Exploiting Zero Forcing Beamforming and TV White Space Band for Multiuser MIMO Cognitive Cooperative Radio Networks

Nawal Bounouader, with Institut National des Postes et Télécommunication (INPT), Sofia Ghacham,*Student,IEEE,* Ghassane Aniba, *Member, IEEE* and Zouhair Guennoun, *Senior, IEEE* are with Electronics and communication laboratory (LEC),Ecole Mohammadia d'Ingénieurs (EMI)

***Abstract*—Cooperative Cognitive Radio Networks (CCRN) is a promising concept recently studied to enhance cellular networks. The basic idea is that a primary user (PU) transmits his traffic assisted by some selected secondary users (SUs), which transmit also their own traffics using the same channel. The existing works in the literature propose the use of the same channel by applying a time division approach, where a time slot is dedicated to secondary traffic transmission, which degrads system performance. To overcome this problem, the use of multiple antennas enables simultaneous primary and secondary transmissions. Furthermore, the integration of beam-forming techniques removes the interference generated by this simultaneous transmissions. However, for almost systems proposed so far, only the PU and one SU can transmit simultaneously. In this paper, we propose a new scheme of CCRN where SUs communicate with a fusion center (FC) over a TV White Space (TVWS) band and perform a modulation matrix that allows simultaneous transmissions of the PU and all SUs with no interferences. Finally, we prove by theoretical studies and simulations that the suggested model improves significantly the rate of secondary users yet retaining good performances for the primary link.**

[1]

***Index Terms*—Cognitive Cooperative Radio Network, Zero-Forcing Beam-Forming, TV White Space, MIMO.**

I. INTRODUCTION

To increase spectrum utilization efficiency, the cognitive communication proposes that a PU, which has full access to frequency resources, selects some other users called secondary users (SUs) to dynamically access the spectrum resources. The selection could be based on different criteria [1,2]. For example, spectrum sharing technique allows PU to allocate spectrum resources to SUs in an autonomous way [3]. Moreover, the cooperative communication gives the possibility that SUs assist primary traffic transmission as relays and benefit of dedicated resources for their own secondary transmission. Hence, CCRN presents a win-win context for PU and SUs. Authors in [4-7] consider that PU and SU are equipped with single antenna. In such configuration the frame duration is divided into three phases. The first one is for transmission between PU and selected SUs, the second one is for the transmission between SUs and the Primary Receiver (PR), whereas the last phase is dedicated to the secondary traffic transmission. The gain obtained from this cooperation is thus still limited. To overcome this inconvenient, Multiple-Input-Multiple-Output antennas (MIMO) systems were integrated to CCRN [8-10]. The degree of freedom is thus increased, allowing a MIMO SU to transmit independent streams. Furthermore, the interference between the independent streams can be canceled using beam-forming techniques [11]. It has been shown that for the studied Multiple User MIMO (MU-MIMO) CCRN systems, the primary link performances is improved with the increase of SUs. However the secondary link quality is limited by the fact that all SUs share the time resource allocated to secondary transmission. In this work, we propose a new MU-MIMO-CCRN schema, which gets profit from both MIMO and TVWS band. TVWS means the spectrum allocated initially to broadcasting services but not used in the considered location [14-16]. In our system, MIMO is used for independent simultaneous streams of all SUs with PU, whereas TVWS band is used for communication between SUs and the FC in order to remove interferences between SUs thanks to a modulation matrix based on Channel State Information (CSI) [12,13]. Hence, our SUs and the FC are considered as secondary users of the TVWS band. -

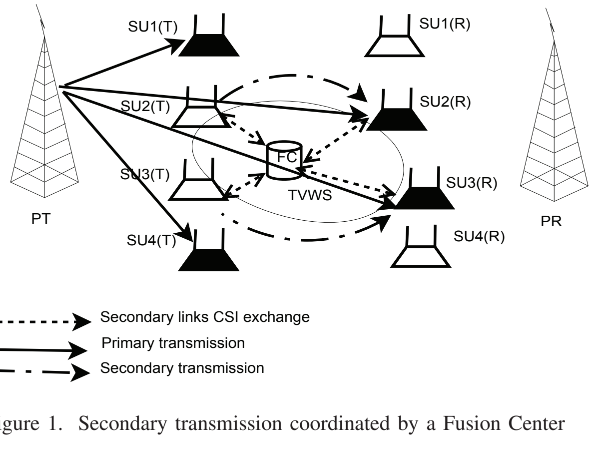

Figure 1. Secondary transmission coordinated by a Fusion Center

In our model, as shown in Figure 1, we consider a PU with a single antenna at both transmitter and receiver sides.

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[1] N.Bounouader assistant professor at Institut National des Postes et Télécommunications (INPT), Avenue Allal El Fassi, Rabat, Maroc, S.GHACHAM, G.ANIBA and Z.GUENNOUN are with Electronics and communication laboratory (LEC), Mohamed V-Agdal (UM5A) University, École Mohammadia d'Ingénieurs (EMI), Rabat, Morocco, e-mails: bounouader@inpt.ac.ma; s.ghacham@gmail.com; ghassane@emi.ac.ma; zouhair@emi.ac.ma.

The PU transmits the primary traffic to the selected multiple antenna relays (SUs), which then transmit this data to the PR. During the first phase, some SUs are allowed to transmit their own traffic SU2 and SU3. They communicate with a FC using TVWS band to exchange the CSI. Then the FC is able to perform an appropriate modulation vector, based on Zero-Forcing-Beam-forming techniques (ZFBF) [12,13] which help each secondary user to cancel interferences with the other SUs. SU2(R) and SU3(R) will receive primary stream and one secondary stream. Then SU2(R) and SU3(R) can estimate primary and secondary data using appropriate decoding vectors. Such original schema improves the utility of both primary and secondary links.

This paper is organized as follows: section II gives an overview of the used technologies namely TVWS band sharing, and ZFBF for MU-MIMO scenarios. Section III presents the system model and formulates the rate of primary and secondary links. Section IV is dedicated to simulation results analysis. Section V concludes the paper and gives some perspectives as future work.

II. CONSIDERED TECHNOLOGIES

A. TVWS band sharing

TV White space refers to a new concept of TV broadcast spectrum sharing that has emerged after digital switchover process where the analogue terrestrial TV was replaced by digital terrestrial TV in almost countries in the world. The use of the TVWS is considered to be a promising technique as it contributes to greater spectrum efficiency, and allows secondary users to take advantages of high transmission quality offered in UHF and VHF bands. Another great advantage is to reduce the spectrum crisis problem by enabling transmission beyond the crowded bands. Recently, a large research work has been dedicated to this promising concept. For instance, many research works and trial tests are led in several countries such as US [14], United Kingdom [15] Canada and others. The coexistence of independent networks in TV-WS was also studied in [16] through the study of different scenarios and mechanism as well as the proposition of coexistence decision algorithms. One major concern of TVWS is to avoid harmful interferences between primary and secondary services via an opportunistic spectrum access for TVWS exploitation, which is finally one feature of cognitive radio [17]. The advantage of opportunistic spectrum access is the dynamic and real-time update of system parameters. Two main methods were proposed to reach opportunistic spectrum access: sensing and geolocation. The former method requires the presence of some sensors in the secondary network; by using one of the sensing techniques, it detects unused bands and transmits this information to secondary network elements. Regarding the last method, each device determines its location and then uses a database to determine the white spaces in his location [18]. In this paper, TVWS band based on geolocation is used for communication between FC and SUs to avoid interferences with radio communication band.

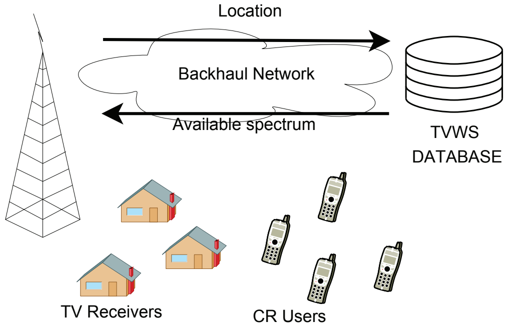

Figure 2. TVWS system using geolocation.

B. ZFBF for MU-MIMO system

The ZFBF techniques are one of the powerful methods used in order to mitigate interference between users [12,13]. This technique calculates coding and pre-coding vectors to cancel the MU interferences. We explain in the following lines this technique under a CCRN context.

Let's consider at first the simple case of two users: a primary single antenna user, and a secondary user with 2 antennas at the transmitting and receiving sides as shown in Figure 3.

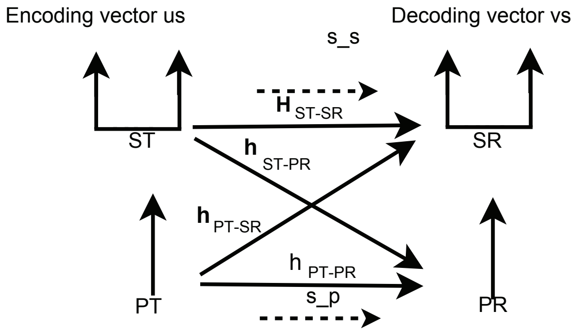

Figure 3. Transmission of two streams for Multi user MIMO system.

We denote by $\mathbf{H}_{\mathrm{ST-SR}}$ (2x2), $\mathrm{h}_{\mathrm{PT-PR}}$ (1x1), $\mathbf{h}_{\mathrm{PT-SR}}$(2x1), $\mathbf{h}_{\mathrm{ST-PR}}$(1x2) channel coefficient matrices between different pairs of transmitters/receivers. The SU performs an encoding vector $\mathbf{u}_{\mathrm{s}}$ so that the secondary stream is canceled at the primary receiver which is expressed as: $\mathbf{h}_{\mathrm{ST-PR}} * \mathbf{u}_{\mathrm{s}} = 0$. The estimation at the PR is expressed as:

$$\tilde{\mathrm{s}}_{\mathrm{P}} = h_{\mathrm{PT-PR}} * \mathrm{s}_{\mathrm{P}} + \mathrm{n}_{\mathrm{P}} \tag{1}$$

For the secondary receiver a decoding vector $\mathbf{v}_{\mathrm{s}}$ is applied to estimate secondary stream such that the next condition is fulfilled $\mathbf{v}_{\mathrm{s}} * \mathbf{h}_{\mathrm{PT-SR}} = 0$:

$$\tilde{\mathrm{s}}_{\mathrm{s}} = \mathbf{v}_{\mathrm{s}} * \mathbf{H}_{\mathrm{ST-SR}} * \mathbf{u}_{\mathrm{s}} * \mathrm{s}_{\mathrm{s}} + \mathbf{v}_{\mathrm{s}} * \mathbf{n}_{\mathrm{s}} \tag{2}$$

Under this configuration one SU can transmit simultaneously with the PU without interferences. The primary link is not affected even the SU has access to the channel.

In general, when K SUs are selected along with the PU, the time dedicated to the secondary transmission will be divided into K sub-time slots which decreasing the CCRN system performance.

In the second part of this section we present a MU-MIMO scenario where many SUs receive independent streams simultaneously without interferences. We denote by K the number of SUs pairs,The K SUs are allowed to access the channel during the same phase. From FC side, these SUs are viewed as one transmitter T_{TF} . each SU j is equipped with n_j and n_{rj} antennas at the transmitter and receiver sides. We consider then the transmitter T_{TF} with $\mathrm{n_t} = \sum \mathrm{n_j}$ antennas and K users each one is equipped with $\mathrm{n_{rj}}$ antennas, the idea is to find a modulation matrix $\mathbf{M}_\mathrm{j}$ for each user such that all MU interferences are zeroed. $\mathbf{H}_\mathrm{j}$is the matrix channel between T_{TF} and the jth SU receiver. If we define $\tilde{\mathbf{H}}_j = \left\{\mathbf{H}_1^T, ...\mathbf{H}_{j-1}^T, \mathbf{H}_{j+1}^T, ...\mathbf{H}_k^T\right\}^T$, the zero-interference constraint forces $\mathbf{M}_j$ to lie in the null space of $\tilde{\mathbf{H}}_j$. The following conditions should be satisfied to ensure the existence of $\mathbf{M}_\mathrm{j}$ [13]:

- Channel matrix $\mathbf{H}_\mathrm{j}$ is not highly correlated
- The rank $(\widetilde{H}_j)$ is strictly inferior to n_t

This conditions are necessary to ensure that the dimension of the null space of $\tilde{\mathbf{H}}_j > 0$. Finally T_{TF} transmits simultaneously secondary streams with the appropriate modulation matrices as one signal: $\mathrm{s} = \sum_{j=1}^{\mathrm{k}} \mathbf{M}_\mathrm{j} * \mathrm{s_j}$.

III. SYSTEM MODEL

The system model is a new architecture of a MIMO CCRN that improves the achievable rate for secondary links by allowing simultaneous transmission of all secondary streams without impacting the primary link. In this scenario SUs communicate via a FC, which receives both the channel matrix $\mathbf{H}_j$ and stream $\mathrm{s_j}$ for each user in order to construct the appropriate beam-forming matrix $\mathbf{M}_\mathrm{j}$. To avoid interferences with the CCRN band, the FC and SUs communicate over a TVWS band.

As shown in Figure 4, we will consider six SUs and two phases of transmission, the first one when PT transmits primary traffic to the relays selected, the second one when relays transmit primary traffic to the PR. Let us note:

$\mathrm{R} = \{\mathrm{ST}_1, \mathrm{ST}_2, \mathrm{ST}_3, \mathrm{SR}_4 \mathrm{SR}_5, \mathrm{SR}_6\}$,
$\mathrm{S}_1 = \{\mathrm{ST}_4, \mathrm{SR}_4, \mathrm{ST}_5, \mathrm{SR}_5 \mathrm{ST}_6, \mathrm{SR}_6\}$,
$\mathrm{S}_2 = \{\mathrm{ST}_1, \mathrm{SR}_1, \mathrm{ST}_2, \mathrm{SR}_2 \mathrm{ST}_3, \mathrm{SR}_3\}$

where R represents the set of relays selected by the PU, S1 the set of SUs allowed to transmit their own traffic during the first phase and S2 the set of SUs allowed to transmit their own traffic during the second phase

A. Phase 1

PT sends $\mathrm{s_p}$ to the relays, at the same time each secondary transmitters in S_1 send their own traffic $\mathrm{s_r}$ simultaneously to the receivers in R . The FC, which has full knowledge of the channel matrix, considers transmitters of S_1 as one transmitter equipped with six antennas and three receivers all equipped with two antennas: {2,2,2}*6.

To construct the modulation matrix $\mathbf{M}_\mathrm{j}$, we define singular value decomposition of $\tilde{\mathbf{H}}_j$, where the last $n_t - rank(\tilde{\mathbf{H}}_j)$ right singular vectors are candidates (note that the modulation matrix is easier to calculate when the number of SUs is important). The $\mathrm{ST_i}$ from S_1 coordinate to transmit as one source based on FC instructions. Each relay receives the following signal :

$$\mathrm{S_r} = \sum_{\mathrm{r_1 \epsilon S_1}} \mathbf{H}_{\mathrm{TF,r}} * \mathbf{M}_{\mathrm{r_1}} * \mathrm{s_{r_1}} + \mathbf{h}_{\mathrm{p,r}} * \mathrm{s_p} \mathbf{+} \mathbf{n}_\mathrm{r} \tag{3}$$

with $\mathrm{r \epsilon R}$.

If the relay belongs to S_1, the received signal is:

$$\mathrm{S_r} = \mathbf{H}_{\mathrm{TF,r}} * \mathbf{M}_\mathrm{r} * \mathrm{s_r} + \mathbf{h}_{\mathrm{p,r}} * \mathrm{s_p} \mathbf{+} \mathbf{n}_\mathrm{r} \tag{4}$$

with $\mathrm{M_r \epsilon null(\tilde{H}_r)}$.

If the relay belongs to S_2, the received signal is:

$$\mathrm{S_r} = \sum_{\mathrm{r_1 \epsilon S_1}} \mathbf{H}_{\mathrm{TF,r}} * \mathbf{M}_{\mathrm{r_1}} * \mathrm{s_{r_1}} + \mathbf{h}_{\mathrm{p,r}} * \mathrm{s_p} \mathbf{+} \mathbf{n}_\mathrm{r} \tag{5}$$

All relays estimate s_p. However only relays of S_1 will estimates_r.

For $\mathrm{r \epsilon S_1}$ and using equation (4), the receiver applies a decoding vector ${\mathbf{u}^{(p)}}_r$ in order to estimate S_p. The decoding vector should satisfy the following condition:

$$\mathbf{u}_\mathrm{r}^{\mathrm{(P)}} * \mathbf{H}_{\mathrm{TF,r}} * \mathbf{M}_\mathrm{r} = 0 \tag{6}$$

We suppose that the receiver has a complete knowledge of CSI.

$$\tilde{\mathrm{s}}_\mathrm{p} = \mathbf{u}_\mathrm{r}^{\mathrm{(P)}} * \mathbf{h}_{\mathrm{p,r}} \mathrm{s_p} + \mathbf{u}_\mathrm{r}^{\mathrm{(P)}} * \mathbf{n}_\mathrm{r} \tag{7}$$

To estimate the secondary data, the receiver applies a decoding vector $\mathbf{u}_r^{(S)}$so that:

$$\mathbf{u}_\mathrm{r}^{\mathrm{(S)}} * \mathbf{h}_{\mathrm{p,r}} = 0 \tag{8}$$

The estimated secondary stream could be then expressed as the following:

$$\tilde{\mathrm{s}}_\mathrm{r} = \mathbf{u}_\mathrm{r}^{\mathrm{(S)}} * \mathbf{H}_{\mathrm{TF,r}} * \mathbf{M}_\mathrm{r} * \mathrm{s_r} + \mathbf{u}_r^{(s)} * \mathbf{n}_r \tag{9}$$

For $r \epsilon S_2$ and based on equation (5), the receiver applies a decoding vector $\mathbf{u}_r^{(P)}$ that cancel all data sent by T_{TF}

$$\mathbf{u}_\mathrm{r}^{\mathrm{(P)}} * (\sum_{\mathrm{r_1 \epsilon S_1}} \mathbf{H}_{\mathrm{TF,r}} * \mathbf{M}_{\mathrm{r_1}} * \mathrm{s_{r_1}}) = 0 \tag{10}$$

The estimation of $\mathrm{s_p}$is expressed as:

$$\tilde{\mathrm{s}}_\mathrm{p} = \mathrm{u}_\mathrm{r}^{\mathrm{(P)}} * \mathbf{h}_{\mathrm{p,r}} \mathrm{s_p} + \mathrm{u}_\mathrm{r}^{\mathrm{(P)}} * \mathbf{n}_\mathrm{r} \tag{11}$$

B. Phase 2

The FC selects the best secondary transmitter in S_1 to cooperate with transmitters in S_2 and considers them as one transmitter. $\mathrm{TF}_2 = \{\mathrm{ST}_1, \mathrm{ST}_2, \mathrm{ST}_3, \mathrm{ST}_4\}$ transmits weight beam-forming vectors to four receivers, three SUs receivers all equipped with two antennas, and the primary single antenna receiver {2,2,2,1}*7.

The beam-forming matrix $\mathbf{M}_r$ and $\mathbf{M}_p$ are chosen so that the following conditions are reached:

$\mathbf{H}_{\mathrm{TF_2,SR_j}} * \mathbf{M}_\mathrm{p} = 0 \ \mathrm{SR_j} \in \mathrm{S}_2$
$\mathbf{H}_{\mathrm{TF_2,PR}} * \mathbf{M}_{\dot{\mathrm{r}}} = 0 \ \dot{\mathrm{r}} \epsilon \mathrm{R} \cap \mathrm{S}_2$

We note that, $\mathbf{M}_\mathrm{p} \in$ Null space of $\mathrm{H_r} = \left\{\mathrm{H_{TF_2,SR_1}}, \mathrm{H_{TF_2,SR_2}}, \mathrm{H_{TF_2,SR_3}}\right\}$ and $\mathrm{M}_r \in$ Null space of $\left\{\mathrm{H_{TF_2,PR}}, \mathrm{H_r} - \left\{\mathrm{H_{TF_2,SR(r)}}\right\}\right\}$

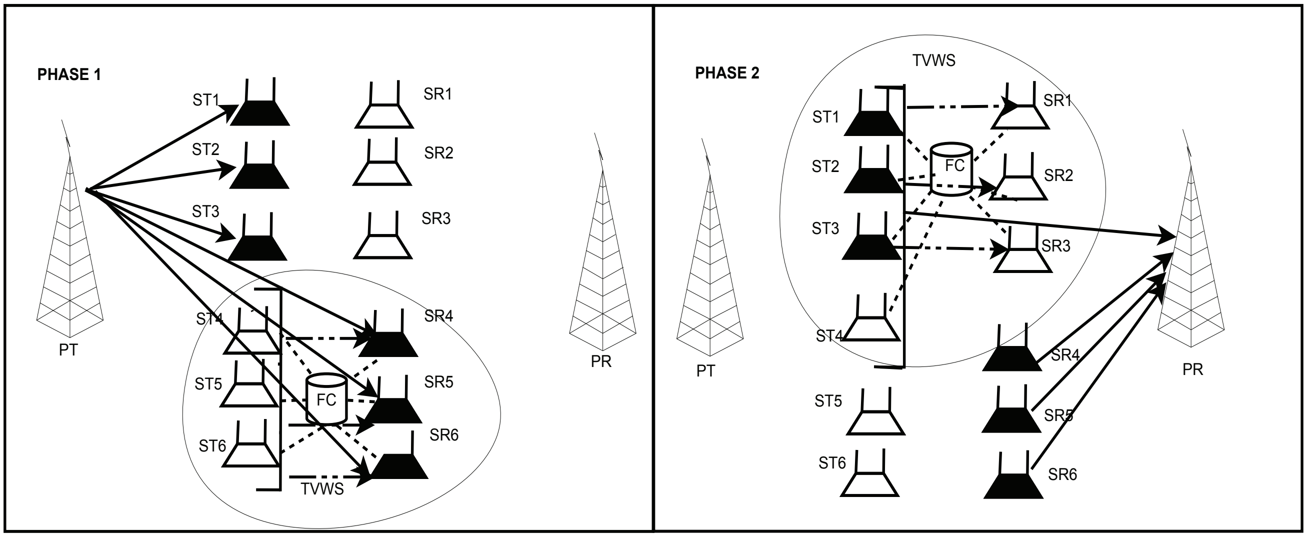

Figure 4. Tow phases CCRN architecture using Zero-forcing beamforming technique between SUs.

The signal transmitted byTF_2 is expressed as:

$$\mathrm{S_{TF2}} = \sum_{\mathrm{r \epsilon R \cap S_2}} \mathbf{M}_\mathrm{r} * \mathrm{s_r} + \mathbf{M}_\mathrm{p} * \mathrm{s}_p \tag{12}$$

Furthermore, relays belonging to S_1 transmit the primary streams using two antennas for each one :

$$\mathrm{S_t} = \sum_{\mathrm{r' \epsilon R \cap S_1}} \mathbf{M}^{\mathrm{p}}_{\mathrm{r'}} * \mathrm{s_p} \tag{13}$$

The received signal for any $SR_j \in S_2$ is expressed as:

$$\mathbf{s}_{\mathrm{SR_j}} = \mathbf{H}_{\mathrm{TF_2,SR_j}*} \mathbf{M}_\mathrm{r} * \mathrm{s_r} + \sum_{\mathrm{r' \epsilon R \cap S_1}} \mathbf{H}_{\mathrm{r',SR_j}} * \mathbf{M}^{\mathrm{p}}_{\mathrm{r'}} * \mathrm{s_p} + \mathbf{n}_{\mathrm{SR_j}} \tag{14}$$

The received signal at the primary receiver is :

$$\tilde{\mathrm{s}}_\mathrm{p} = (\mathbf{h}_{\mathrm{TF_2,Pr}} * \mathbf{M}_\mathrm{P} + \sum_{\mathrm{r' \epsilon R \cap S_1}} \mathbf{h}_{\mathrm{r',Pr}} * \mathbf{M}^{\mathrm{p}}_{\mathrm{r'}}) * \mathrm{s_p} + \mathrm{n}_{\mathrm{P}r} \tag{15}$$

To estimate secondary data, SR_j applies a decoding vector $\mathbf{u}_\mathbf{r}^{(\mathrm{S})}$ so that :$\mathbf{u}_\mathbf{r}^{(\mathrm{S})} * \sum_{\mathrm{r' \epsilon R \cap S_1}} \mathbf{H}_{\mathrm{r',SR_j}} * \mathbf{M}^{\mathbf{p}}_{\mathbf{r'}} * \mathrm{s}_p = 0$ for $\mathrm{SR_j \epsilon S_2 \cap R}$
The estimated secondary data is:

$$\tilde{\mathrm{s}}_r = \mathbf{u}_\mathrm{r}^{(\mathrm{S})} * \mathbf{H}_{\mathrm{TF_2,SR_j}} * \mathbf{M}_\mathrm{r} * \mathrm{s_r} + \mathbf{u}_{\mathrm{SR_j}}^{(\mathrm{S})} * \mathbf{n}_{\mathrm{SR_j}} \tag{16}$$

C. Performance analysis

In the following we will elaborate a data rate analysis for both secondary and primary links.
For each secondary transmitter $\mathrm{ST_k}$ we assume that power to transmit secondary stream is fixed at $P_k^{(s)}$. According to (9) and (16) we can derive the transmission rate of the secondary link during the first and second phase respectively :

$$\mathrm{R}_1^{(\mathrm{S})} = \log_2(1 + \frac{\mid \mathbf{u}_r^{(S)} * \mathbf{H}_{TF,r} * \mathbf{M}_r \mid^2 * P_k^{(s)}}{\mathrm{N}_0}) \tag{17}$$

$$\mathrm{R}_2^{(\mathrm{S})} = \log_2(1 + \frac{\mid \mathbf{u}_{SR_j}^{(S)} * \mathbf{H}_{TF2,SR_j} * \mathbf{M}_r \mid^2 * P_k^{(s)}}{\mathrm{N}_0}) \tag{18}$$

Where N_0represents the variance of the noise.

Our model gives a similar expression of the secondary rate as expressed in [8]. Unlike the existing works where the rate is calculated over the time slot allocated to this SU, the rate in our model is calculated over all frame duration for each SU. Let us now consider the primary link and specifically the phase1. According to (8) and considering the worst channel between PT and relays where the transmission power of PT is fixed to Pp. the rate is giving by

$$\mathrm{R}_1^{(\mathrm{P})} = \log_2(1 + \mathrm{mi}n_{\mathrm{r \epsilon R}} \frac{\mid \mathbf{u}_r^{(P)} * \mathbf{h}_{p,r} \mid^2 * P_p}{\mathrm{N}_0}) \tag{19}$$

In the second phase PR receives many copies of the primary stream from different channel paths. For more simplicity, we consider Maximum Ratio Combining method. According to (15), the rate is given by:

$$R_2^{(P)} = \log_2(1 + \frac{|\mathbf{h}_{TF_2,Pr} \mathbf{M}_P + \sum_{\mathrm{r \epsilon R \cap S_1}} \mathbf{h}_{\mathrm{r,Pr}} \mathbf{M}^{\mathrm{p}}_{\mathrm{r}}|^2 * P_r}{\mathrm{N}_0}) \tag{20}$$

Pr refers to the transmission power used by relays to forward the primary stream. Our architecture gives a similar expression of the primary link rate, thereby not affecting the quality of primary link.

IV. PERFORMANCE ANALYSIS

In this section we evaluate the performances of our system based on the distance between PU and relays (SUs), and the number of pairs of SUs. In order to get a fairly comparison, we consider the same simulation parameters and the same geometrical model as considered in most CCRN scenario as in [8]. The distance between PT and PR is D=100 meters. All relays are located at the same distance d from PT (D-d from PR). For the secondary link, distance between ST and SR is 40 meters from the same pair, and 120 meter from different pairs. The transmitting power for the primary link $P_p$is equal to the thermal noise (SNR=0), we also consider transmission power used by relays to forward the primary stream equal toP_p. the cost per unit transmission energy is 10. All channels are assumed to be rayleigh fading with path loss exponent equal to 2. Finally we simulate our model over 300 frame durations and for 100 independent simulations.Table 1 gives a summary of the simulation parameters.

Figure 5 presents the average utility of the primary link of our MIMO-CCRN model versus different values of d. The simulation results show that cooperative transmission presents good performances compared to direct transmission , both rates converge to the same value for d=90. The average utility achieves 4 Mb/s for direct transmission and a maximum of 11 Mb/s for d=40 for cooperative transmission.We can conclude that MIMO-CCRN using ZFBF between SUs does not impact the primary link performance that keeps almost the same value.

Figure 6 presents the average utility of the secondary link versus different values of K (number of secondary pairs) and compares the secondary rate with and without ZFBF technique between SUs , the rate is calculated for two values of d (d=30 and 50 meters). The simulation results show that the secondary performance improves significantly by adding ZFBF. As mentioned above the primary link performances is improved with the increase of SUs. However in those works without using ZFBF techniques, the secondary link quality is limited by the fact that all SUs share the time resource allocated to secondary transmission. The simulation prove that in our architecture, the increase of SUs pairs does not impact secondary links performances, which is the main contribution of this work. Table 2 gives some rate values comparing the two scenarios when the ZFBF is either applied or not.

As we can conclude from Figure 6, the secondary average utility still almost stable for different value of K, the small difference between values is due to the beam-forming vectors that are choosing randomly, this can be improved by adding an algorithm that find the best beam-forming vectors that null the interferences and give the best rate to the SUs.

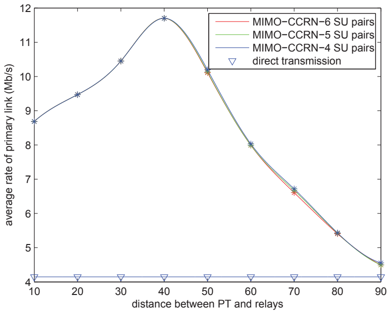

Figure 5. Average utility of primary link.

Table I
Simulation parameters

Parameter	value
D(distance between PT and PR)	100 meters
Distance between ST and SR (same pair)	40 meters
Distance between ST and ST or SR (different pairs)	120 meters
path loss exponent	2
Cost per unit transmission energy	10

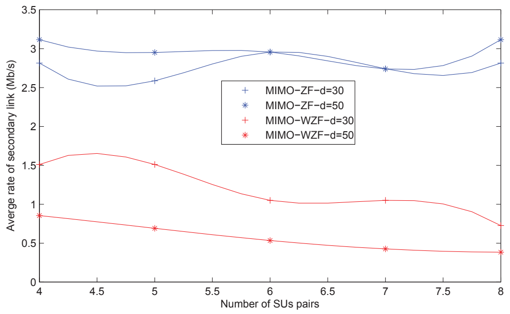

Figure 6. Average utility of secondary link.

K	4	5	6	7	8
Rate with ZFBF(Mb/s)	3.115	2.950	2.955	2.738	3.115
Rate without ZFBF(Mb/s)	0.853	0.690	0.534	0.425	0.383

Table II
Performance analysis of secondary average utility for d=50m.

V. Conclusion

In this paper we improve secondary link performance without impacting primary link by: using the MIMO zero forcing beam-forming techniques under a Cognitive Cooperative system and using a fusion center that communicates with the secondary users over a TV White Space band. Simulation results have shown that our model presents a higher average utility compared to direct transmission scheme. The main contributions of this paper can be summarized as follows: We proposed a new schema of a MU-MIMO-CCRN that gets advantage from TVWS band to allow SUs to transmit simultaneously without interferences. We formulated the theoretical expression of primary and secondary capacity under this architecture. We evaluated the system performances in terms of average utility.

As future woks we will exploit the MIMO antennas by adding the Space Time block Coding that achieves a good performance, and find the optimal beam-forming vectors for the secondary transmission.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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