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Classification and analysis of spectrum sensing mechanisms in Cognitive Vehicular Networks

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Abstract

Vehicular Ad hoc Networks (VANETs) is an essential part of Intelligent Transportation System (ITS), which aims to improve the road safety. However, the main challenge in VANET is the spectrum scarcity which is more severe especially in the urban environment. In this view using Cognitive Radio (CR) technology in VANET has emerged as a promising solution providing additional resources and allowing spectrum efficiency. But, vehicular networks are highly challenging for spectrum sensing due to speed and dynamic topology. Furthermore, these parameters depend on the CVNs' environment such as highway, urban or suburban. Therefore, solutions targeting CVNs should take into consideration these characteristics. As a first step towards an appropriate spectrum sensing solution for CVNs, we first, provide a comprehensive classification of existing spectrum sensing techniques for CVNs. Second, we discuss, for each class, the impact of the vehicular environment effects such as traffic density, speed and fading on the spectrum sensing and data fusion techniques. Thirdly, we derive a set of requirements for CVN's spectrum sensing that takes into consideration specific characteristics of CVN environments. Finally, we propose a new CVN scheme adopted in particular for urban environment where the spectrum sensing is more challenging due to dense traffic and correlated shadowing.

Keywords: Cognitive radio, CVNs, Spectrum sensing, Data fusion, Dense traffic, Correlation.

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1. Introduction

Recently, Vehicular Ad hoc Network (VANET) [1] has attracted a lot of interest from industries and research institutions, particularly with increasing number of vehicles on the road especially in urban area. VANET is a special kind of Mobile Ad hoc Networks (MANETs) that are applied to vehicular context. They provide Vehicle to Vehicle (V2V) and vehicles to infrastructures (V2I) communications. On the opposite of MANET, in VANET the movements of vehicles are predictable due to the road topology. Besides, the high mobility leads to a higher probability of network partitions, and the end to end connectivity is not guaranteed [1]. The VANET applications can be classified into two categories: safety applications which provide the drivers with early warnings to prevent the accidents from happening, this represent the higher priority traffic, and user applications which provide road users with Network accessibility which represent traffic with less priority. Growing usage of applications such as exchanging multimedia information with high data in car-entertainment leads to overcrowding of the band and thereby giving rise to communication inefficiency for safety applications [1]. Furthermore, the 10 MHz reserved in the IEEE 802.11p standard as a common control channel is likely to suffer from large data contention, especially during peaks of road problem Cognitive Radio (CR) technology has been

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proposed [2]. The main role of CR is to allow the unlicensed users (a.k.a Secondary Vehicular Users: SVUs) to identify spectrum holes and exploit them without interfering with the licensed users (a.k.a Primary Users: PUs). This makes the spectrum sensing (SS) a crucial function in CR networks. Even if spectrum sensing in CR networks is well studied, however the research solutions proposed in static CR networks may not be directly applicable to CVNs due to high dynamic networking environment. The works in [3–5] provide comprehensive surveys about spectrum sensing in CVNs. The authors in [3] review the existing studies related to SS in CVNs and provide the open issues in this area. In [4, 5], the authors provide an overview of distributed and centralized cooperative SS for CVNs and review some challenges and open issues in CVNs. In this paper, we provide an overview of spectrum sensing mechanisms and we propose a classification for existing CVN schemes. In fact, four classes are presented: centralized, distributed, partially centralized and integrated schemes. Indeed, the main characteristic that influences the spectrum sensing mechanisms used in CVNs is the changeable topology of vehicular environment which may be urban, suburban or highway area. The common features of these vehicular environments are the vehicles speed, fading and traffic density. But, the effect of these features differs from vehicular environment to another. Therefore, we analyze for each class the impact of the characteristics of each vehicular environment including speed, fading and traffic density on the spectrum sensing techniques and data fusion techniques used to combine the reported or shared sensing results for making a cooperative decision. This analysis allowed us to derive the main spectrum sensing requirements in CVNs. In addition to the set of sensing and data fusion techniques that we recommend to use according to the specific characteristics of CVN environment, we develop a new CVN architecture that should be adequate with vehicular environment of the urban context.

The rest of this paper is structured as follows: in Sect. 2, we present background information on CVNs and we present the most used spectrum sensing techniques. In Sect. 3, we classify the existing CVNs sensing schemes. In Sect. 4, we analyze the environment effects on the sensing mechanisms used by these classes and we derive the corresponding spectrum sensing requirements for each environment. In Sect. 5, we present our proposed CVN scheme for urban environment. Finally, we draw final conclusions in Sect. 6.

2. Background on CVNs and Spectrum Sensing

This section provides some background on Cognitive Vehicular Networks and the properties of vehicular environments that affects the spectrum sensing, followed by an overview of spectrum sensing techniques.

2.1. Cognitive Vehicular Networks

The CVNs are composed of vehicles equipped with the CR system, allowing SVUs to change their transmitter parameters based on interactions with the environment in which they operate. Similarly to the traditional CR, The execution of CVNs is defined by a cycle which is composed by four phases: observation, analysis, reasoning and act [6].

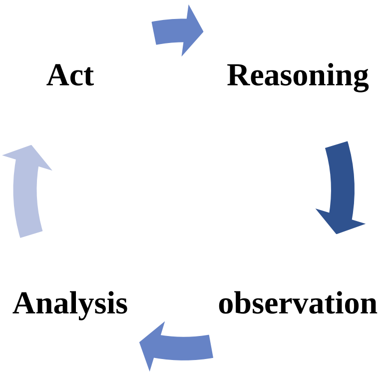

Figure 1. The cognitive vehicular cycle

The observations phase consists of sensing and gathering the information (e.g. modulation types, noise, and transmission power) from its surrounding area in order to identify the best available spectrum hole. In analysis phase, after sensing, some parameters have to be estimated (e.g. interference level, path loss and channel capacity). In reasoning phase, the best spectrum band is chosen for the current transmission considering the QoS requirement. The optimal reconfiguration is finally done in Act phase.

However, the main novel characteristic that differentiates CVNs from the traditional CR is the nature of SVUs mobility. In one hand, due to road topology and usage of navigational systems, the vehicles can predict the future position and then it can know in advance the spectrum resources available on its path. On the other hand, the mobility increases spatial diversity in the observations taken on the different locations. This may influence the sensing performance. Furthermore, fast speed increases the number of collected samples which improves the sensing performance and requires less cooperation from other SVUs [7]. But, when the high fading (i.e. correlated shadowing) and the presence of obstacles are taken into account, the correlated samples affect the performance [8]. Besides, with faster speed the SVUs will have a higher probability to miss detect the PUs, because the PU will be outside the sensing range of SVU very quickly [9]. In addition, another parameter which can affect particularly the cooperation is the traffic density; the road topology becomes congested with dense traffic which declines the speed and the vehicles tend to be closer to each others, this decreases the performance due to correlation [8]. Thus, the main features of vehicular environment which influence the sensing are speed, fading, traffic density and the obstacles. These parameters vary according to the area type (i.e. urban, suburban, or highway).

Table 1. Vehicular environment characteristics

	Urban	Suburban	Highway
Density traffic	Very high	light	low
Vehicle' speed	low	Medium	Very high
Degree of fading	Very high	High	Low to High

The urban area is characterized by high fading, and dense traffic with low speed (around 50 km/h). The main features of suburban area are light traffic with medium speed, surrounded by some buildings which give rise to fading. The highway area is characterized with few surrounding structures which decline the fading effect, and vehicles can exceed 120 km/h [10].

2.2. Spectrum sensing techniques

The Spectrum Sensing techniques are divided into two types local spectrum sensing (performed individually) and Cooperative Spectrum Sensing [11]. Depending on the availability of the knowledge about the Primary Users (PUs), the local spectrum sensing techniques can be classified into two main classes: informed and blind spectrum sensing techniques [12].

2.2.1. The Local Informed Spectrum Sensing Techniques

These techniques require the prior knowledge about PU's features such as sine wave carriers, hopping sequences, pulse trains, repeating spreading, modulation type etc. [12]. In addition they are robust to noise uncertainties, but their implementation is complex. In the informed techniques, we mention Matched Filtering Detection (MFD) [12] and Cyclostationary Detection (CD) [12]. The MFD could achieve the higher sensing accuracy with less sensing time, whereas sensing accuracy in CD requires long sensing time and it is not capable to differentiate the PUs from the secondary users.

2.2.2. The Local Blind Spectrum Sensing Techniques

The blind techniques don't require any information about the primary signal. Among these techniques: Energy Detection (ED) [12], Eigenvalue-based Detection (EBD) [12] and the Compressed Sensing (CS) [11]. They present the advantage of requiring less sensing time. Even if the ED is the most popular technique due to its simplicity, it is the worst performer technique, especially in the case of noise uncertainty. The EBD deals well with noise uncertainty than the ED, while the CS facilitates wideband SS, and reduces the channel switching overhead of narrowband SS. However the CS incurs additional hardware cost and computational complexity [11].

2.2.3. Cooperative Spectrum Sensing

The Cooperative Spectrum Sensing (CSS) has been proposed in [11] and [13] to improve the performance of SS under fading environment conditions which is especially in the case of vehicular channels characterized by a strong fading. The key concept of CSS is to exploit spatial diversity among observations made about the status of channel by multiple SVUs [11]. The process of CSS requires the use of some techniques such as: local observations using individual sensing techniques, cooperation models, eventually a user selection technique can be used, reporting, and data fusion [11]. However the gain of CSS is limited by cooperation overhead which includes: sensing delay, shadowing, energy efficiency, mobility and security [11].

Table 2.Summary of spectrum sensing techniques

	Blind SS techniques			**Informed SS techniques**	
	ED	EBD	CS	CD	MFD
Sensing Time	short	medium	short	long	short
Performance	low	high	high	high	high

3. Classification of the Spectrum Sensing Schemes in CVNs

In literature, CVNs are usually based on the cooperative spectrum sensing, but can also integrate a geo-localization database to assist the traditional spectrum sensing. Hence, in this section, we classify these spectrum sensing schemes in CVNs into four classes: centralized, distributed, partially centralized and integrated. And we identify the SS and fusion techniques used in these classes (Table 3)

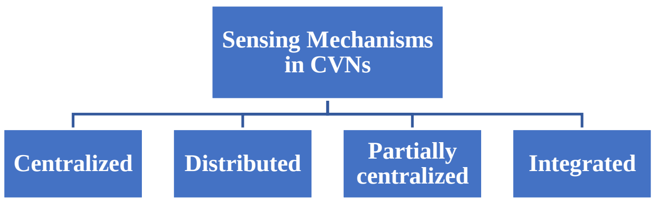

Figure 2. Spectrum Sensing Mechanisms in CVNs

3.1. Centralized CVN Schemes

In centralized CVN schemes, a central node act as fusion center (FC) that controls the process of cooperation. In the case of V2I a fixed node such as RSU (Road Side Unit) or BS (Base Station) acts as a FC [14, 15]. But, having a fixed FC may not be always possible in the case of CVNs. Thus, some works focus on a clustering strategy where the vehicles are selected to act as a FC cluster head [16, 17].

The cooperation process is defined as follow: Firstly, the SVUs sense the channels selected independently by the FC using Compressed Sensing (CS) in [14], Eigenvalue-Based Detection (EBD) in [15] and Energy Detection (ED) in [17]. The FC combines the local sensing received from SVUs for making a final decision by using the data fusion techniques such as Hard Fusion (HF) [14, 17], Soft Fusion (SF) [15] or Hidden Markov Model (HMM) [16]. Using SF at FC provides better sensing accuracy than HF [11], because the SVUs report to FC the entire local sensing samples. However it incurs control channel overheads in terms of time and energy consumption especially with large number of cooperating SVUs. While, the HF requires much less control channel because the SVUs report to FC one decision bit (0 or 1), the performance can be decreased. While, the HMM is used to speed up the detection of PUs by indicating to FC the observations' number that should be received before making the fusion [16]. Once the final decision is made, the FC broadcasts it to SVUs.

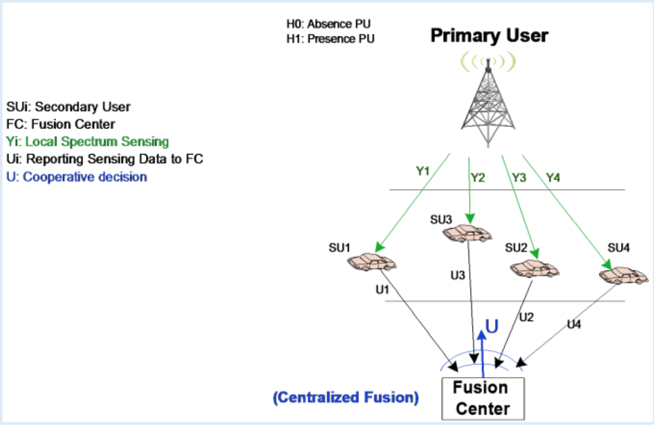

Figure 3. Centralized CVN Schemes

3.2. Distributed CVN Schemes

Works in [18–20] focus on using decentralized CVN architectures where SVUs are cooperating in a distributed way. In [18], a distributed scheme based on the belief propagation algorithm is proposed specifically for highway, where each SVU senses the spectrum independently. Then, each vehicle combines its own belief with information received from other neighbors and a final decision can be generated after several iterations. In [19] the road topology is taken into account, where the highway road is divided into equal short segments which can be recognized with a unique identifier. Periodically, each SVU senses the spectrum, stores the results in its internal memory and share it later to inform others vehicles about spectrum holes in their future segments. This framework is further enhanced in [20] by an experimental study. The measurements are undertaken from moving vehicle travelling under different urban conditions and vehicular speeds. And then, a cooperative spectrum management framework is proposed, where the correlated shadowing is taken into consideration. Data fusion in [19, 20] is based on a weighted algorithm.

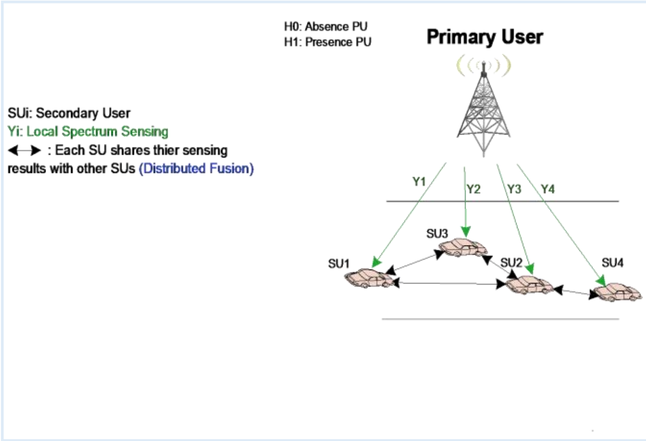

Figure 4. Distributed CVN Schemes

3.3. Partially Centralized CVN Schemes

The partially centralized CVN schemes [21, 22] are composed of two sensing levels. The first level is fast sensing (generally energy detection) performed by a central node [21] or by a set of selected nodes using cooperation [22]. In the second level, the requesting vehicles (RVs) rescan the list of holes received from coordinators using fine sensing such as cyclostationary detection [21, 22]. This may reduce the overhead of identifying all holes. Besides, the RVs use the sensed holes without seeking permissions from the coordinator. This scheme is then a partially unshackle master/slave sensing relationship between FC and SVUs.

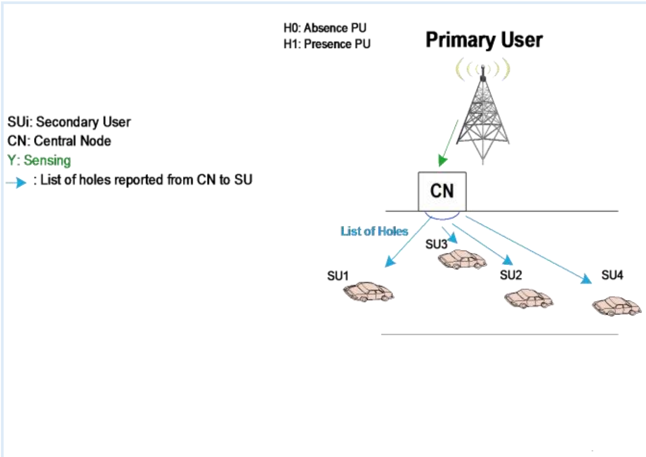

Figure 5. Partially CVN Schemes

3.4. Integrated CVN Schemes

In CR the integrated concept is based on the use of a geo-localization database. This later is described in [23] as a spectral map of available channels in a given geographical area, that can be provided to secondary users according to their location. However, its implementation may not be suitable for CVNs when road traffic is congested which leads to many vehicles trying to query the database. Thus, to mitigate the problems above, the use of database is combined with traditional sensing [24, 25]. In [24], in each segment of the highway, the vehicles should dynamically select their role (Mode I, Mode II or Sensing-only) according to the traffic load. In low traffic, vehicles choose the mode II to access the spectrum database through an internet connection. In mode I the vehicles get informed from vehicles on mode II. While in high traffic, the vehicles perform Sensing-only and cooperate to detect PUs. In [25], a BS is directly connected to a TV white space and database similarly to [24], the vehicles should dynamically select their role but this time according to the traffic load and the coverage of BSs.

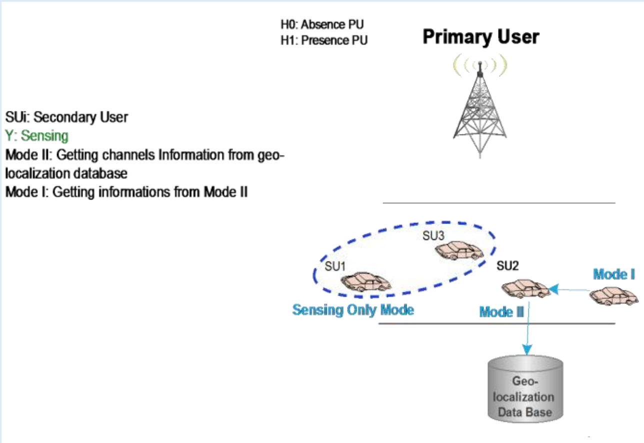

Figure 5. Integrated CVN Schemes

Table3.Summary of classification of CVN schemes

Classes	Ref.	Coordinator nodes	Sensing technique	Data fusion algorithm	Road Topology
Centralized	[14]	Base Station	Compressed Sensing	Hard Fusion	Highway
	[15]	Base Station	Eigenvalue-Based Detection	Soft Fusion	Not specified
	[16]	vehicle	Not specified	Hidden Markov Model	Not specified
	[17]	Three vehicles	Energy Detection	Hard Fusion	Highway/ Suburban
Distributed	[18]	Coordination is not needed	Not specified	Belief algorithm	Highway
	[19]		Energy Detection	Weighted algorithm	Highway
	[20]		Energy Detection	Weighted algorithm	Urban
Partially centralized	[21]	RSU or vehicle	-Energy Detection at coordinator -Fine sensing at Requesting Vehicles	Data fusion is not needed	Highway
	[22]	Three vehicles	-Cooperation among coordinators -Fine sensing at Requesting Vehicles	Hard Fusion (Majority rule)	Highway/ Suburban
Integrated	[24]	Coordination is not needed	Dynamic detection: Mode I, Mode II or Sensing-only (local or cooperative detection)	Data fusion is not needed	Highway
	[25]			Hard Fusion (Majority rule)	Not specified

4. Derived Requirements of Spectrum Sensing in CVNs

As seen in previous section each area has its own features including speed of vehicles, traffic density, and the surrounding obstacles. In fact, the spectrum sensing accuracy depends on the vehicle's speed, traffic density and the channel fading. To the best of our knowledge, the conditions of the surrounding area are not taken into account in literature.

In this section, we first analyze the impact of the vehicular environment (i.e. highway, Suburban and Urban), especially the effect of traffic density, mobility and fading, on both spectrum sensing and fusion techniques for each class. Second, we derive the corresponding spectrum sensing requirements for each environment.

4.1. The Impact of CVN Environment on the Local Spectrum Sensing

The detection techniques for local spectrum sensing include cyclostationary detection (CD), matched filtering detection (MFD), energy detection (ED), compressed detection (CS) and eigenvalue-based detection (EBD). Each of these techniques has its pros and cons in terms of sensing time and performance as shown in Table 2. Thus, the choice of the appropriate spectrum sensing according to the environment properties is very important.

In highway context, high speed requires fast detection (ED, CS and MFD). However, ED could be used for open space but with high fading, it is better to use the fast and accurate detection (CS or MFD). In suburban context, the speed is light which can affect the sensing performance, and fading effect is more challenging than highway context.

Thus, in these cases the fast and accurate detection (CS or MFD) is favored. Whilst in urban context, the fast detection is not necessary due to low speed, but the accurate detection

(EBD, CS, MFD or CD) is required due to strong fading.

4.2. The Impact of CVN Environment on Data Fusion of the Centralized Schemes

Generally, the cooperative spectrum sensing schemes are a composition of local SS and data fusion. As previously mentioned, each fusion technique in centralized schemes such as soft fusion (SF), hard fusion (HF) or hidden Markov model (HMM), has its pros and cons in terms of delay and overhead. Thus, we have to carefully choose the appropriate fusion techniques according to the environment properties.

In highway context, the data fusion such as HF and HMM present the advantage of fast fusion, but due to low density, sometimes there will not be enough vehicles to cooperate for sensing, thus the SF is preferred. In suburban context, the traffic density effect is challenging than highway context. Thus, it is better to use fast fusion. While in urban context, the fast fusion is vital due to high traffic.

4.3. The Impact of CVN Environment on Data Fusion of the Distributed Schemes

The data fusion techniques which may be used in distributed schemes are belief algorithms and weighted algorithms. In belief algorithm, the data from different cooperating vehicles is merged considering the spatial and temporal correlation of different observations hence the performance of this algorithm will be affected by fading (i.e. correlated shadowing). Furthermore, belief procedure is rather time consuming when larger number of SVUs participate in the process. While in weighted algorithm, the data is merged using weights and only if the correlation between the sensing samples of two vehicles are below a given threshold. Besides, the performance of weighted algorithm degrades under low density.

In highway context with open space, belief algorithm performs well under low density. But, if fading is considering this algorithm is not preferred. In both suburban and urban contexts, the data fusion techniques are affected by dense traffic and fading. Hence in this case, it is better to use the selection of cooperating nodes (i.e. correlation selection) either to reduce the number of cooperating SVUs and to select the uncorrelated SVUs. Generally, for both urban and suburban contexts, belief algorithm may not be suitable due to fading and high traffic density. While, weighted algorithm is required because it performs well under dense traffic.

4.4. The Impact of CVN Environment on the Partially Centralized Schemes

As mentioned in Sect. 3, in the partially centralized, the first level (i.e. fast sensing) is based on the local sensing at the coordinator or at a subset of selected coordinators. At second level (i.e. fine sensing), it is possible to use cyclostationary detection (CD) or eigenvalue-based detection (EBD).

In highway context, to speed up the detection at first level it is required to use fast detection or both fast and accurate detection according to fading effect. While in the case of cooperation at first level, it is possible to use fast fusion. At second level, it is better to use EBD because sensing time of EBD is less than CD. In suburban and urban context, it is favored to use at first level the cooperation among the coordinators to alleviate the problem of hidden PU due to presence of obstacles. At second level, it is required to use EBD in the suburban context because the effect of speed is considered, while in the urban context it is possible to use CD and EBD.

4.5. The Impact of CVN Environment on the Integrated Schemes

For integrated schemes, an optimal ratio between querying the spectrum database and sensing according to the traffic density and BSs coverage is required. In dense traffic the SVUs perform in sensing-only mode (local SS or cooperative sensing). The accuracy in this mode is also important; hence the choice of the appropriate sensing and fusion techniques depends on the environment requirements as mentioned above in Subsects. 4.1, 4.2 and 4.3.

Generally, in highways, it is preferred to use mode I and mode II due to low traffic density. While in suburban and urban context, it is possible to use sensing only mode due to high traffic density. However, as mentioned above, due to the hidden PU issue it is better to use cooperative spectrum sensing (CSS) at sensing-only mode.

4.6. Summary of Spectrum Sensing Requirements in CVNs

The main constraints in urban and suburban context are hidden PU, strong fading and dense traffic. The hidden PU issue requires CSS among SVUs, but due to fading and dense traffic a correlation selection is very important. The cooperation in highway context is affected by fast speed and low density, thus the accurate SS techniques with short sensing time at local SS are required such as matched filtering detection (MFD) or compressed detection (CS). The fusion techniques in CSS (centralized or distributed) should be adequate with the surrounding environment. For example, soft fusion (SF) and belief algorithm are favored in low traffic, while, hard fusion and weighted algorithm are required in dense traffic. In contrast, we can observe that these requirements are not always respected in literature, as in [14] where the CS with hard fusion (HF) is considered for highway. Hence the effect of low density is not taken into account by using HF. In [17], the energy detection (ED) with HF is considered applicable for both highway and suburban, which could not be optimal since SF is preferred for highway and ED does not provide the required accuracy in urban context. Furthermore, the schemes in [15, 16] are considered applicable for all contexts, and in [16] the SS technique is not also specified.

Therefore, the real features of the surrounding area are not studied well in the literature either for centralized or distributed CVNs. Generally, it is important to use adequate spectrum sensing and fusion techniques according to the properties of the surrounding environment. Furthermore the restricted and predictable mobility is not addressed for improving the spectrum sensing accuracy (Table 4).

Table 4.Summary of sensing requirements in CVNs

Classes	Context		
	Highway	**Suburban**	**Urban**
Centralized	Fast and/or accurate local detection with soft fusion	Fast and accurate local detection with fast fusion	Accurate detection and fast data fusion.
Distributed	Fast and/or accurate local detection with belief algorithm	- Fast and accurate local detection - Weighted algorithm	- Accurate local detection - Weighted algorithm with correlation selection
Partially centralized	- First level :local spectrum sensing or CSS - Second level : EBD	- First level : CSS (fast local detection with fast fusion) - Second level: EBD	- First level: CSS (fast local detection with fast fusion). - Second level: EBD or CD
Integrated	Mode I and Mode II	Sensing-only mode (CSS)	Sensing-only mode (CSS)

5. Proposed CVN scheme for urban context

In addition to the set of sensing and data fusion techniques that we recommend to use according to the specific characteristics of CVN environment (Table 4), we want to develop a new architecture that should be adequate for CVNs especially in the urban context. We are mainly interested in spectrum sensing in the urban context because the spectrum scarcity is more severe, and secondly the spectrum sensing in urban context is not studied well. Thirdly in the urban context, there are many challenging constraints that significantly deteriorate the performance of spectrum sensing.

According to our analysis, in the urban context the strong fading and the PU's hidden problem requires the collaboration among the SVU to make more reliable decision [13]. But, its application in the urban environment which characterized by dense traffic and mobility of SVUs provokes significant problems. For instance, as the traffic density is always rising, the number of collaborating SVUs is increasing, and then the signalling overhead associated with reporting the sensing results tends to be considerably large. Moreover, the SVUs tend to be closer to each other and then the SVUs are likely suffer from similar shadow fading which will reduce the performance of cooperative spectrum sensing. Besides, due to the mobility of SVUs, the correlation between the SVUs varies over time and the SVUs need to join or leave the group of collaborating SVUs which increases the overhead in cooperative sensing [11].

Thus, under the mobility condition, the connectivity among the collaborating SVUs should be maintaining for a long period of time. In this view the approach of clustering will be very helpful to stabilize a group of collaborating SVUs moving together along the road. In other hand, to minimize the overheads and the correlated shadowing associated with dense traffic, the SVU selection based on the correlation should be taken into account in the clustering approach.

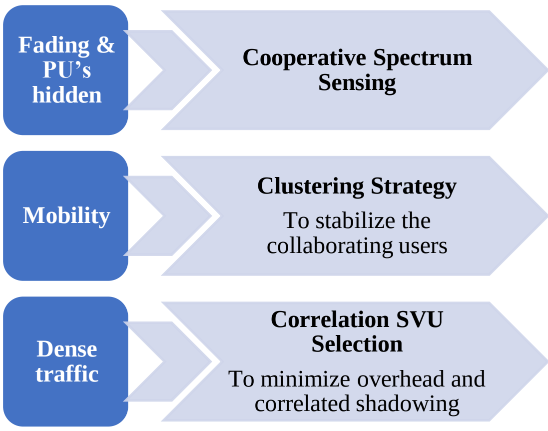

Figure 6. The main CVN requirements for urban context

5.1. The main components of the proposed CVN scheme for urban context

Our proposed CVN architecture is composed of the following entities as shown in the figure 7:

- **The Cluster Head (CH):** is local coordinator of a cluster; it has multiple roles such as:
  - Ensuring the stability of cluster in order to maintain the collaborating SVUs in contact for a long period of time.
  - Selecting among its members the uncorrelated SVUs that will participate in the cooperation. In this case, these uncorrelated SVUs are called by the active SVUs.
  - Collecting and combining the local sensing results received from the active SVUs.
- **The Active SVUs:** are the uncorrelated SVUs that will perform local sensing and participate in cooperation.
- **The Passive SVUs:** are the correlated SVUs that don't participate in cooperative spectrum sensing, but they can get the information about opportunities from CH.
- **Gateways:** are used to exchange the sensing results between the CHs.

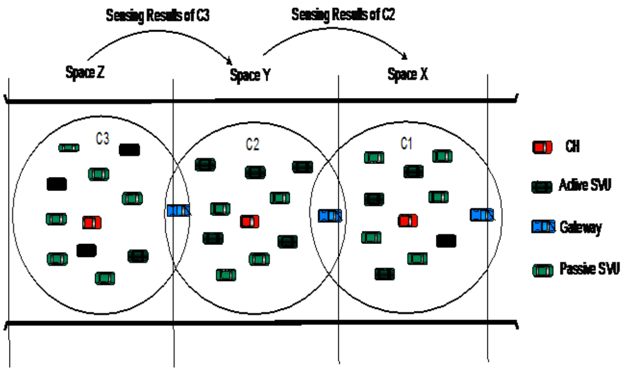

Figure 7. The main components of CVN scheme for urban context

The general idea of our propose CVN scheme for urban context is that each CH can collect the information about the availability of the licensed channels at future location along its path. For example if it was said that the cluster C_2 performs sensing in the Space Y, but due to the mobility, this cluster will enter another Space Z, and it will not be able to use the spectrum opportunities found in the previous Space Y. Thus, the cluster C_2 can benefit from the sensing results found by cluster C_3 at the future Space Z, and the CHs get these information by using gateways (Figure 7).

Each entity (i.e. CH and its members: Active and Passive) in our proposed scheme has a specific role in cluster. Hence for selecting the appropriate CH and its members, we need to define what metrics and specifications that should be available in each entity. Therefore, in the next subsections 5.2 and 5.2 we define the metrics for CH selection and for active SVU selection.

5.2. The metrics used for CH selection

If we suppose that the SVUs have the same capability of sensing data fusion, it is not necessary to consider it as a metric. In fact, the CH has to be able to manage its CMs by accepting or refusing the adhesion of new arrivals. Besides, due to mobility the selected CH is expected to maintain the cluster stability to minimize the overhead associated with re-clustering. Hence, the SVUs which may be more qualified for winning the act of CH, are supposed to have a higher connectivity degree and a closer speed to the average speed of their neighbors. Therefore, the metrics of CH selection are related to the nodal degree and the relative speed.

- **The nodal degree**

The nodal degree dN_i is the total number of neighbors of a given SVU_i. Usually, SVUs broadcast their current state to all other nodes within their transmission range r. Therefore, two SVUs: SVU_i and SVU_j are said to be neighbors if the distance between them is less than the transmission range r, and we define the neighborhood N_i of a SVU_i at time t as follows:

$$N_i = \{j, such\ as\ d_{i,j} < r\}$$

$d_{i,j}$ is the distance between SVU_i and SVU_j.

Thus, the nodal degree dN_i of SVU_i is finding by counting their neighbors and it is deduced as the cardinality of the set N_i as follows:

$$dN_i = |N_i|$$

- **The relative speed**

The elative velocity rv_i of SVU_i is calculated as follows:

$$rv_i = |v_i - Average\ velocity\ |$$

The smaller the value of rv_i, the closer the velocity of the SVU_i to the average velocity.

- **Procedure of calculating the Score function of SVU_i for being a CH**

Each SVU_i in one-hop have to measure its utility for being a CH while considering the aforementioned criteria dN_i and rv_i. We define the utility of each SVU_i through a function called $Score\ Fuction$ that combines those criteria with each other. We can define the Score function by the following formula:

$$S_i = (dN_{Ni})^{w_{dN}} * (rv_{Ni})^{w_{rv}}$$

Where dN_{Ni} and rv_{Ni} are the normalized values of dN_i and rv_i respectively. We use the normalization in order to prevent the compensatory problem.

To normalize the value of dN_i we use the value M, where M is the maximal number of neighbors that a CH can accept as neighbors:

$$dN_{Ni} = \frac{dN_i}{M}$$

To normalize the value of rv_i we use the value L, where L is the difference between maximum and minimum allowed speeds on the road:

$$rv_{Ni} = \frac{rv_i}{L}$$

The values of w_{dN} and w_{rv} are the relative weights of importance of dN_{Ni} and rv_{Ni} respectively. According to our problem description there are contracting criteria, such as we want to maximize the nodal degree and minimize the relative speed. Therefore, we can assume that the w values are in rang $[-1,0,1]$, then our relative weights would be: $w_{dN} = 1, w_{rv} = -1$. Therefore, the SVU with high $Score$ will be chosen as CH.

5.3. Correlation-based member selection

Spatial correlation is a crucial factor that may affect the performance of cooperative spectrum sensing. Thus, after CH selection, CH should select among their members the uncorrelated members (SVUs) that are supposed to perform sensing (Active SVUs).

The spatial correlation can be evaluated by correlation coefficients. It describes the correlation index between the samples observed by two vehicles SVU_i and SVU_j. We model the correlation function with the exponential decaying model proposed by Gudmundson [26] as follows:

$$R_{i,j} = e^{\frac{-d_{i,j}(t)}{d_{corr}}}$$

Where $R_{i,j}$ is the distance dependent correlation index and it is time-varying on account of vehicle mobility, and

$d_{i,j}(t)$ denotes the separation distance between SVU_i and SVU_j at time t. And d_{corr} is the threshold distance which represents the correlated distance of shadow fading which usually varies according to the environment and it set to $20m$ for the urban environment. If $R_{i,j}$ exceeds a given threshold η, then SVU_i is strongly correlated with SVU_j.

- **The Selection procedure based on Spatial Correlation**

Our proposed algorithm for selection the Active SVU is as following:

- At first step the CH computes the correlation coefficients $R_{i,j}$ for all possible pairs of members.
- A matrix *M* of size *N*N* is built. *N* is the total number of candidate cooperative members that belong to a cluster, *{N} ={SVU$_1$, SVU$_2$, ….., SVU$_N$}*
- A threshold of correlation is defined η
- The diagonal elements of matrix *M* are auto-correlated coefficients $R_{i,j} = 1$.

$$
\begin{array}{c|ccccc}
 & \boldsymbol{SVU_1} & \boldsymbol{SVU_2} & \boldsymbol{SVU_3} & \boldsymbol{\ldots..} & \boldsymbol{SVU_N} \\
\hline
SVU_1 & 1 & R_{1,2} & R_{1,3} & \ldots.. & R_{1,N} \\
SVU_2 & R_{2,1} & 1 & R_{2,3} & \ldots.. & . \\
. & . & . & 1 & & . \\
. & . & . & & . & . \\
SVU_N & R_{N,1} & R_{N,2} & & & 1
\end{array}
$$

Figure.8.the matrix M of correlation coefficients

- The algorithm of selection of the active SVUs:

We suppose that $\{A\}$ is the list of the Active SVUs and $\{P\}$ is the list of the Passive SVUs. At the beginning $\{A\} = \emptyset$ and $\{P\} = \emptyset$

// Initialization to start the selection procedure, one *SVU$_i$* is selected randomly from *{N}*.

- **Best** ← *SVU*
- *{N}*← *{N}*- *{SVU}*
- *{A}*← *{SVU}*

While $\{N\} = \emptyset$ ***do***

// the *SVUs that are* correlated with **Best** will be removed from *{N}* to the *{P}*

For each *SVU* ∈ $\{N\}$ ***do***

if *R(Best, SVU)* > ***then***

{N}← *{N}*- *{SVU}*

{P}← *{SVU}*

end if

end for

// selecting randomly one *SVU* from *{N}* to be the new **Best**

Best ← *SVU*

{N}← *{N}* - *{SVU}*

{A}← *{Best}*

End while

Compared with the existing works [16, 17] that are based on clustering, we don't just describe the entities of our proposed CVN scheme for urban context but we also provide a set of metrics and procedure for selecting the CH and the active SVUs that participate in cooperation. In our future we will give more details about the process of clustering phase and the cooperative sensing phase

6. Conclusion

In this paper, we have analyzed the impact of environment effects (traffic density, speed and fading) on spectrum sensing and fusion techniques applied in CVNs. And then, we have derived the main spectrum sensing requirements in CVNs. This analysis enabled us to conclude that the real effects of vehicular environment are not studied well in literature for CVNs, this motivate further research needed for practical implementation. Thus, our discussions on the environmental effects on CVNs are needed to be grounded in established empirical studies as a part of future directions pertaining to CVNs. In addition to the set of sensing and data fusion techniques that we recommend to use according to the specific characteristics of CVN environment, we develop a new CVN architecture that should be adequate with vehicular environment of the urban context.

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