency factors have been investigated; namely complementary cumulative distributions, bit rates, energy efficiency, the lifetime of cluster head and the ordinary nodes reattaching-head average times.

Corresponding Author:

Omar Daoud,
Department Communication and Electronics Engineering,
Philadelphia University,
Jerash Highway, Amman, 19392, Jordan.
Email: odaoud@philadelphia.edu.jo

1. INTRODUCTION

During the last decade, vehicle networking became vital part in the latest wireless system's generation. Therefore, a rapid development has been found in the literature, which is based on the Internet of things (IoTs). Nowadays, enhancing the performance of the Vehicular Adhoc Network (VANET) standard (IEEE 802.11p) has acquired an increasingly frequent petition. This is due to what is being considered as a special ad-hoc mobile network. In another way, the concept of Vehicle to Everything (V2X) is rising on the surface for the vehicle networking communication, such as vehicle-to-vehicle (V2V) and vehicle-to-roadside (V2R). Those modes are based on the nodes themselves i.e. both of the information awareness, the access to it and the prediction to nodes trajectory. However, VANET lacks reliability under the real-time data distribution. This is true due to the rapid changing and the instabilities of the wireless channels [1, 2].

Different propositions to enhance the vehicle network communication standards have been found in literatures, such as the combination between the VANET and the Long Term Evolution (LTE) mobile systems (i.e. the new trend for the intelligent transportation systems). In such combined network, the VANET is having the permission to access the internet through the existing LTE cellular network, which could lead to huge VANET system improvements [3-6]. To realize such combination modes, the Orthogonal Frequency Division Multiplexing (OFDM) model has been introduced to enhance Quality of Service (QoS). Thus, the adequateness between such systems (the VANET and the LTE) was attained, as a result of lowering the delay time and getting the high speed communications. Multiband OFDM (MBOFDM) [7-10] technique is found in the literature to attain the requirements for the application of high-data rate. A very promising technique was shown with over 100 Mbps downlink connections. It is considered as a promising technique due to its robustness in the dispersive channels (i.e. avoids the channel's waste, due to the inter symbol interference (ISI)). In addition, it has the capability of reducing the consumed power by managing the limited frequency resources. However, it suffers from high implementation complexity that leads to high cost [11-20]. Thus, this work tackles this QoS issues by proposing a multi-parallel processing reclustering technique for the multiband OFDM (MP-RC-MBOFDM). It consists of two parts; the facilitating part of reusing the spatial resources by reclustering the huge number of mobile nodes (i.e. vehicles) and the enhancing part of overcoming the spectrum limitations. Thus, the QoS features will be attained such as low power consumptions, low power effects, high data rates, flexibility and low cost.

For the facilitating part, a single hop clustering V2V based on LTE systems through the IEEE 802.11p architecture was introduced. In this clustering system, a cluster weighting factor (CWF) has been proposed based on the relative velocities, the communications maximum range, and a specific adaptive weight factor (AWF). This part introduces a criterion that chooses the head of the cluster, as well as a criterion that maintains an acceptable overhead for updating the cluster’s head. Hence, the re-clustering part is based on the previously mention specifications to manage the vehicles in the clusters.

For the enhancing of MBOFDM part, the QoS has been studied by proposing a multi-parallel processing technique for the MBOFDM (MP-MBOFDM). This proposition has been analyzed extensively by making use of the wavelets decomposition criteria. This is to show the powerfulness of sending the data between the cluster heads and the LTE system in the parallel process. As a result, we can overcome the bandwidth limitations such as the ones for the Internet of Vehicles (IoV). This feature has been investigated by checking some crucial factors such as the energy efficiency (EE) factor, complementary cumulative distribution function (CCDF) curves, and the bit error rates (BER), the system throughput, the spectral efficiency, and the effect of the modulation ring ratio efficiency. Thus, the target is to enhance the QoS under the following parameters; namely lowering the complexity issues and optimizing the data rates.

The rest of this paper is organized as follows. Section 2 detailed some related work in addition to the system model. The performance of the proposed clustering technique and the enhancement part based on the multi-parallel processing technique are given in section 3. Section 4 presented the analysis of the simulations in order to evaluate the proposed schemes. Finally, the conclusion is drawn in section 5.

2. SYSTEM MODEL FOR THE LTE-BASED V2V COMMUNICATIONS ENHANCEMENT

At any moment, the moving node (vehicle) in any clustered network is classified as either a cluster head or as a normal node (members). Accordingly, the cluster head is considered as the coordinator for the normal nodes (members). They can talk to each other by a specific neighbour table, which is formed according to the communication between the cluster head and the members. The scope of this work is limited to proposing an enhancement over the clustering algorithms in the literature, while creating the neighbor table will be deferred to another work.

Clustering algorithms objectives diverge according to the needed QoS optimization process for such systems; such as the clusters stability, the cost, and the quality. In the LTE-based V2V communication system, the following issues are taken into consideration; the behaviour of the mobile nodes (vehicles) and the stability that brings the low cost.

The behaviour of the mobility nodes consists of different mobility behavior such as the relative speed, the direction of moving nodes. For instance, clustering according to the relative speed could only bring cost penalties; this is due to the V2V network restrictions. From this impairment, there is need for improvement in order to re-cluster the nodes based on calculating the weight parameter. This parameter will be based on the speed of the moving nodes, so as to choose the cluster head appropriately. Then, an optimization criterion will be derived to attain both the stability and the low cost maintenance. After that, an improvement on VANET protocol will be investigated based on the MP-MBOFDM. This will enhance the QoS of the LTE based communication.

Figure 1 shows the LTE-based V2V topology. In this figure, the vehicles (nodes) at different tracks and lanes are grouped into clusters. This figure shows that N independent moving vehicles are considered. They are moving with different directions. The maximum range for the communications is defined as R_{max}.

The scope of this work will be limited to one-hop only that could relate the cluster head with the members. The nodes are assumed to be equipped with the depicted transmitter in Figure 2, which is adequate to the LTE standard. Their LTE-based communication will be through the cluster head, which is considered as the coordinator for the other nodes (i.e. the ordinary nodes).

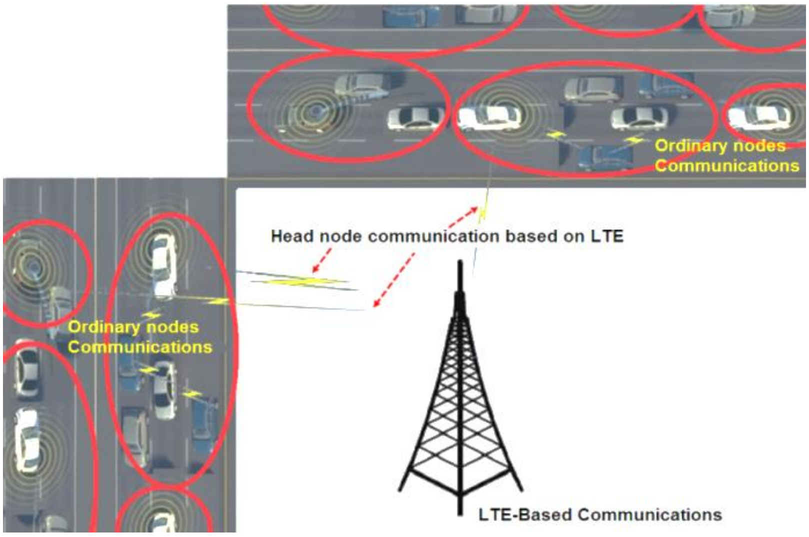

Figure 1. LTE-based V2V communications topology

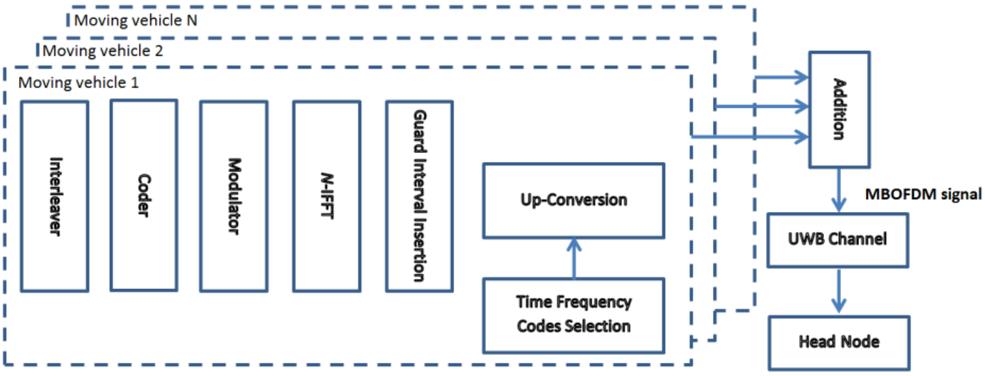

Figure 2. UWB-MBOFDM transmitter's schematic diagram.

2.1. Related work

The clustering issue of the Mobile Ad hoc networks has been extensively done in the literature [21]. Different clustering techniques have been found based on different objectives. However, the scope of this work will be limited to cover the mobility-attentive and/or the low maintenance. The mobility-based clustering work is trying to regroup the moving vehicles with respect to some specific mobile metrics, such as the explicit relative speed, the direction. However, those techniques have much impairment such as the ripple effect, the cost, the resource efficiency appropriateness [22-25].

In order to overcome such impairments, another re-clustering work has been found in the literature such as the Distributed Dynamic Clustering Algorithm (DDCA) that tries to reduce the ripple effect. However, it brings some cost on path finding. This is due to that, regardless of the hop distance, every moving vehicle has its own path to others [26]. Another proposition to increase the throughput is based on region clustering mechanism; each region is limited to a specific number of moving nodes, so that the channel contentions could be avoided [27].

The work of Gunter et. al. [28] came up with the idea of giving the cluster head the role of managing the communication of the intra-cluster. This is as a result of combating the burden load of the hidden terminal. Thus, the MAC layer will be improved accordingly. However, this brings the overhead communications and could affect the whole communications stability.

According to Trestian and Muntean [29], a proposition has been made in order to enhance the stability of the clustering process. Thus, a new protocol has been studied to minimize the re-clustering issues; i.e. low maintenance clustering. This protocol is based on two criteria; Highest-Degree and Lowest-ID. This proposition works and reduces the re-association times of the clusters by tolerating the changing of the clustering hop in a given range. However, there are some concerns to be used in real-time V2V communications.

The lowest-ID-based clustering has been emphasized in the work of Gerla et al and Maslekar et al. [25, 30], where the ID is the only used term to identify the cluster head. It can be periodically obtained during the broadcasting process, and then cluster head updating process will be somehow stable. Thus, it will take long time to be updated, which will minimize the maintenance cost under the impairment of short lifetime for the whole cluster. Therefore, the distributed clustering algorithm is introduced under the generalization of the lowest-ID to weight-based work. Thus, the weighting term is a vital role for dealing with the moving nodes (vehicles) and choosing the cluster head.

This opens a research scope to choose the best technique of weighting assignments. Therefore, our work presents an adaptive cluster's weighting factor, which will take into consideration both the relative distance and the relative velocity. It aims to attain the clustering stability in addition to propose the MP-MBOFDM in order to reduce the cost factor.

2.2. Proposed clustering scheme

In order to avoid the penalties that were found in the literature; such as the ripple effect, maintenance clustering cost, this clustering work is based on optimizing a clustering work factor (CWF). This is attained through an adaptive parameter to choose the criterion that should be considered, and to arrange the priorities among the used parameters. For example, the CWF in an urban road is calculated under the assumption that the relative distance has the highest priority. After that the node that has the highest CWF will be chosen as a cluster head. The CWF is based on some mobile metrices that could be considered as basic mobile parameters; such as the maximum range, the location and the relative speed [26]. Thus, we can make a modification base on the lowest-ID clustering algorithm by defining an AWF. This AWF consists of two parts that link both the relative location and the relative speed. Then, the average degree of the link dependence is defined by the division over the total number of neighbouring nodes. The following equation concludes the proposed CWF as:

$$CWF_i = \begin{cases} 0 & \cos(\theta) \leq 0 \\ \dfrac{\sum_{j=1}^{J}\left(\delta_1\left(\frac{R_{max}-\sqrt{\left(x_i-x_j\right)^2+\left(y_i-y_j\right)^2}}{R_{max}}\right)+\delta_2\left(\frac{\min(v_i,v_j)}{\max(v_i,v_j)}\right)\right)}{J} & O.W. \end{cases} \quad (1)$$

where J is the total number of neighboring nodes of node i, the maximum range for the communications is defined as R_{max}, (x_i, y_i) depicting the (x, y) location details for node i, v_i stands for the velocity for node i, and δ_k stands for AWF(i.e. the needed priority for the mobile nodes parameters in the scenarios themselves). Here, the summation of those AWF should equal to 1. θ; defining the angle (the direction) between the two moving nodes. Based on (1), CWF could be determined for all moving nodes. Accordingly, the head node will be selected and the clustering maintenance of each node will be executed continuously.

Figure 3, describes the process of selecting the cluster head; H_i, among sets of neighboring moving nodes for node i; namely N_i.CWFis considered as the main factor that plays avital role in assigning the cluster head. Then, the inspection process depend on the number of neighboring nodes; if the neighboring node j has lower CWF, then the status would be checked whether it is a member of cluster i. If it is true, it could be declared that the cluster head is the node *i*. Otherwise, if the CWF of node j is higher than the one of node i, the status of node j is considered as the cluster head; if it is true, it would be announced as a cluster head, else, node i will be asked to join the cluster with H_j.

The scope of this work is limited to apply the proposed clustering technique under the scenario of straight road. In this scenario, the role of the cluster head is kept unchanged. This means that the frequent updating of the cluster head is reduced. Accordingly, the resulted overhead from changing the cluster is reduced; therefore, the stability of the cluster structure is attained. This will lead to modification of the proposed CWFin (3) to check the need for updating the cluster head. A threshold that could optimize the cluster head changing criterion is defined as η. The following equation defines the derived new CWF factor for two nodes as:

$$CWF_{ij} = \begin{cases} 0 & cos(\theta) \leq 0 \\ \delta_1 \left(\frac{R_{max} - \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}}{R_{max}} \right) + \delta_2 \left(\frac{min(v_i, v_j)}{max(v_i, v_j)} \right) & O.W. \end{cases} \quad (2)$$

where CWF_{ij} is the clustering weighting factor between the two nodes i and j.

Figure 4, shows the proposed clustering maintenance to lower the resulted overhead from changing cluster head. This process starts with separate nodes that are not belonging to a defined cluster. Before grouping those nodes, the cluster head was chosen on the basis of the process that was exhibited in Figure 3. After that, the ordinary nodes start sending a joint request to form a cluster. Then the cluster head would distribute the resources to the ordinary nodes inside their cluster. At the final stage, dynamically and repetitively, ordinary nodes would calculate their CWF, this factor will be compared with the thresholds η in order to keep the clustering maintenance process.

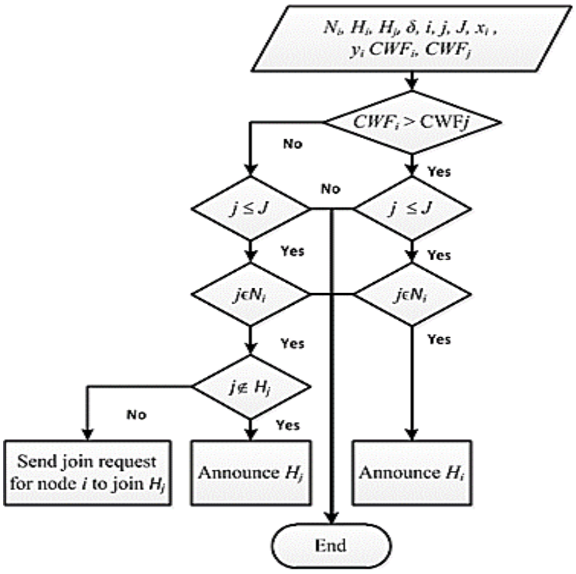

Figure 3. Selecting the cluster head flowchart

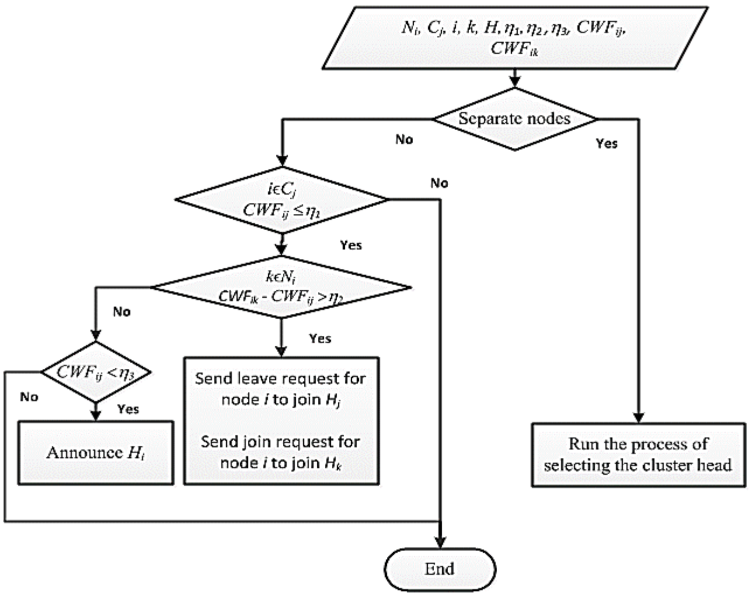

Figure 4. Clustering maintenance process flowchart

3. LTE-BASED V2V COMMUNICATIONS PERFORMANCE ENHANCEMENT

The performance of the proposed clustering technique has been simulated and compared to the work of Trestian and Munteanand Gerla et al. [25, 29-30]. This comparison contains the effect of both the maximum speed and the communications range for a lifetime on the cluster's head. The simulation has been limited to two-lanes cross road, a maximum speed up to 20 km/h, and a communication's range up to 50 km. Figure 5 (a) depicts the effect of the vehicle speed on the life time of the cluster head. It is clearly shown that an inverse proportional relationship is drawn between the lifetime cluster's head and the maximum speed; the faster the moving nodes the more the cluster would result in instability. Moreover, another metric's effect has been checked in Figure 5 (b); the communication's range from depicted results, our proposed work has extra stability over the lowest-ID DCA work [25, 29-30]. This is because our proposed work has been built based on the adaptive parameterAWF.

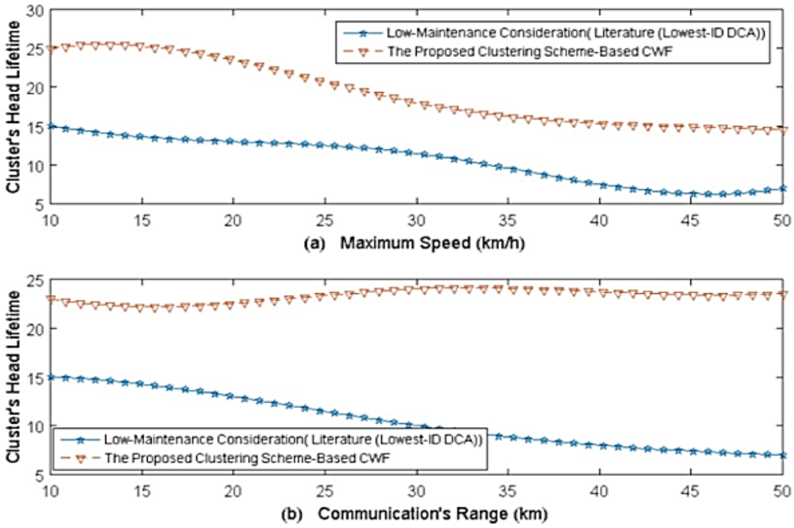

Figure 5. Cluster's head average lifetime versus: (a) maximum speed, (b) communication's range

Another metric has been involved in this performance test and depicted in Figure 6; clustering maintenance average time. It has been chosen due to the fact that it has a direct impact on the cost factor as a result of re-clustering. Another positive response has been drawn from the depicted results in Figure 6 for the proposed work versus the work of Trestian and Muntean [29] and Gerla et al. [25]. It is clearly shown that the cluster's head re-attaching time has been reduced, which is related to the adequateness for the chosenAWF values; i.e. the used weight factor for the given scenario. This conclusion will be examined in detail in future work, since there is a difference in the used scenarios such as urban transport, highways, or even a suburban.

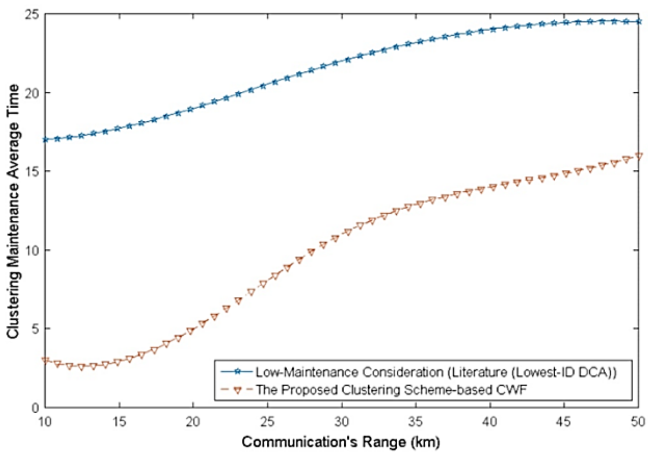

Figure 6. Clustering maintenance average time

3.1. Performance enhancement based multi-parallel processing

In this subsection, the performance of the proposed clustering technique has been investigated through the data rate and communications speed. The idea of multi-parallel processing has been imposed. This enhancement; multi-parallel processing reclustering technique for the multiband OFDM (MP-RC-MBOFDM); is clearly depicted in Figure 7. In this system, the transmission speed would be enhanced by K factor while reducing the generation complexity to $\frac{1}{K}$, where K is the total number of the OFDM generation stages. This means that a room of dealing with K-OFDM signals at the same time duration without any extra calculation time is created (*i.e.* reconstructing/regenerating K-OFDM signals with processing time equals the processing time of one OFDM signal). Therefore, the spectrum limitations for communication among the clusters' head through the LTE systems have been mitigated.

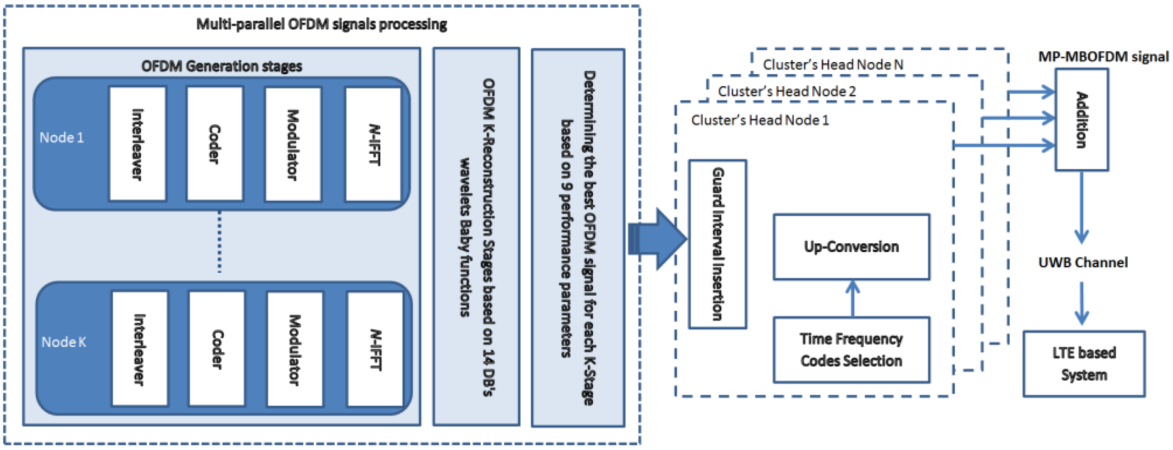

Figure 7. The proposed MP-RC-MBOFDM transmitter's schematic diagram

In this part, the simulation parameters have been limited to the ECMA-368 specifications, where the UWB technique usually allocates the spectrum into 14 different sub-bands each of 528 MHz bandwidth [8], and a zero-padded guard interval has been imposed with 0.25 duration of the OFDM symbol duration, i.e. 60.61ns. The TFC hopping ought to be confirmed with 15.6% of the guard interval. Furthermore, the used UWB channel is based on [31, 32]. Furthermore, the modulation technique is limited to 16-amplitude phase shift keying (16-APSK) [33, 34].

The idea of the OFDM systems was proposed by Chang [15], in order to allow high data rates (parallel N low bit rate channels) transmission at the system's complexity of $N \times log_2(N)$. This would give the privilege of fulfilling the needed high-speed data requirements and overcoming the allocated spectrum's limitations. This will also allow all moving vehicles (nodes) to communicate at the same time with the head node. Then, the head nodes would communicate with each other through the LTE system. Furthermore, for better performance enhancement, the MP-RC-MBOFDM system has been proposed to overcome the head nodes spectrum limitations.

MBOFDM signal can be expressed as shown in (3). The transmitted data is divided into M-groups, each of which has N-symbols with an average transmitted energy of E_t before entering the N-point IFFT stage.

$$x^M(n) = \sqrt{E_t}\sum_{p=0}^{N-1} d^M(p) \times e^{\left(\frac{j2\pi pn}{N}+\varphi_n\right)} \quad (3)$$

where n has values between 0 and N-1,φ_n stands for the frequency offset. As a result, a problem could arise due to the summation of in-phase signals as found in [9]. This problem can be expressed as in (4) and dented by the peak-to-average power ratio (PAPR):

$$PAPR = \frac{N\times\left(maximum_{n=0,..N-1}|x^M(n)|^2\right)}{\sum_{n=0}^{N-1}|x^M(n)|^2} \quad (4)$$

At the receiver side and after the assumption of perfect synchronization, the received signal from k path with α gain coefficient and a $\hat{z}$ noise sample of the M^{th}-group is expressed as:

$$y^M(n) = \sqrt{E_t} x^M(n) \sum_{k=0}^{K-1} \alpha^M(k) \times e^{\left(\frac{-j2\pi kn}{N}\right)} + \hat{z}^M(n) \quad (5)$$

16-points amplitude phase shift keying (16-APSK) has been used as a modulator and a demodulator in the transmitting and receiving stages, respectively. Many different 16-APSK constellations have been found in the literature [33, 34]. This paper is limited to (4+12)-APSK in order to of reduce the average power. This will bring an enhancement for reducing the PAPR. Furthermore, the average power could be easily linked to the inner and the radii of the outer ringsr_1 and r_2 respectively. In order to choose the best fit of r_1 and r_2 and their effect on the OFDM system's performance, an optimization process should be applied. Therefore, there should be different input back-off (IBO) values taken into considerations; this is clearly presented in Figure 8.

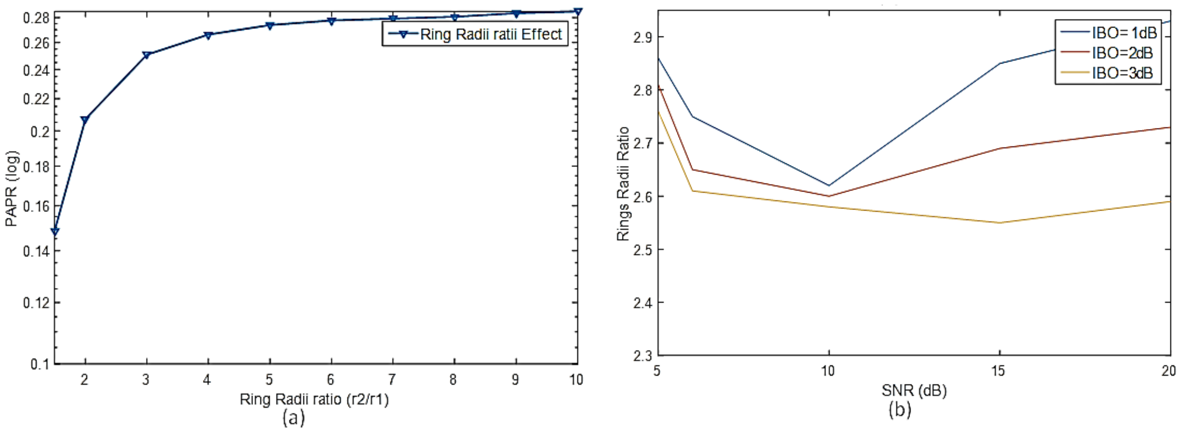

Figure 8. UWB-based APSK performance (a) the effect of the APSK rings radii ratio on the PAPR, (b) the rings radii ratio values related to the IBO values

As mentioned earlier, the spectrum limitations for the communication among the clusters' head through the LTE systems should be mitigated. Thus, MP-RC-MBOFDM is proposed. In this proposition, we are keen to check the efficiency of the proposed work based on two factors; the needed power and the allowable data rate. Thus, another parameter was involved in this simulation; it is denoted by *EE* and it checks the effect of transmitted power to the capacity of the UWB-based systems. The *EE* factor is clearly defined in (6), where *EE*(n) is the energy efficiency of the n-th carrier, $E_{ckt}(n)$, stands for the consumed power by the circuit, the transmitted energy is defined by $E_t(n)$, the received energy is defined by $E_r(n)$, the n-*th* channel's gain factor; $|h(n)|^2$, N_o represents the noise density during the transmission period of T.

$$EE(n) = \frac{\sum_{n=0}^{N-1} log_2\left(\left(\frac{E_t(n)}{TN_o} \times |h(n)|^2\right)\right)}{E_{ckt}(n)+E_t(n)+E_r(n)} \quad (6)$$

Figure 9 (a) depicts the relationship between the spectral efficiency in bpspHz and the *EE*. From those curves, a directional relationship between the spectral efficiency and the data rates has been extracted. For example, taken from Figure 9 at -6dB *EE*; spectral efficiency increased at a ratio of 12% when the data rate has increased from 1 Mbps to 6 Mbps. From the derived *EE* formula in (6), it is obvious that in Figure 9 (b) the relationship between the specific data rate of the OFDM signal and the *EE* is directly proportional. As a result, a trade-off between the spectral efficiency and the *EE* must be taken into consideration in order to manage the UWB-MBOFDM systems capacity.

Further enhancement step has been taken into consideration by involving the wavelet functions in the reconstruction stage. This step is used to differentiate the parallel transmission from different clusters' head. 14 Daubechies wavelets baby functions (db1, db2, db3, db4, db5, db7, db10, db13, db20, db25, db30, db35, db40, db45) have been used in this work. The scope of this work is limited to Daubechies due to the choice of different vanishing moments in which they trace the nature of the used signal. At the decomposition stage, the complementary cumulative distribution function (CCDF) curves have been used to distinguish among the 14 different wavelet aby functions; the one with the lowest CCDF value is the better in the decomposition stage. In order to choose the best CCDF curves, two main factors have been defined; the wavelet decomposition level and the performance distinguishing criteria. In this work, the maximum used

decomposition level is set to be eight, while eight performance criteria have been included in the distinguishing stage:
- The sum of the absolute difference between the reconstructed OFDM signals,
- The maximum absolute value of the sample differences. The reconstructed signals have been taken directly from the reconstructed structure,
- The maximum absolute value of the sample differences. The reconstructed signals have been taken directly from each reconstructed signal separately,
- The correlation matrix between the reconstructed and the observed OFDM signals,
- The signal to noise ratio,
- The mean squared error between the reconstructed and the observed OFDM signals,
- The peak signal to noise ratio,
- The relative error.

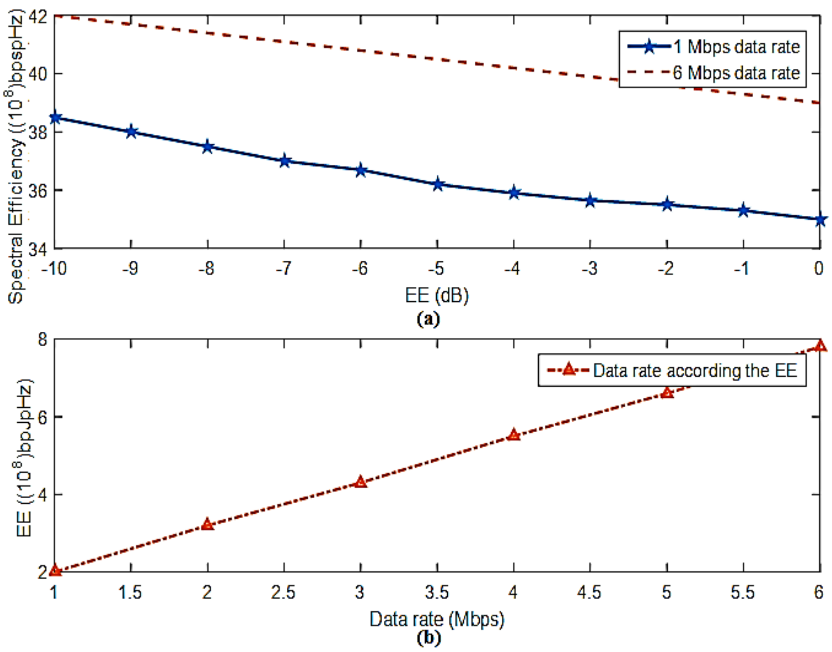

Figure 9. The efficiency of the consumed energy:
(a) spectral efficiency with respect to EE, (b) data rates relationship with EE

Thus, each cluster head transmitting signal through the LTE system is processed for eight hundred and ninety six times $(14(\text{wavelet baby functions}) \times 8(\textit{wavelet levels}) \times 8(\textit{performance criteria}))$. Accordingly, the best-decomposed signal with the lowest CCDF values will be chosen to be processed during the UWB channel. Figure 10 depicts the CCDF measurements for different processed performance criteria compared to the original one.

Figure 10 shows a noticeable enhancement of the signals' probability that exceeded certain threshold dB values. The depicted results in Figure 10 show that the SoD method gives the best CCDF curve. Furthermore, to differentiate those criteria, another test was done in order to choose the best one that gives the best CCDF values among the 869 test signals. These results have been summarized in Table 1. From the depicted results in Table 1, the best value for the Sum of Difference (SoD) performance criterion would be by using the db40 and 7 decomposing levels. This step will help in decomposing the moving node’s transmitted signal by choosing the best of the bests.

From the illustrated results in both Figure 10 and Table 1, the best scenario for the decomposition process would be the SoD at level 7 and using db40. Adaptively, this proposition is capable of processing a huge number of generated OFDM signals at the same time. Furthermore, this work gives a positive impact on the ability to increase the system's data rates. This brings the QoS enhancement without the spectrum limitations.

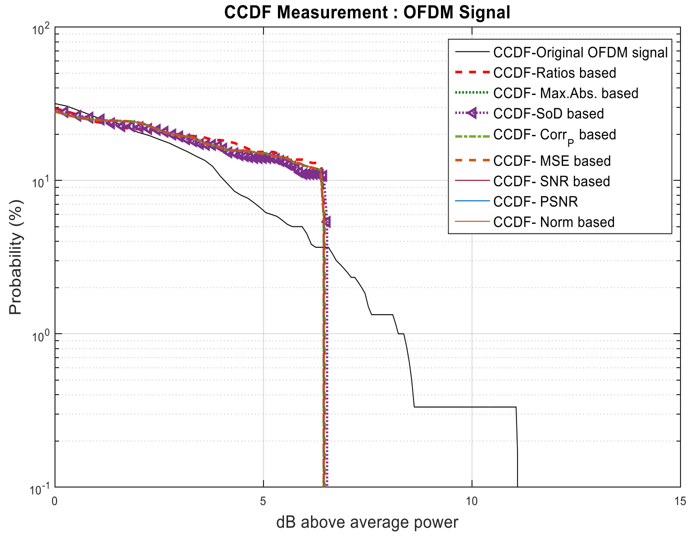

Figure 10. OFDM Decomposition based on the best performance criterion and the decomposition level

Table 1. The best performance criteria value for decomposition purposes

Method	The Best Values		
	The Level	The Wavelet Type	The Value
SoD	7	db40	60.31
SNR	7	db40	11.967
Compression Ratio	8	db10	68.21%
PSNR	7	db40	23.046
Norm	7	db40	0.252
Max. Abs.	7	db35	0.68
MSE	7	db40	0.063
Correlation	7	db40	0.968

4. RESULTS AND ANALYSIS

In order to check the proposed work performance, a federal Communications Commission (FCC) based simulation was performed. In this contest, the following factors have been taken into consideration in order to check the validity of our propositions; namely the CCDF curves, the BER curves and the quality of the transmitted data. The system's parameters have been limited and set to:

- 128 OFDM subcarrier (100 data subcarriers, 12 pilots, 10 guards)
- 242.42 ns, symbol interval
- 4.125 MHz, subcarrier frequency spacing
- 2/3 coding rate
- 16-APSK modulation technique
- CM1 and CM4 –UWB channels
  a. 0.0233, 0.0667 cluster arrival rate (per ns), respectively
  b. 2.5, 2.1 ray arrival rate (per ns), respectively
  c. (3.5, 3.4 dB) (σ_1, σ_2, respectively)
  d. LOS, NLOS, respectively
- Two lanes crossroad,
- node speed 10-25 km/h,
- Communication's range up to 50 km in terms of the cluster's head life time and the clustering maintenance average time.
- Time of changing the head equals 2 s.
- *eNodeB* coverage of 7 km

Figure 11 depicts the performance of the proposed MP-RC-MBOFDM. It uses a clustering technique based on $AWF$and V2V communications (IEEE 802.11p standard based) through LTE systems. It is divided into four sections; section (a) depicts the probability of the PAPR that exceeds certain thresholds. This performance term is investigated to check the validity of sending huge data rate over the connections. Sections (b-to-d), the cumulative distribution function has been investigated according to the clustering criteria. Thus, three more different metrics have been involved; namely, cluster head duration, cluster member duration and cluster head change rate.

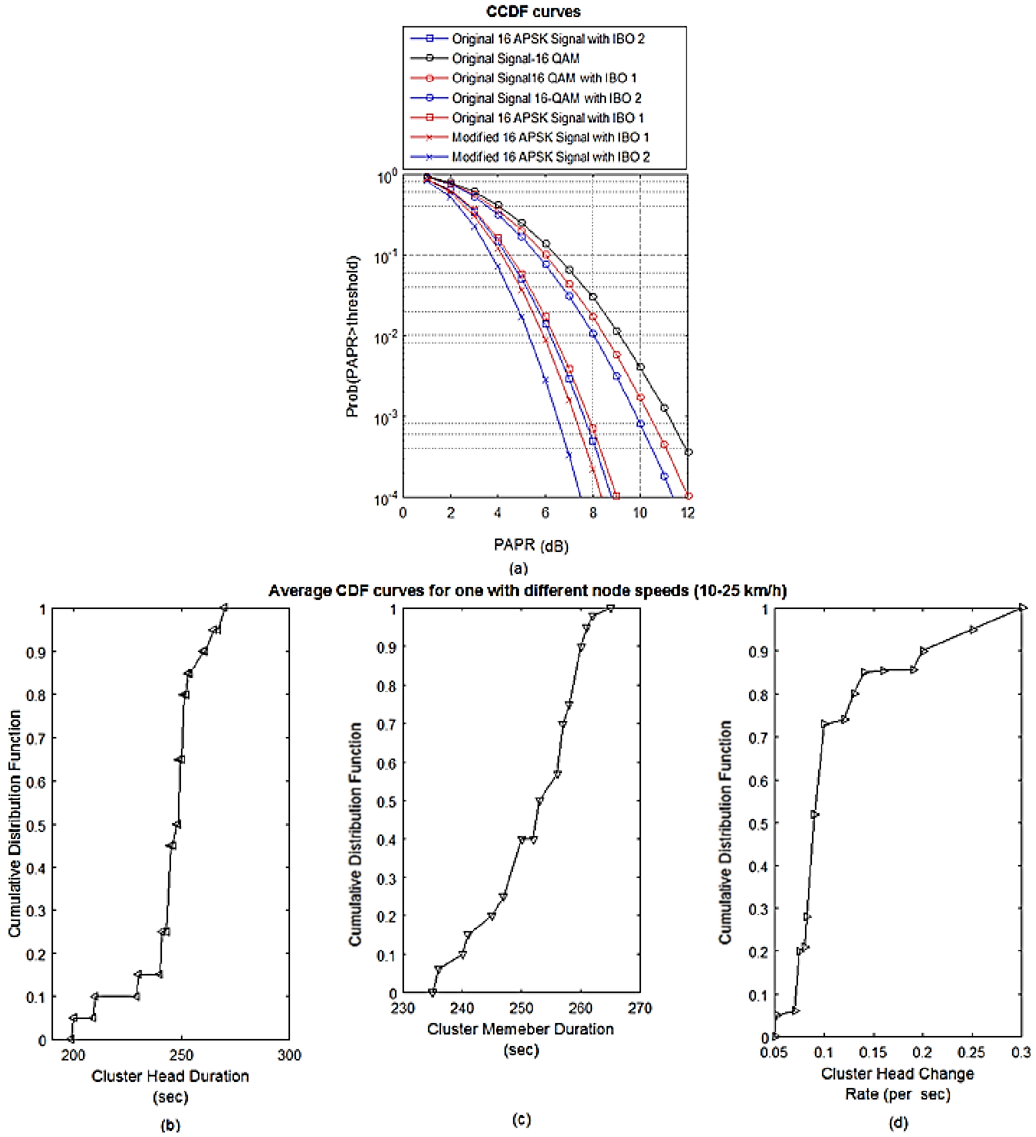

Figure 11. System's enhancement based on CDF comparison curves

From the depicted results in Figure 11 (a), the CCDF curves show a promising enhancement for the probability of exceeding a certain threshold. As an example, at a probability less than 1%, the CCDF value has been improved from 0.1 to 0.05 for IBO of 1. Furthermore, the modified APSK work gave an extra enhancement of around 15% over the achieved results of the APSK signal. At the probability of 1%, the modified work was giving an enhancement of 68.23% in the PAPR over the 16-QAM value, while the 16-APSK was reducing the PAPR of the 16-QAM to be 6.3 dB from 8.6 dB.

As a conclusion from Figure 11 (a), the CCDF-based performance enhancement is related to the IBO level and also to the same modulation category. It is clearly shown that IBO 2 results are better than the IBO 1. This is in addition that the 16-APSK has better results than the ones of the 16-QAM. Furthermore, the modified 16-APSK work by imposing the wavelet function has the best results. For instance, at a percentage of 0.1%, the modified-16-APSK work would reduce the PAPR from 7.9 dB to 6.3 dB, while it was for the 16-QAM around 9.3 dB.

In Figure 11 (b-d), the results have been drawn after averaging 10 trials for different velocities between 10 km/h and 25 km/h. Figure 11 (b) depicts the CDF performance based on the cluster head duration of our proposed scheme. It shows that the proposed work seems to be stable when the variation around the average is very small. This result would open the way to extend the work for a scope of the multi-hop proposition. Therefore, another investigation should be made to check the relationship between the number of hops and the achieved cluster head duration average. Furthermore, the CDF showed an insignificant variation around the average time between joining and leaving the cluster. Hence, the same results (i.e. the stability issue) could be extracted from Figure 11 (c). In Figure 11 (d), the CDF curve shows the reduction of the cluster head changing rate. The result proved the stability of the proposed work again based on the changing rate from the cluster head to a cluster member. Therefore, in future work, the verification would be done for relating the vehicle velocities with increasing hope numbers. This would be for checking the unnecessary mode changing between the cluster head and the cluster members.

As an optimization process, the best ratio should be chosen while the effect on the CCDF curves, the BER results, and the overhead of the cluster should be taken into consideration. The overhead of the cluster stands for the ratio between the packets of a specific cluster and the total generated packets in the network. Thus, Figure 12 (a) and (b) depict the results of the BER with two different ratio values and the overhead of the cluster, respectively.

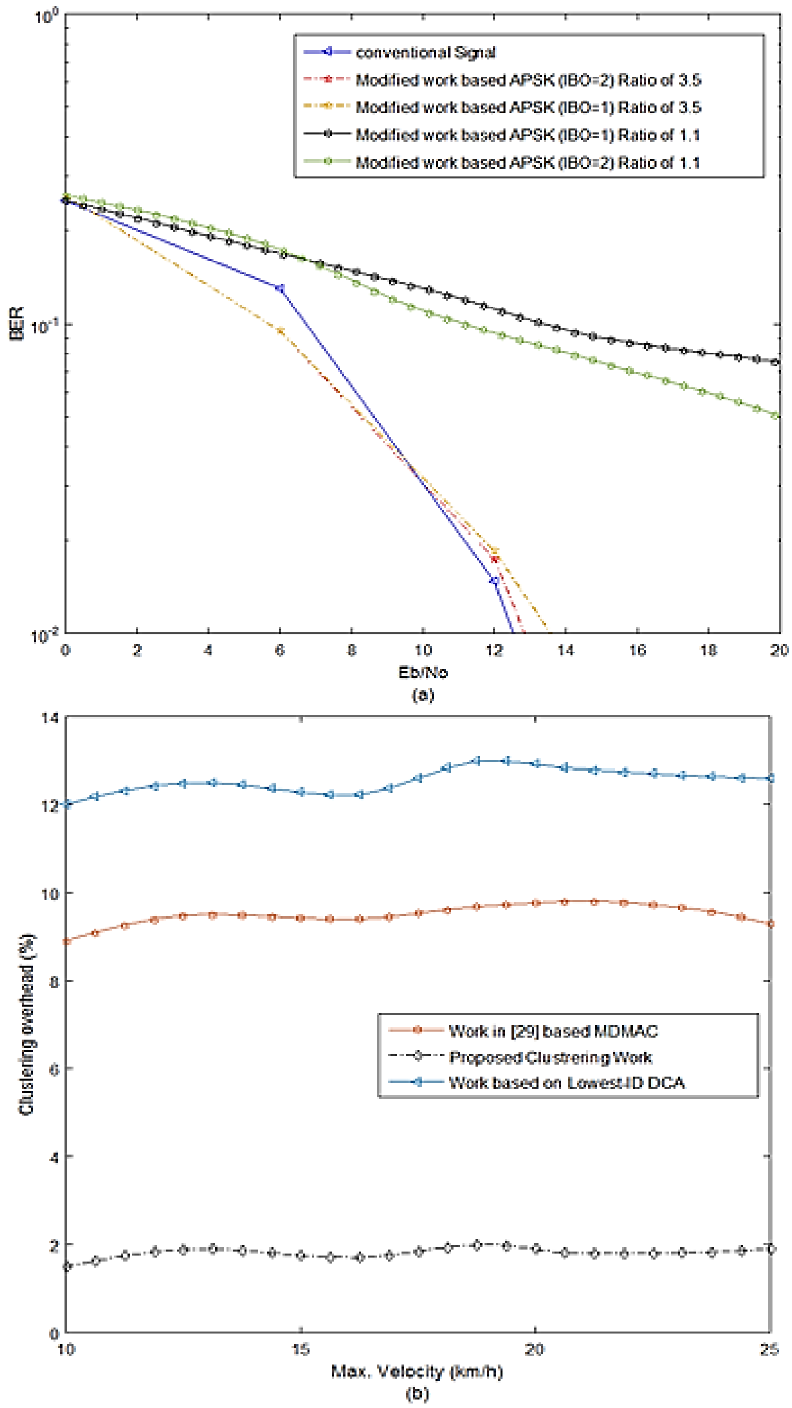

Figure 12. Ring radius ratio effect on the BER curves, modified 16-APSK signals with different IBO

In Figure 12 (a), there are three different kinds of signals that were simulated and classified as linear signal, signal with IBO of 1 and signal with IBO of 2. From the depicted results, it can be concluded that the lowest ratio gives the poorest BER performance. If the bit energy to noise ratio (Eb/No) of 20 dB has been chosen, the best performance has been extracted from the modified 16-APSK linear signal. At 20 dB, the linear signal BER has almost reached 1×10^{-5} for the ratio of 3.5. If the ratio has been decreased to 1.1, the BER would have decreased to be 9×10^{-2}. In other words, the ratio of less than 3.5 would be the optimum from the BER values point of view. Thus, it is possible to conclude that the higher the ratio, the higher the probability and consequently the higher the PAPR values. The ratio of 1.1 would give the best PAPR values. For example, for the probability of 0.1%, the PAPR value has been reduced from 8.3 dB to almost 7 dB.

On the other hand, Figure 12 (b) summarizes the result of the achieved percentage clustering overhead with respect to the maximum vehicles velocity. These results have been drawn after averaging 10 trials for different velocities between 10 km/h and 25 km/h. Furthermore, the results have been compared to the work in [29] that describes clearly the proposition of Modified DMAC clustering algorithm for VANETs. The results showed that the proposed work is more stable than the work described in [29]; the overhead percentage was so much smaller in addition to higher duration for both the cluster head and cluster members.

5. CONCLUSION

In this paper and under the boom of the combination between the LTE and the V2V systems, a clustering architecture was introduced. It integrates the LTE cellular system with the V2V communications based on IEEE 802.11p networks. It was divided into two main stages; a one hop-based vehicle clustering scheme and a multi-parallel processing scheme for high speed communications.

A clustering weighting factor was proposed based on the communications maximum range, the relative velocities, and the locations; namelyCWF. This work has been compared to two different works in the literature; namely, the lowest-ID DCA and the Modified DMAC clustering algorithm. From the depicted results, our proposed work showed a noticeable stability, especially for the clustering overhead, the cluster head duration, the cluster member duration and the cluster head change rate. In order to enhance the QoS for the LTE-based V2V systems, a wavelet-based reconstruction stage was imposed on each vehicle.

An extensive simulation based on MATLAB, NS-3 and SUMO was performed. The MP-RC-MBOFDM shows promising results compared to the work of [25, 29-30]. It was drawn based on the following performance parameters: the CCDF curves, BER curves, the *EE* results, the cluster head life time, the clustering maintenance average time and the clustering overhead percentage. Furthermore, the results showed the powerfulness of using the 16-APSK modulation technique instead of the 16-QAM. It has been concluded based on the modulation ring ratio and the IBO level factors.

REFERENCES

[1] A. Abdelgader, and W. Lenan, “The Physical Layer of the IEEE 802.11p WAVE Communication Standard: The Specifications and Challenges,” *Proceedings of the World Congress on Engineering and Computer Science* vol. 2, San Francisco, USA, 22-24 October 2014.
[2] Q. Wang, S. Leng, H. Fu, Y. Zhang, “An IEEE 802.11p-based Multi-channel MAC Scheme with Channel Coordination for Vehicular Ad Hoc Networks,” *IEEE Transactions on Intelligent Transportation Systems*, vol. 13, no. 2, pp. 449-458, June 2012.
[3] H. King, K. Nolan, M. Kelly, “Interoperability Between DSRC and LTE for VANETs,” *IEEE 13th International Symposium on Industrial Embedded Systems (SIES)*, pp. 6-8, Graz, Austria, June 2018
[4] S. Ucar, S. Ergen, O. Ozkasap, “Multihop-Cluster-Based IEEE 802.11p and LTE Hybrid Architecture for VANET Safety Message Dissemination,” *IEEE Transactions on Vehicular Technology*, vol. 65, no. 4, pp. 2621-2636, April 2016.
[5] A. Bazzi, B. Masini, A. Zanella, “Performance Analysis of V2V Beaconing Using LTE in Direct Mode with Full Duplex Radios,” *IEEE Wireless Communication Letters*, vol. 4, no. 6, pp. 685-688, Dec 2015.
[6] A. Moller, T. Kurner, “LTE link level performance evaluation using stochastic channel models for V2X communication,” *2015 IEEE Vehicular Networking Conference (VNC)*, pp. 25-31, Kyoto, Japan, 2015.
[7] Multiband OFDM Alliance (MBOA) Special Interest Group (SIG), WiMedia Alliance, Inc. (WiMedia). Multiband OFDM Physical Layer Specification. Release 1.1, July, 2005.
[8] ECMA-368, "High rate ultra wideband PHY and MAC Standard," [Online], Available: https://www.ecma-international.org/publications/files/ECMA-ST/ECMA-368.pdf, 2008.
[9] R. v. Nee and R. Prasad, “OFDM for Wireless Multimedia Communications: Artech House,” Inc., 2000.
[10] G. T. Nguyen, B. Noble, R. H. Katz, and M. Satyanarayanan, "A trace-based approach for modeling wireless channel behavior," *Proceedings Winter Simulation Conference*, pp. 597-604, USA, 1996.

[11] A. Batra, J. Balakrishnan, G. R. Aiello, J. R. Foerster, and A. Dabak, "Design of a multiband OFDM system for realisticUWB channel environments,'" *IEEE Trans. Microw. Theory Techn.*, vol. 52, no. 9, pp. 2123-2138, September 2004.
[12] X. Ge, S. Tu, T. Han, and Q. Li and G. Mao, "Energy efficiency of small cell backhaul networks based on Gauss_Markov mobile models," *IET Netw.*, vol. 4, no. 2, pp. 158-167, 2015.
[13] Y. Ren, C. Wang, D. Liu, F. Liu, E. Liu. "Applying LTE-D2D to Support V2V Communication Using Local Geographic Knowledge," *IEEE Vehicular Technology Conference* (*VTC*), pp. 1-5, Boston, MA, USA, September 2015.
[14] T. S. Rappaport, S. Sun, R. Mayzus, H. Zhao, Y. Azar, K. Wang, G. N. Wong, J. K. Schulz, M. Samimi, and F.Gutierrez, "Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!," *IEEE Access*, vol. 1, pp. 335-349, 2013.
[15] R. W. Chang, "Synthesis of band-limited orthogonal signals for multichannel data transmission," in *The Bell System Technical Journal*, vol. 45, no. 10, pp. 1775-1796, Dec. 1966.
[16] N. Doose and P. A. Hoeher, "Massive MIMO Ultra-Wideband Communications Using Multi-Mode Antennas," in *SCC 2015; 10th International ITG Conference on Systems, Communications and Coding*, pp. 1-6, 2015.
[17] D. H. Holma and D. A. Toskala, "LTE for UMTS-OFDMA and SC-FDMA Based Radio Access," Wiley Publishing, 2009.
[18] O. Omomukuyo, M. P. Thakur, and J. E. Mitchell, "Simple 60-GHz MB-OFDM Ultrawideband RoF System Based on Remote Heterodyning," *IEEE Photonics Technology Letters*, vol. 25, pp. 268-271, 2013.
[19] S. Roy, J. R. Foerster, V. S. Somayazulu, and D. G. Leeper, "Ultrawideband radio design: the promise of high-speed, short-range wireless connectivity," *Proceedings of the IEEE*, vol. 92, no. 2, pp. 295-311, 2004.
[20] Liuqing Yang and G. B. Giannakis, "Ultra-wideband communications: an idea whose time has come," in *IEEE Signal Processing Magazine*, vol. 21, no. 6, pp. 26-54, November 2004.
[21] J. Y. Yu and P. H. J. Chong, "A survey of clustering schemes for mobile ad hoc networks," in *IEEE Communications Surveys & Tutorials*, vol. 7, no. 1, pp. 32-48, First Qtr. 2005
[22] M. M. C. Morales, C. S. Hong and Y. Bang, "An Adaptable Mobility-Aware Clustering Algorithm in vehicular networks," *2011 13th Asia-Pacific Network Operations and Management Symposium*, pp. 1-6, Taipei, 2011.
[23] C. Shao, S. Leng, Y. Zhang, A. Vinel, and M. Jonsson, "Performance Analysis of Connectivity Probability and Connectivity-Aware MAC Protocol Design for Platoon-Based VANETs," *IEEE Transactions on Vehicular Technology*, vol. 64, no. 12, pp. 5596-5609, December 2015.
[24] C. Lai, P. Lin, W. Liao,*et al*., "A Region-Based Clustering Mechanism forChannel Access in Vehicular Ad Hoc Networks," *IEEE Journal on Selected Areas in Communications*, vol. 29, no. 1, pp.83-93, 2011.
[25] N. Maslekar, M. Boussedjra, J. Mouzna, *et al.*, "Direction Based Clustering Algorithm For Data Dissemination In Vehicular Networks," *2009 IEEE Vehicular Networking Conference*, pp. 1-6, Tokyo, Japan, 2009.
[26] A. B. McDonald and T. F. Znati, "Design and performance of a distributed dynamic clustering algorithm for ad-hoc networks," *Proceedings. 34th Annual Simulation Symposium*, pp. 27-35, USA, 2001.
[27] Y. Lai, P. Lin, W. Liao and C. Chen, "A Region-Based Clustering Mechanism for Channel Access in Vehicular Ad Hoc Networks," *IEEE Journal on Selected Areas in Communications*, vol. 29, no. 1, pp. 83-93, January 2011.
[28] Y. Gunter, B. Wiegel and H. P. Grossmann, "Cluster-based Medium Access Scheme for VANETs," *2007 IEEE Intelligent Transportation Systems Conference*, pp. 343-348, Seattle, WA, 2007.
[29] R. Trestian and G.-M. Muntean, "Paving the Way for 5G Through the Convergence of Wireless Systems: Advances in Wireless Technologies and Telecommunication," 1st Edition, ISBN-13: 978-1522575702, IGI Global, 2019.
[30] M. Gerla, T. Tsai, "Multicluster, Mobile, Multimedia Radio Network", *Wireless Networks*, vol. 1, no. 3, pp. 255-265, 1995.
[31] A. Molisch, J. Foerster, and M. Pendergrass, "Channel models for ultrawideband personal area networks," *IEEE Wireless Communications*, vol. 10, no. 6, pp. 14-21, 2003.
[32] M. Samimi and T. Rappaport, "Ultra-wideband statistical channel model for non line of sight millimeter-wave urban channels," *2014 IEEE Global Communications Conference*, pp. 3483-3489, Austin, USA, 2014.
[33] J. Gazda, D. Dupák, and D. Kocur, "M-APSK modulation for SC-FDMA communication systems," *Proceedings of 21st International Conference Radioelektronika 2011*, pp. 1-4, 2011.
[34] C. Manimegalai and R. Kumar, "Efficacy of 16-APSK modulation for Multiband Pulsed-OFDM UWB-communication systems," *2012 World Congress on Information and Communication Technologies*, India, pp. 150-155, 2012.

BIOGRAPHIES OF AUTHORS

Omar R. Daoud (odaoud@philadelphia.edu.jo) has achieved the PhD in the field of Communication and Electronics Engineering at DMU/ UK 2006. He joined Philadelphia University in 2007 as Assistant Professor. His current work is about achieving the Quality of Service for the 4^{th} Generation of the Wireless and Mobile Communication Systems by combining the advantages of the OFDM and the multiple antenna technology. He is the Assistant Dean in the Faculty of Engineering in addition to the Head of Communications and Electronics engineering department. Moreover, and in March 2012 he has promoted to the associate professor rank.

Ahlam A. Damati (adamati@philadelphia.edu.jo) has achieved the MSc in the field of Electrical Engineering/Communications from The University of Jordan/ Jordan 2002. She had worked as a lecturer in different universities since 2003; UJ and GJU, while she joined Philadelphia University in 2014 as a lecturer in the Electrical Engineering department. Her research interests are in achieving the Quality of Service for the wireless new technologies based on a variety of digital signal processing techniques.

Qadri J. Hamarsheh (qhamarsheh@phladephia.edu.jo) has received the master degree of Computer Machines, Systems and Networks from the department of Computer Engineering, Lviv Polytechnic Institute in 1991. He obtained his Ph. D degree from Lviv National University “Lvivska Polytechnica”, Ukraina in 2001. Currently he is working as assistant professor of Computer Engineering, Philadelphia University-Jordan. He is in teaching since 2001. His areas of interest include Digital Signal Processing (DSP), Digital Image, Speech Processing, Object-Oriented Technology and Programming Languages, Internet Technology and Wireless Programming.