Cognitive Radio does wonders to VANET

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Abstract: In cognitive radio the most important and re-searched issue is spectrum sensing for the communication techniques. Spectrum sensing is a technology which helps the detection of the presence of primary user. Likely, vehicular networks was put under surveillance due to increasing traffic congestion and accidents. An efficient network can not only improve the communication between vehicles but also reduces the risk of congestion and accidents. VANET have in recent year gained a lot attention. Vehicular Ad-hoc network is used for intelligent transportation wherein the ad-hoc network protocol is used to transmit information reliably and efficiently over network. But at same hand characteristics of VANET, including high-speed mobility, channel fading property, channel competition mechanism, and various quality of service (QoS) of user services, etc., offer certain hurdles for the data transmission in VANET. To overcome these challenges and difficulties many solutions and methodologies came up where cluster-based scheme for data transmission in VANET topped the list until cooperative sensing technique was employed to VANET. In this paper, we put into practice both the techniques namely, clustering-based scheme and co-operative sensing for data transmission in VANET, and then a stark contrast between the two methodologies will be put up in terms of their performance parameters with respect to number of vehicles. The numerical results and simulation graphs will demonstrate the efficiency of the proposed algorithms.

Keywords: VANET, Ad-hoc, Cognitive radio, Co-operative sensing, Clustering, Spectrum sensing.

Introduction

World is now advancing to an era where wireless communications is the fourth need of people after food, water and shelter. Wireless technology is the most harnessed resource in the present era. Look around ourselves and we shall find us surrounded with several things which run on wireless communication techniques ex. from television to mobile phones to radio etc. Increasing population and its need for wireless media access has come as a peer pressure on the limited radio spectrum. A solution was very much needed to effectively utilize and increase efficiency of the channel utilization which would result in better performance. Cognitive Radio's (CR) invention was a boon to the market and technology dependent on the wireless modes of communication.

Cognitive radio is a canny remote correspondence frame-work, it can detect and get data from the encompassing condition. The CR innovation has as of late been examined because of its capacity to adjust the remote condition by changing the working parameters. A standard for remote local region systems is proposed by the IEEE 802.22 Working Committee, which embraces the CR innovation. Cognitive radio has risen as the key answer for supporting the expanding interest of range for remote interchanges, through the execution of the Opportunistic Spectrum Sharing (OSS) paradigm. Taking after such a worldview, CR gadgets are permitted to utilize all the accessible range assets, under the imperative that the operations of the authorized clients of the bands must not be influenced. The greater part of flow research on CR innovation has concentrated on applications to: increment the limit in back-haul remote work systems, build up solid correspondence in crisis systems or support the crossing over of heterogeneous remote systems.

Around 1.5 million individuals kick the bucket each year and almost 10 to 40 million are influenced by lethal wounds because of street mischances around the world as indicated by a report distributed by the World Health Association. The report additionally expresses that street mishaps are the eighth driving reason for deadly wounds and may move toward becoming the fifth driving cause if legitimate measures are definitely not taken to diminish street mishaps.

Late advances in remote systems have prompted the presentation of another sort of network called vehicular ad-hoc systems (VANETs). This kind of systems has as of late drawn noteworthy research consideration since it gives the foundation for growing new frameworks to upgrade drivers' security. Furnishing vehicles with different sorts of detecting gadgets and wireless correspondence capacities help drivers to procure ongoing data about street conditions permitting them to respond on time. For case, cautioning messages sent by vehicles required in a mischance upgrades activity security by helping the drawing nearer drivers to take appropriate choices before entering the crash perilous zone. In addition, data about the current transportation conditions encourage driving by taking new courses in the event of clog, in this manner sparing time and changing fuel utilization. Notwithstanding well-being concerns, VANET can likewise support other non-safety applications that require a quality of service (QoS) ensured.

In field of VANETs research many solutions came up out of which clustering algorithms gave the best results. Again as the CR technology came into existence, replacements to old technology with this new efficient and intelligent system were performed. When VANETs scenario came to picture with this new technology results were much better than expected. In this work, we present a VANET scenario to which both Clustering algorithm and co-operative sensing method shall be applied separately.

VANETs are described by high vehicle portability. Because of high mobility, VANET topology changes quickly, in this way, presenting high correspondence overhead to exchange new topology data. A few control plans for media and topology administrations have been proposed. One of these plans is building up a various leveled clustering structure inside the system. The clustering permits the arrangement of element virtual spine used to compose media access, to support QoS and to improve steering. Mostly, nodes are divided into clusters, each with a cluster head (CH) node that is in charge of all administration and coordination undertakings of its group (cluster).

In first sprint, we present another grouping approach with the point of expanding the security of the system topology and making it less dynamic. This approach takes the speed distinction, notwithstanding the location and direction, into thought amid the clustering procedure. Be that as it may, with the incorporation of the speed difference as another parameter, another challenges emerges as: how to parcel the system into least number of clusters, to such an extent that at the point when the clusters are at last shaped, the appropriation of the vehicles among them in light of their portability examples is accomplished with high likelihood. To put it plainly, we require a calculation to precisely recognize hubs indicating comparable versatility examples and gathering them in one group. In this paper, our principle commitments are as per the following: to start with, building up another clustering algorithm that runs on all nodes in a fully distributed way. This calculation is utilized to separate the system network into groups (cluster) with the end goal that when the system is at long last apportioned (clustered), the probability of partitioning along cluster boundaries is achieved with high probability. This implies vehicles with high versatility are assembled in one cluster and vehicles with low versatility are gathered in another cluster. Second, building up another multi-metric decision technique that can be utilized by network nodes to decide their reasonableness to be a cluster heads.

In the second sprint we examine the utilization of CR standards on Vehicular Ad-hoc Network (VANETs), with the objective of expanding the accessible transfer speed for between vehicle correspondences. In this paper, we propose to utilize the CR standards in the vehicular condition keeping in mind the end goal to increment the range open doors for between vehicle correspondences. We propose an agreeable detecting and range distribution plot through which vehicles can share data about range accessibility of Television channel on their way, and powerfully choose the channels to use on every street segment. We design auto-correlation spectrum sensing and then model it to network layer of the communication channel.

System Model

As proposed, in initial stage of the work we generate a VANET scenario which shall remain common to both clustering algorithm and spectrum sensing method. Upon generating the VANET scenario, say for 30 vehicles, we then proceed with applying clustering algorithm or spectrum sensing method to the same. Both the methodologies are to be applied in the network layer defined for the vehicles communication. We generate a scenario where each times vehicle number will increase, say by 5 or as many number mentioned, and goes up to certain number of vehicles. The major objective will be to analyze three parameters, namely:

- Delay,
- Throughput, and
- Transmission of packets

All with respect to number of vehicles. In first stage we generate our clustering algorithm and then use it in the network layer while in the second stage to the same VANET scenario we implement auto-correlation spectrum sensing method.

Clustering Algorithm

The level of the speed distinction among neighboring vehicles is the key rule for developing moderately stable clustering structure. Neighboring vehicles participate with each other to frame clusters. Simply, vehicles assemble their neighborhood relationship utilizing the position information implanted in the occasional messages. As a rule, vehicles communicate their present state to every other node inside their transmission extend r. Hence, two vehicles are considered r-neighbors if the separation between them is not as much as r. The aggregate number of r-neighbors of a given vehicle is known as the nodal level of the vehicle.

To show how the degree of the speed difference is used in our technique, we first introduce the statistical distributions of the vehicles velocity. According to [7-9], the velocity can be modelled using the normal distribution with mean, μ, and variance, s2, and its probability density function (pdf) is given by:

$$p_v(v) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-(v-\mu)^2}{2\sigma^2}} \quad (1)$$

The speed difference, Δv, between a vehicle and its r-neighbor follows normal distribution with pdf given as:

$$p_v(v) = \frac{1}{\sigma_{\Delta v}\sqrt{2\pi}} e^{\frac{-(\Delta v-\mu)^2}{2\sigma_{\Delta v}^2}} \quad (2)$$

Where,
$\Delta v = v1 - v2$, $\mu_{\Delta v} = \mu 1 - \mu 2$, and $\sigma_{\Delta v}^2 = \sigma_1^2 + \sigma_2^2$
The probability that the speed difference between two r-neighbors falls within the threshold Δv_{th} can be obtained by:

$$p_{\Delta v}(-\Delta v_{th} < \Delta v < \Delta v_{th}) = \frac{1}{\sigma_{\Delta v}\sqrt{2\pi}} \int_{-\Delta v_{th}}^{\Delta v_{th}} e^{\frac{-(\Delta v-\mu)^2}{2\sigma_{\Delta v}^2}} d\Delta v \quad (3)$$

For the above given Δv_{th}, the $p_{\Delta v}$ value decreases as $\sigma_{\Delta v}$ increases. Thus, the expected number of stable neighbors (SN) will vary. So, in order to avoid having high variation of this number, the threshold can be set as a function of the standard deviation.

Network Scenario
In this paper, a VANET application scenario consisting of multiple vehicles and one AP is considered as shown in fig.1. It is accepted that different clusters have been framed from contiguous vehicles in particular regions. For each group, one CH (Cluster Head) is picked and different vehicles in the bunch are termed as CMs (Cluster Member). CMs of same cluster are permitted to communicate with each other, while to collaborate with the AP or vehicles in different clusters, the CMs need to interact with the CH, which then acts as the transfer vehicle for sending client information to the AP or different clusters.

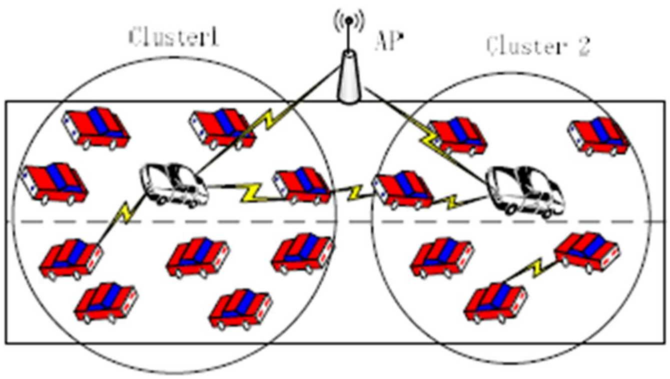

Fig.1 Network Model

Channel Model
In this paper, the communication channel between one CH and the AP is modelled as Nakagami-m fading channel with the channel gain h_1 following the probability distribution

$$f(h_1) = \frac{2m^m}{\Omega(d)^m \Gamma(m)} h_1^{2m-1} \exp\left(-\frac{m}{\Omega(d)} h_1^2\right) \quad (4)$$

Where *m* is the Nakagami fading parameter (m ≥ 1/2), Γ(.) represents the gamma function [11], Ω(d) denotes the power loss corresponding to transmission distance *d*, and can be expressed as [9]:

$$\Omega(d) = \frac{P_t G_t G_r h_t^2 h_r^2}{d^\theta L} \quad (5)$$

Where, P_t is the transmission power, G_t and G_r are antenna gains of the transmitter and receiver, respectively, h_t and h_r are the antenna heights of transmitter and receiver, respectively, θ denotes path loss exponent, and *L* denotes system loss.

Auto-correlation Spectrum Sensing

In this work, spectrum sensing algorithm is obtained from auto-correlation of the received signals. It is demonstrated that with legitimate decision of measurements, the limit of detection can be made autonomous of the noise power. The proposed strategy is extremely viable in dispersive channel as sample signals are more correlated under this condition. Range of unknown primary signal is derived via auto-regressive (AR) investigation.

As of late, the auto-correlation based detecting techniques are proposed in [2], [3], [4].The change/variance in the noise does not be assessed as a result of the “self-normalizing” highlight of the narrow band signals. These detectors can recognize the primary users signal in view of the property that a large portion of the narrow band signals auto-correlation matrices are not diagonal.

We noticed that the correlation feature of the received signal does not considered by the conventional energy detector. Thus when the variance of noise is already detected by the sensors, if we consider the power and the auto-correlation of the signal jointly, the sensing performance will be improved.

In this paper, a new spectrum sensing algorithm is proposed based on the assumption that the primary user’s signal is not white. The reason why the received signal is correlated is discussed in [10]. We noticed that the correlation feature of the received signal does not considered by the conventional energy detector. Thus when the variance of noise is already detected by the sensors, if we consider the power and the autocorrelation of the signal jointly, the sensing performance will be improved.

Define,

$$R(\tau) = E\{x(n)x(n+\tau)\} \tag{6}$$

$$= \lim_{N\to\infty} \sum_{n=0}^{N-\tau-1} x(n)x(n+\tau)$$

is the autocorrelation function of x(n). Since the samples number is finite in the real environment, the true value of R(τ) cannot be obtained. Thus, we use R̂(τ) as the estimation value of R(τ), which is defined as follows

$$\hat{R}(\tau) = \frac{1}{N-\tau} \sum_{n=0}^{N-\tau-1} x(n)x(n+\tau) \tag{7}$$

Since the autocorrelation function of the primary user’s signal is hard to be obtained in the real environment, similar with the energy detector, we can obtain the threshold by the giving probability of false alarm which is derived as

$$P = \frac{1}{2\sigma_w^2\sqrt{\pi/N}} \int_{\gamma}^{\infty} e^{\frac{(z-\sigma_w^2)}{2\sigma_{w/N}^4}} dz \tag{8}$$

Hence, for a given probability of false alarm P, the threshold λ of an energy detector can be derived as

$$\lambda = \sigma_w^2(1 + \sqrt{\frac{2}{N}}Q^{-1}(P)) \tag{9}$$

Where $Q(x) = \left(1/\sqrt{2\pi}\right)\int_x^{\infty} e^{-t^2/2}\,dt$ is the normal Q-function.

Simulation and Results

We made use of software tool MATLAB 2014 version for the simulation of the results of both the methodologies. A successful outcome as assumed was obtained. To both the methods VANET scenario was applied and then the performance parameters help in deciding the efficiency of methods.

Clustering Algorithm

We have successfully implemented our cluster algorithm and obtained various clusters depending on the velocity, distance between vehicles, and difference between speeds in vehicles. There shall be in total 16 figurative windows on MATLAB popping up, as we defined our range of vehicles to be from 30 to 100 in steps of 5. Each time we enter the loop of vehicles clustering algorithm is implemented again and again for 16 times. And each time we shall encounter new clusters and different cluster heads.

In fig.2, we see the exact values of x and y co-ordinates and the velocity of each of 30 vehicles which is allotted randomly. These parameters are very essential as on basis of these parameters clusters and cluster heads are decided for vehicles.

```
xloc =

  Columns 1 through 20

    18    10    18    19     6    12     5    12    18    12     7    10     8    13     4     6     9    12    16     4

  Columns 21 through 30

     6    16    17    15     7    11     4     3    15    17


yloc =

  Columns 1 through 20

    20     6    12    17     4    15    11    10    18     2    15    15     9    18    14    11    17    11     3    13

  Columns 21 through 30

     1    11     1    10    14     2     6    10     3     4


vel_vech =

  Columns 1 through 20

     7     7    28    35    33    25    26    10    30    37    39    24    11    38    35    10    18    21    23    40

  Columns 21 through 30

     8    26    17    32    21    16    24     3    32     7
```

Fig.2. Random values allotted to 30 vehicles distributed based on x direction, y direction and velocity

In fig.3 we see a clusters defined for 30 vehicles depending mainly on speed difference between vehicles, location and distances.

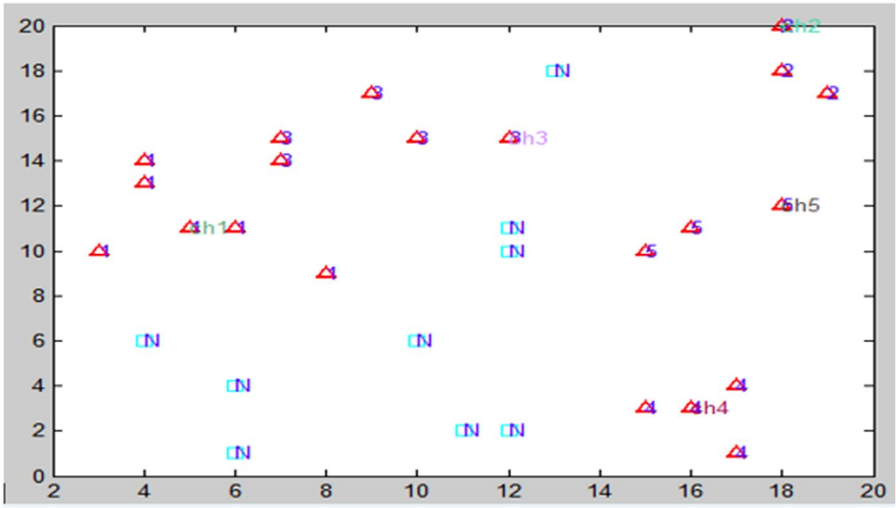

Fig.3 Clusters defined for the 30 vehicle scenario in an area of 20x20

In fig.4, we see that from 30 vehicles to upto 100 vehicles we obtain our parameteric measure for accounting for the efficiency of the algorithm with respect to our spectrum sensing methodology.

The delay characteristic demonstrates the adequate exchange time of a data from source to its goal. Delay is brought on by network blockage and transmission issues that cause blunders, and also equipment and programming inefficiencies.

Our aim is to achieve less delay during communication. Delay introduced may lead to false information's and sometimes may cause many errors in decisions. Hence the system says that to achieve a good and error free effective communication it is necessary to have delay least. In fig.6 we obtain our output for delay versus no. of vehicles, where we see the delay rising with increase of users (vehicles).

```
vech_val =

   30    35    40    45    50    55    60    65    70    75    80    85    90    95   100

throughput_val1 =

   1.0e+03 *

  Columns 1 through 12

    0.5895    0.6760    0.9266    1.2535    1.3781    1.4763    1.5214    1.5676    1.6035    1.6540    1.7556    1.8262

  Columns 13 through 15

    1.9193    1.9705    2.1066

tx_val1 =

  Columns 1 through 12

    0.7997    0.7117    0.5248    0.4967    0.4860    0.4424    0.3854    0.3637    0.2357    0.2197    0.1643    0.1448

  Columns 13 through 15

    0.1397    0.0813    0.0143

dly_val1 =

  Columns 1 through 12

    9.0344    9.2498    9.3187    9.3631    9.3812    9.5496    9.5528    9.5539    9.6677    9.6761    9.7438    9.8777

  Columns 13 through 15

   10.2058   10.9596   17.8712
```

Fig.4 Obtained values for Throughput, Delay and transmission of messages for vehicles

A very important consideration in data communication is how fast data we can send, in bit per second, over a channel. So based on different cluster formed, transmission rate is evaluated with respect to number of vehicles. We observe in fig.4, the rate of transmission decrease as the number of vehicles increase. This can be related with how too much crowding over a server decreases the upload and download rate. Nevertheless, our aim is to get as high transmission rate we can, for the same number of crowd (here vehicles).

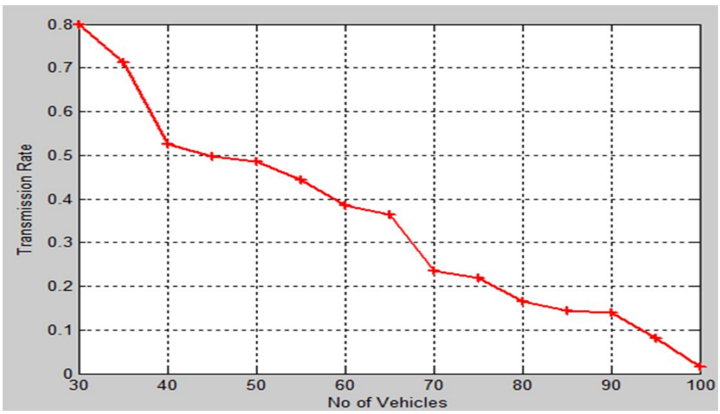

Fig.5 Transmission rate (bps) v/s No. of vehicles

Throughput is typically characterized as time average of the number of bits per second that can be transmitted by each node to its goal. It depends for instance, on the spectral (transfer speed) efficiency in a given bandwidth and how productively the impedance is kept away from or suppressed, and is consequently identified with the utilization of data transfer capacity and transmitted vitality.

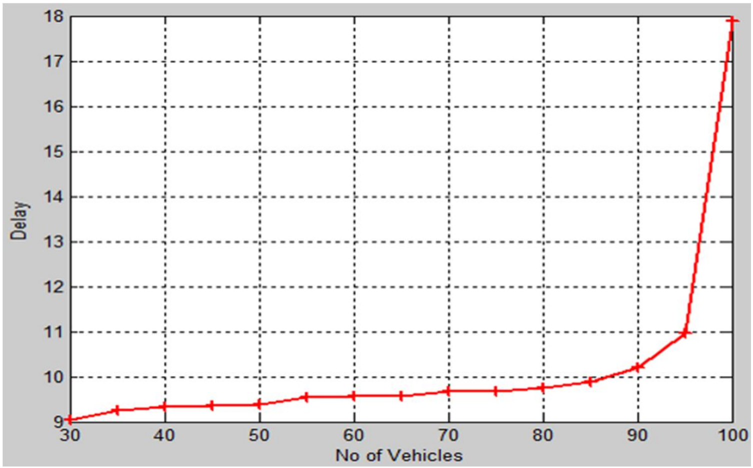

Fig.6 Delay (millisecond) v/s No. of vehicles

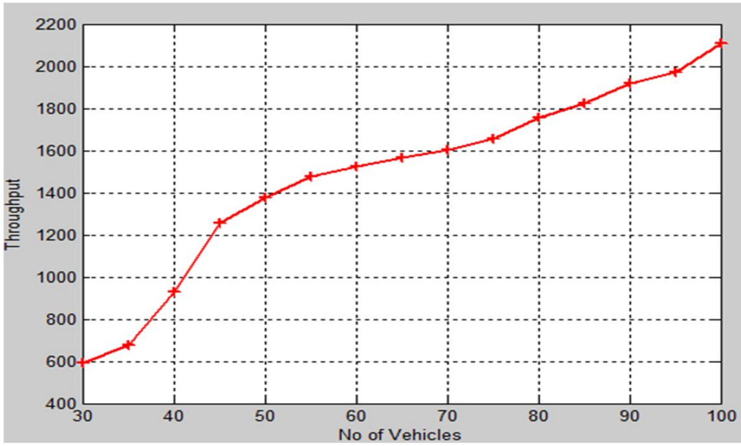

Fig.7 Throughput (bps) v/s No. of vehicles

In fig.7, we see how this algorithm has effectively helped in increasing the throughput of the system just with the help of its clusters. As we see how the throughput has increased we can say that the cluster heads have definitely come into picture and managed the data.

Autocorrelation Clustering algorithm

In fig.8 we first get the x and y locations of each the 30 vehicles randomly generated and their corresponding velocity
In fig.9 unlike the clustering algorithm, where we had a cluster head playing substantial role in broadcasting of messages, here we make all vehicles sense each other's information. This has been effectively possible because of the auto-correlation spectrum sensing method.
Fig.10 shows the theoretical values hence obtained for measuring the performance parameter. The graphical representations for the same parameters are followed up from fig.11-13.
Also after seeing the 16 windows result we also learn that spectrum sensing method leads to less number of cluster formation compared to that of clustering algorithm where we were getting say about 15 different clusters but in sensing method for the same number of vehicle scenario i.e., 100 we get around 7 to 8 clusters. One reason to an increased throughput of sensing method is likely this.
On contrary every method has its trade offs as well, while cognitive radio spectrum sensing gave the best outcome for transmission and throughput but at the cost of high increment in delay.

```
xloc =

  Columns 1 through 27

   19    5    5   14    6   14    2    4    3    3   18   20   16   15   17   11   13   15    4    8    8    3   14    9    9    2    7

  Columns 28 through 30

    5   11    5


yloc =

  Columns 1 through 27

    5   19    4   17    3   10   11   14   14   14   11    5    4    8    2   12   16   14    8    1    8   15    1    3   20    2    9

  Columns 28 through 30

   11   18   12


vel_vech =

  Columns 1 through 27

   16    6    2   22   18    6   20   11    8   28   18    8   23   31   14    7   36   39   17    3   19    9   12   23   30    2   38

  Columns 28 through 30

   20    6   15
```

Fig.8 Random values allotted to 30 vehicles distributed based on x direction, y direction and velocity

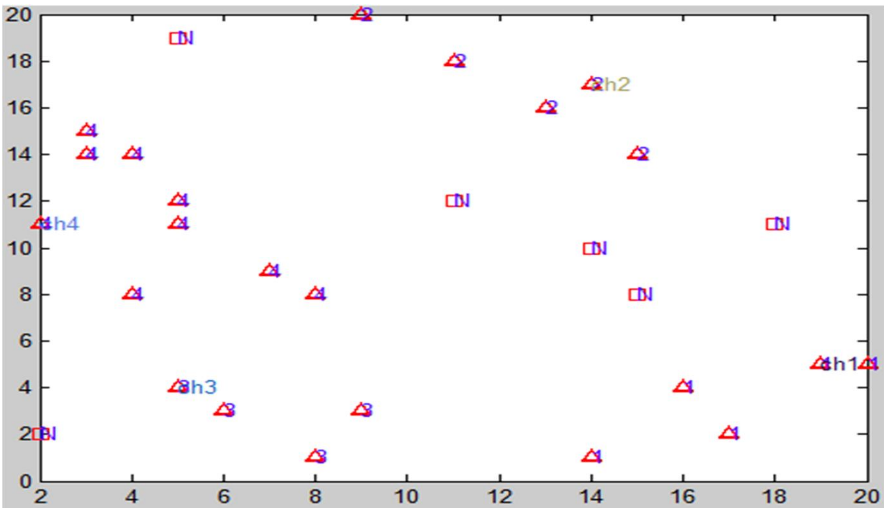

Fig.9 Clusters defined for the 30 vehicle scenario in an area of 20x20

```
vech_val =

    30    35    40    45    50    55    60    65    70    75    80    85    90    95   100


throughput_val1 =

   1.0e+03 *

    2.5890    2.6417    2.7403    2.7484    2.8196    2.8228    2.8621    2.8914    2.9084    2.9116    2.9203    2.9385    2.9440    2.9456    2.9514


tx_val1 =

    0.9967    0.9920    0.9884    0.9858    0.9856    0.9758    0.9703    0.9640    0.9627    0.9469    0.9411    0.9297    0.9093    0.8323    0.7612


dly_val1 =

    9.2387    9.4243    9.4880    9.5517    9.5878    9.6180    9.6436    9.7278    9.7458    9.8630   10.3365   10.4002   10.4666   11.1470   46.3503
```

Fig. 10 Values obtained for throughput, transmission of message and delay ranging from 30 vehicles to 100

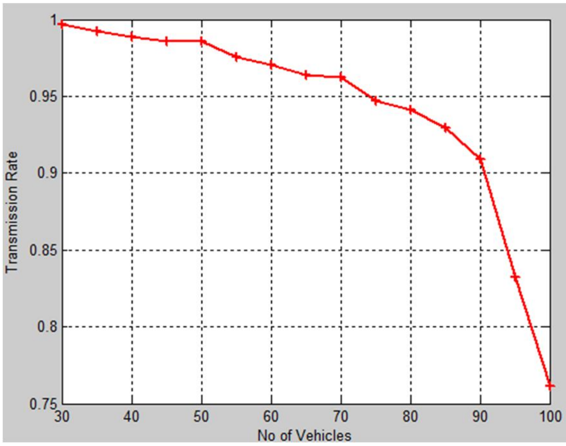

Fig. 11 Transmission rate (bps) v/s No. of vehicles

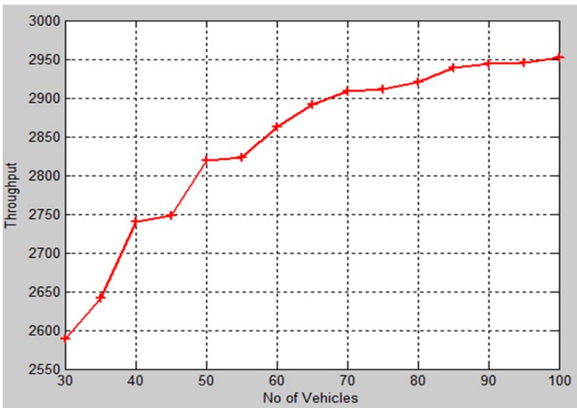

Fig.12 Throughput (bps) v/s No. of vehicles

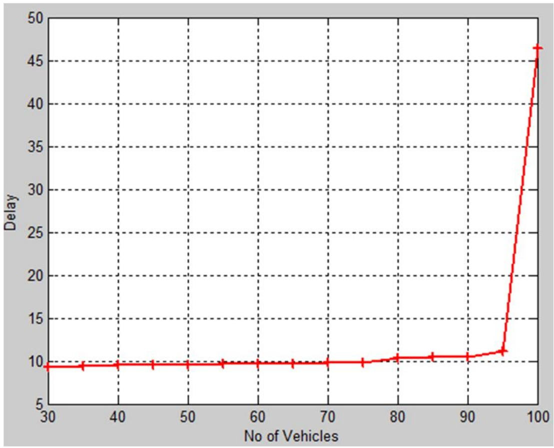

Fig.13 Delay (ms) v/s No. of vehicles

A tabular numerical analysis was made on both clustering algorithm and spectrum sensing algorithm for VANET scenario

Table. 1 Spectrum sensing versus Clustering Algorithm

No. of Vehicles	**THROUGHPUT 1.0e+03 ***		**TRANSMISSION RATE**		**DELAY**	
	Spectrum Sensing	**Clustering Algorithm**	**Spectrum Sensing**	**Clustering Algorithm**	**Spectrum Sensing**	**Clustering Algorithm**
30	2.4275	**0.4883**	.9924	**0.8716**	9.2585	**8.7769**
35	2.7211	0.5765	.9922	0.8449	9.2640	8.8808
40	2.7340	1.0459	.9782	0.7086	9.3821	8.9865
45	2.8027	1.0634	.9749	0.6979	9.5624	9.0557
50	2.8870	1.1510	.9700	0.6425	9.8395	9.0727
55	2.8872	1.2174	.9653	0.6018	9.8945	9.1578
60	2.8905	1.3496	.9651	0.4350	9.9323	9.1741
65	2.8934	1.4426	.9567	0.4002	9.9534	9.2032
70	2.9059	1.6966	.9551	0.3908	9.9978	9.2940
75	2.9200	1.7173	.9501	0.3169	10.0859	9.4783
80	2.9251	1.7806	.9481	0.2823	10.2053	9.4836
85	2.9350	1.8064	.9354	0.2424	10.2409	9.5094
90	2.9366	2.0109	.9290	0.0934	10.2765	10.4398
95	2.9550	2.1003	.8227	0.0372	10.2899	10.5157
100	2.9574	**2.1301**	.6183	**0.0197**	48.6663	**24.5796**

Fig. 14-16 show the contrast graphically obtained for clustering versus spectrum sensing algorithm for VANET scenario.

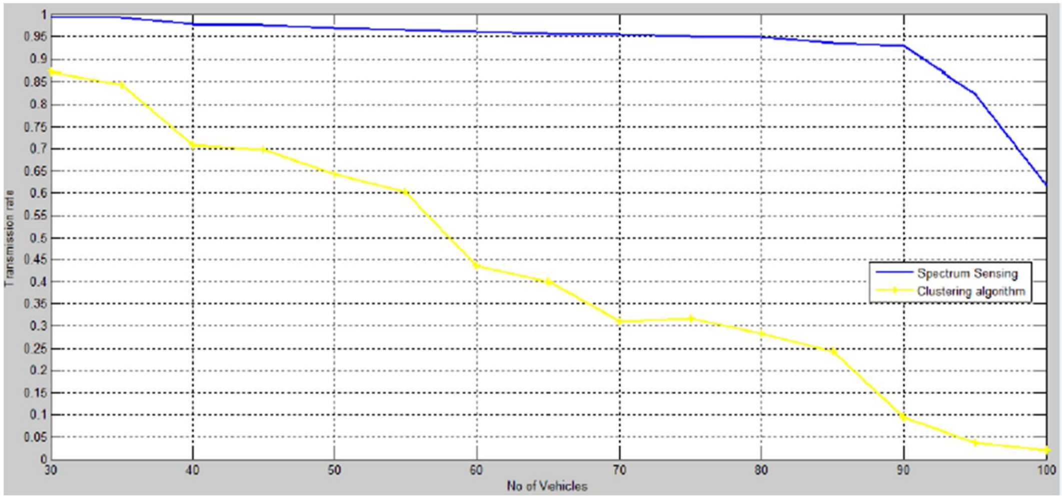

Fig. 14 Transmission rate for Spectrum sensing versus clustering algorithm

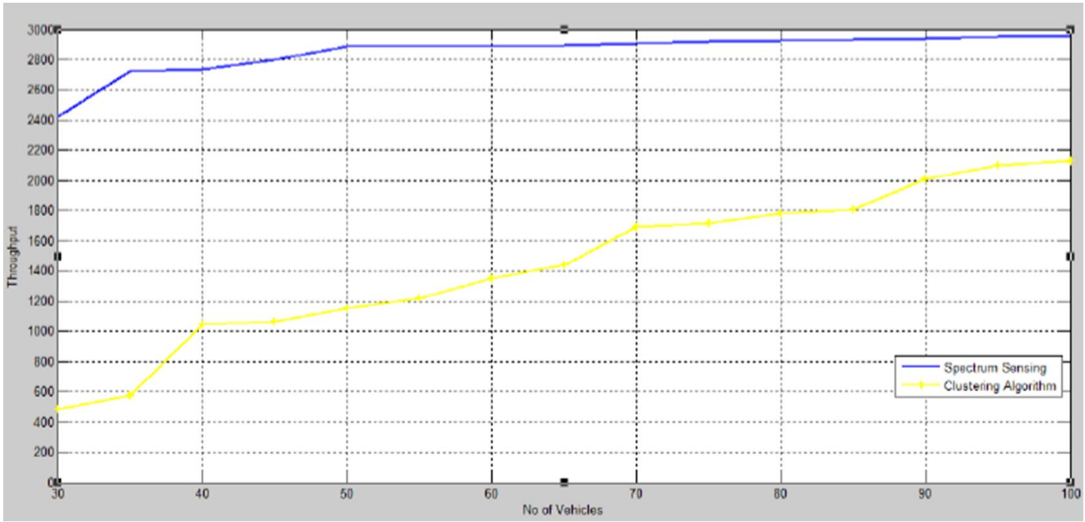

Fig.15 Throughput for Spectrum sensing versus clustering algorithm

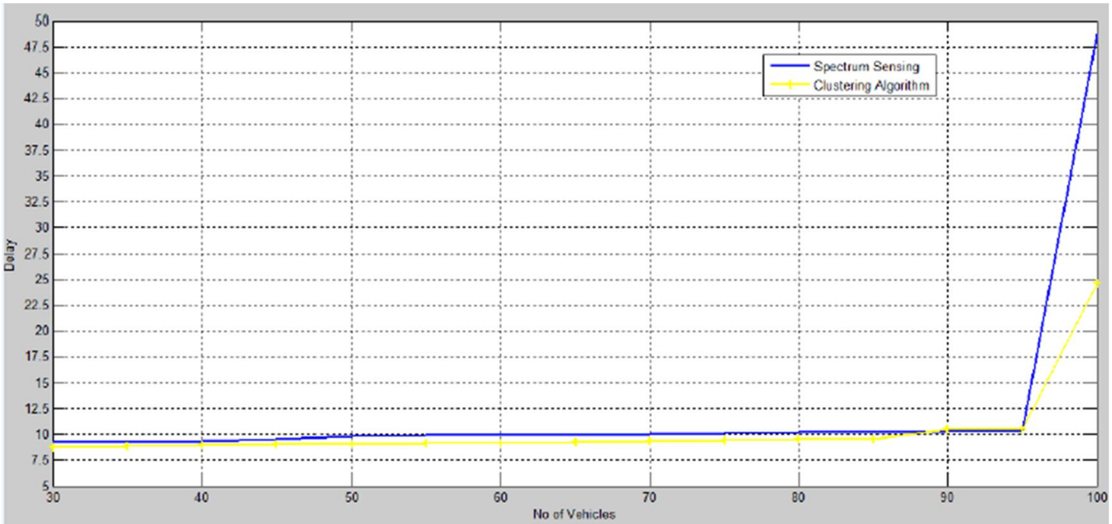

Fig.16 Delay for Spectrum sensing versus clustering algorithm

Conclusion

In this paper, we proposed another VANET cluster formation calculation that tends to gather vehicles similar showing mobility patterns in one cluster. This calculation takes into record the speed difference among vehicles also the position and the course amid the cluster formation process. The principle issue in existing works of communication through higher route density is because of high load on street, message communication get overhead because of less amount of network bandwidth to defeat this issue Intellectual (Cognitive) Radio is used for information transmission by channel sensing and messages are transmitted effectively through cognitive radio channels. In this paper, we have explored the utilization of Cognitive Radio principles to Vehicular Ad-Hoc Networks (VANETs) with a specific end goal to build the spectrum opportunities openings. In this paper, we propose an auto-correlation based spectrum sensing calculation. The proposed recognition calculation depends on the assumption that the auto-correlation matrix of the primary user's signal is not diagonal. We analyze the execution of the proposed detector and results comes about demonstrate that when we utilize the proposed spectrum sensing, the detection execution is improved. Likely with the graphs we can make out that with spectrum sensing method though we obtain an improved transmission and throughput as compared to that of clustering method but a high increase in delay. One reason that spectrum sensing is yet not being implemented in VANET is likely the delay which it introduces to system. Work is being carried out in obtaining a better spectrum sensing algorithm to achieve less delay.

Acknowledgment

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References

[1] S. Kay "Robust detection by autoregressive spectrum analysis", IEEE Trans. Acoust., Speech, Signal Process., vol. 30, no. 2, pp. 256–269,April 1982.
[2] Y. Zeng and Y. C. Liang, "Spectrum-sensing algorithms for cognitive radio based on statistical covariances", IEEE Trans. Veh. Technol., vol. 58, no. 4, pp. 18041815, May 2009.
[3] M. Naraghi-Pour and T. Ikuma, "Autocorrelation-based spectrum sensing for cognitive radios", IEEE Trans. Veh. Technol., vol. 59, no. 2, pp. 718733, Feb. 2010.
[4] S Yousefi, E Altman, R El-Azouzi, M Fathy, "Analytical model for connectivity ad hoc networks", IEEE Trans Veh Technol. 57(6), 33413356 (2008).
[5] M Rudack, M Meincke, M Lott, "On the dynamics of ad hoc networks for intervehicles communications (IVC)", in Proceedings of the ICWN 4048 (2002).
[6] Di Benedetto, Maria, et al. "Cognitive Radio Technology [Guest Editorial]." IEEE Signal Processing Magazine 25 (2008): 10-198.
[7] N. Ahmed, D. Hadaller, and S. Keshav, "GUESS: Gossiping updates for efficient spectrum sensing," in Proc. 1st Int. Workshop Decentralized Resource Sharing in Mobile Comput. Netw., New York, 2006, pp. 12–17.
[8] Q. Zhao and B. Sadler, "A survey of dynamic spectrum access," IEEE Signal Process. Mag., vol. 24, no. 3, pp. 79–89, May 2007.
[9] L. Cao and H. Zheng, "SPARTA: Stable and efficient spectrum access in next generation dynamic spectrum networks," in Proc. IEEE INFOCOM, 2008, pp. 870-878.
[10] Y. Zeng and Y. C. Liang, "Spectrum-sensing algorithms for cognitive radio based on statistical covariances," IEEE Trans. Veh. Technol., vol. 58, no. 4, pp. 1804–1815, May 2009.
[11] IEEE, "IEEE Guide for Wireless Access in Vehicular Environments (WAVE)-Architecture," IEEE Std 1609. 0-2013, pp. 1-78, 2014.
[12] J. Chennikara-Varghese, null Wai Chen, O. Altintas, null Shengwei Cai "Survey of routing protocols for inter-vehicle communications " (2006), pp. 1–5