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Spectral Sensing & Multi-Objective Spectrum Allocation over MIMO-OFDMA Based On 5G Cognitive Wssns for Iot Intelligent Agriculture

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ABSTRACT: *This paper describes a spectral sensing & multi-objective spectrum allocation over MIMO-OFDMA based on 5G cognitive WSSNs for IoT intelligent agriculture application. This project addresses the spectrum allocation problem with respect to both spectrum utilization and network throughput in the cognitive radio wireless smart sensors network-based IoT intelligent agriculture application. The cognitive radio is promising in handling spectrum efficiently. However, the existing cognitive radio model for WSSNs is not efficient in utilizing spectrum. They also suffer from interference which induces collision. To address this work, we present an opportunistic spectrum access for WSSNs. The channel availability of likelihood distribution is computed using continuous-time Markov chain considering primary transmitting users, temporal channel usage, channel pattern and spatial distribution. The 5G promising techniques, MIMO-OFDMA based cognitive radio CWSSN schemes are proposed to significantly improve the system capacity while mitigate the interference for dynamic spectrum access networks. An improvement of 26.3% is achieved in terms of collision reduction and improvement of 40.8% in terms of throughput is achieved. An optimization of channel availability is considered to further analyze and improve the performance of cognitive radio WSSNs.*

KEYWORDS: *IoT intelligent agriculture, MIMO-OFDMA, Multi-objective spectrum allocation, Spectral sensing, 5G cognitive radio wireless smart sensors network.*

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I. INTRODUCTION

The IoT ecosystem is quite complex because it integrates several technologies and areas of expertise. From a general point of view, it calls and requires multi-skills in the areas of hardware, communication protocols, software, cloud and mobile.

New LPWA technologies addressing the needs of low-power connectivity are driving the development of the IoT market. LPWA networks are low-consumption, low-speed, long-range wireless networks optimized for equipment with limited resources for which a multi-year autonomy is required (between 5 and 15 years).

Several objectives can be achieved in LPWAN such as Low Power Transmission Technology, Long Distance Communication, Low Energy Consumption, Long Battery Life, Low Cost Communications and Infrastructure, Scalable System, Allow Mobility and Reliable Communication. Among the LPWAN networks there are the two big competitors SigFox and LORA Wan. LPWA networks use free ISM frequency bands. Wireless networks in industrial, scientific and medical (ISM) bands are typically established by placing access points that connect terminals to each other and to networks. ISM Bonds (Industrial, Scientific and Medical) around 868 MHz for Europe, the 868 MHz band is also used in domotic equipment networks such as EnOcean, Z-Wave or M2M networks like SigFox and Lora. ISM frequency bands are also used for telecommunication applications, mainly short-range.

Cognitive radio (CR) is a technological innovation being considered to provide a solution to the problem of static spectrum allocation and thus enable access and dynamic spectrum management in wireless communication systems. CR offers dynamic spectrum allocation and high reliability communications technique is considered the best solution to solve low-spectrum use. Spectrum detection is an important technology requirement in the search for Dynamic Spectrum Access (DSA) in the wireless world [1]. Dynamic access allows a dynamic allocation of the bandwidth; one can distinguish two types of access: Deterministic access: A decision mechanism makes it possible to choose the station which has the right to emit its data for a definite period of time. It has a definite duration of time. Random Access: A station that wants to send a frame does not need permission to do so, access is then direct to the channel. In this case, the access conflict must be avoided.

There are several spectrum detection techniques such as paired filter detection, energy detection, waveform detection, cyclostatic feature detection and wavelet detection.

Next-generation communication systems promise to implement a wide variety of new features. 5G designs require MIMO antenna arrays with hundreds of antenna elements on base stations (eNodeB) MIMO technology uses spatial multiplexing gain to achieve higher spectral efficiency [2]. Since several transmit antennas can be applied to OFDM-based cognitive radio systems, the researchers have designed and proposed the very promising candidate, called MIMO-OFDMA, which can compensate for lack of capacity while increasing spectral efficiency [2]. OFDMA is considered a modulation and multiple access technique for next-generation wireless networks. OFDMA is an extension of orthogonal frequency division multiplexing (OFDM). OFDMA can achieve adaptive bandwidth allocation in cognitive wireless smart sensors networks.

The Wireless Smart Sensors Network (WSSN) is a multi-hop network. The WSSN nodes are located in a monitoring field in a distributed manner. CR-based wireless networks can help overcome the bandwidth limitation of wireless networks by detecting ghost holes using technologies to improve spectrum utilization and minimize interference. Due to the characteristics and limitation of smart sensor nodes, the coupling of cognitive technology into smart sensor nodes introduces other challenges such as spectrum detection, spectrum sharing and spectrum management.

The organization of the paper is as follows. Section II defines the model of the proposed system. Section III describes the theoretical analysis of the network metrics. The simulations and model of the Intelligent Agriculture IoT application are presented in Section IV. Finally, section V concludes the article.

II. SPECTRUM MODEL & NETWORK ARCHITECTURE

Software-defined wireless smart sensors Cognitive radio networks (SD-WSSCRN) are smart sensors network consisting of smart sensor nodes and a base station on which all detected data is transmitted. The network can be reconfigured remotely after deployment. The network is agile and adapts to topological changes. It is also programmable, which makes it easy to manage the network [3]. To meet the challenges of the spectrum, smart sensor nodes are equipped with cognitive radio that is promising in effective spectrum management.

2.1 Integration of the CR in the WSSNs

Cognitive radio (CR) is one of the technologies that enables smart sensor nodes (as secondary users) to detect and temporarily use the underutilized spectrum under license when primary users (PUs) do not use [4].

In general, cognitive radio systems, mainly, are based on two aspects: On the one hand, the use of spectrum detection technology before the occupation of unused spectrum in the needs of cognitive users before access cognitive, requires the use of spectral detection technology to determine an inactive frequency spectrum. On the other hand, the cognitive user after the access occupation, to a spectrum hole, then to avoid normal communication of the primary user still influences the need for real-time detection of authorized spectrum using Spectrum detection technology, but also need to perceive other channels to prepare the main users come to achieve transparent transfer, prevent the impact on cognitive communication. The cognitive technique is the process of knowledge through perception, planning, reasoning, action and continuous updating and updating with a learning history for that can say that the CWSSNs are networks ad specialized hoc of distributed smart sensors. Some advantages of using CR in WSSN such as: Efficient use of spectrum and spaces for new technologies, use of multiple channels, Energy efficiency, Application-specific spectral band utilization, Avoid attacks and financial benefits. One of the primary goals of integrating a CR into wireless smart sensors is to use the unused, opportunistic licensed spectrum.

Software-Defined Wireless Smart Sensors Cognitive Radio Networks (SD-WSSCRN) are radio-activated cognitive smart sensors networks that use cognitive radio to detect available spectrum and use it if it is available and free. The SD-WSSCRN also consists of a base station or sink node (Sink). Sink is a special node responsible for receiving, storing and processing data from other nodes and distributing the different requests on the network. Smart sensor nodes use a specific low-power, low-speed, long-range network that is typically LPWAN networks. In our research, we will use the SigFox network. The SigFox network is a communication system that uses the high-speed band (UNB) for IoT devices [5]. SigFox offers several advantages such as long range, ubiquity, lower power consumption and lower cost. This specialized network for M2M (machine to machine) low speed, it is operated using cellular networks such as 3G / GPRS / LTE ... The network, we will use in our example, is the 5G network that is a new generation communication system that has several features.

To address the above-mentioned issue and challenges that exists in implementing efficient spectrum access mechanism in cognitive radio wireless smart sensor network. This work presents an opportunistic primary user spectrum access mechanism by using continuous-time Markov chain. Let us consider a cognitive radio wireless smart sensors network, which consists of set of primary users such as the base station (sink) and the unlicensed secondary users (smart sensor devices). A smart sensor device is fitted with cognitive radio for opportunistic access of licensed spectrum. Let us consider H set of nonempty opportunistic channel that can be accessed by smart sensor devices. There exists limited channel availability for smart sensor device due to characteristics nature of primary user and smart sensors devices positions/locations. The characteristic of spectrum opportunity depends on the channel availability to smart sensor device which is defined as the amount of time the channel is available to smart sensor devices or not. The accessibility of channel c, c Є H, for a smart sensor device is defined by temporal channel usage pattern of primary user and spatial distribution on channel c and the location of smart sensor devices. Therefore, estimating the channel availability plays an important role in improving the QoS of secondary user and improves the utilization of spectrum. Let us consider a continuous-time Markov chain that considers primary user channel usage pattern and the secondary user location. The continuous-time Markov chain consists of three modes and is denoted as M_l is the mode in which a node within coverage area of idle primary transmitting user that transmit on channel c, M_B is the mode in which a node within coverage area of active primary transmitting user that transmit on channel c and M_Z is the which a node is outside the coverage area of primary transmitting user that transmit on channel c. When the position of smart sensor devices is changed the mode changes from one form to another form and channel is inaccessible only when mode in M_B. The mode M_l and M_Z can be merged to one mode where the channel is accessible to the smart sensor device which is represented by M_X. The mode of unavailability of channel is represented by M_N. Let $\mathbf{K}_{X,c}$ and $\mathbf{K}_{N,c}$ be the time duration of smart sensor node in M_X and M_N respectively. The likelihood distribution of channel availability of $\mathbf{K}_{X,c}$ and $\mathbf{K}_{N,c}$ is important to compute the transition mode of $\mathbf{M}_{l,}$ $\mathbf{M}_B$ and $\mathbf{M}_Z$ i.e. Let $\mathbf{K}_{i,c}$ be the time period in which a smart sensor device is inside the range of primary transmitting user on channel c and $\mathbf{K}_{u,c}$ be and the time period in which a smart sensor device is outside the range of primary transmitting user on channel c. Thus, the rate of transition modes depends on the likelihood distribution of $K_{i,c}$ and $K_{u,c}$. To compute $K_{i,c}$ and $K_{u,c\,,}$ a two-dimensional Markov chain model is considered. The spatial distribution of primary transmitting user that process on common channel c are distributed in square area. The distance among two adjacent primary transmitting users in vertical direction is represented as $A_{q,c}$ and in horizontal direction is represented $A_{p,c}$. The square area of $2T_c$ is considered for coverage area of primary transmitting user where $T_c < \min(A_{p,c}, A_{q,c})$ to avoid overlapping section among primary transmitting user. To protect primary transmission, we consider the approximate coverage greater than the actual coverage area. The temporal usage of pattern of primary transmitting user that communicates on channel c is exhibited as idle (primary transmitting user does not communicate) and busy (primary transmitting user is active and communicate) mode. The smart sensor nodes in coverage area of primary transmitting user do not have access to transmit on the same channel during the transmission period of primary transmitting user in order to avoid the interference with primary using network. The periodic length of idle/busy mode is exhibited as an exponential random variable as μ_l/μ_B, that is, $K_{l,c}\approx e(\mu_{l,c})$ and $K_{B,c}\approx e(\mu_{B,c})$; Where $F\approx e(\mu)$ indicates that variable F is an exponential distribution with μ. $A_{l,c}= \mu_{B,c}/\mu_{l,c} + \mu_{B,c}$: are the steady mode likelihood that primary transmitter being active on channel c and $\alpha_{B,c} = 1- \alpha_{l,c}$: are the steady mode likelihood that primary transmitter being inactive on channel c. Therefore, the mean fraction channel availability of an area at any instance of channel c is represented by ω_c. $\omega_c= (1-\beta_c)+\beta_c\alpha_{l,c}=1-\beta_c\alpha_{B,c}$ where $\beta_c=4T^2/A^2_{l,i}$.

The model proposed in Figure 1 uses the notion of cluster or clustering. Cluster is a subset of connected nodes (smart sensor nodes), this notion is a process of grouping nodes into clusters, giving the network a hierarchical structure.

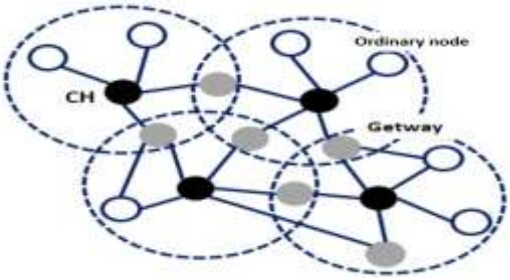

Figure 1: Cluster example

In a cluster, there are 3 different nodes: firstly, CH (cluster head or Sink) it is the group leader that allows to coordinate the members of its cluster, to aggregate, to process the data and to transmit them to the data collector. Secondly, gateway node (or Gateway) that has inter-cluster links and can access neighboring clusters and route data between them. Finally, ordinary node is a smart sensor. The clustering method has several objectives such as reducing power consumption, reducing communication, load balancing, extending network lifetime, ensuring total connectivity and reducing delays, optimizing bandwidth and ensuring high Quality of Service (QoS) [6]-[14].

2.2 System model & Channel model

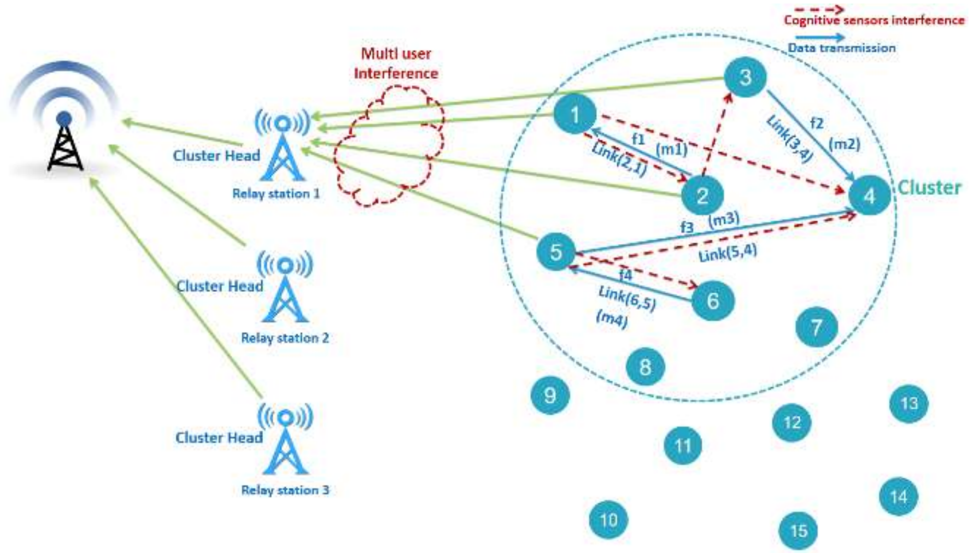

Figure 2: CWSSN network model based on MIMO-OFDMA

The model is formulated by a graph R = (N; L; C; F), with
N: is the set of nodes of the network.
L: is the set of links that are possible communication pairs on the duty of transmissions.
C: is the set of spectrum channels that are currently assigned to links in L.
F: is the set of simultaneous multi-hop data streams in the network.

In MIMO, there are two concepts based on how base station antennas are used to serve users. They are divided into two categories MIMO single user and MIMO multi-user. In single-user MIMO, all streams from base station antennas are focused on a single user. In multi-user MIMO, different streams produced using a combination of different antennas are focused on different users or subscribers. In the cognitive radio based IoT, there exist some multi-hop concurrent data flows. The routing path of these flows are composed of some successive object links. The following schematic figure 3 shows the processing for the channel sounding modeled.

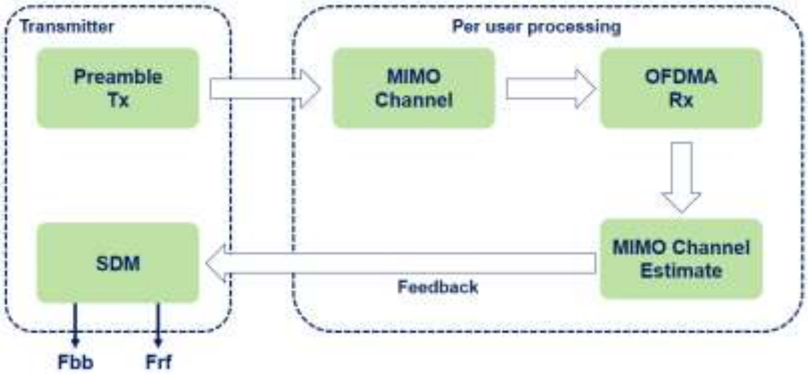

Figure 3: CWSSN network model based on MIMO-OFDMA

For the selected MIMO system, a preamble signal is sent on all transmitting antenna elements and processed at the receiver representing the channel. The antenna elements of the receiver perform preamplification, OFDMA demodulation and frequency domain channel estimation for all links. The previous figure uses the Spatial Division Multiplexing (SDM) technique for a multi-user system to determine the Fbb and RF digital baseband Frf analog precoding frequencies for the selected system configuration.

SigFox uses a proprietary technology that uses an Industrial, Scientific and Medical band on 868 MHz frequencies in Europe. The band that will be used in the IoT agriculture application is the same band as Europe (868 MHZ). In the radio frequency domain noise plays an important role in data transmissions and existing channels as well. The band was chosen to characterize Additive White Gaussian Noise (AWGN) for the SigFox service at a fixed point [4]. We consider the following matrix (1) of the channel with t it is time and f frequency.

$$B = \begin{bmatrix} A1(t1, f1) & A1(t1, f2) & \cdots & A1(ti, fm \\ & \vdots & \ddots & \vdots \\ An(tn, f1) & An(tn, f2) & \cdots & An(tn, fm) \end{bmatrix} \tag{1}$$

To measure the Gaussian noise probability density function is as follows with μ: it is the mean and σ: it is the variance.

$$PDF_{\mathrm{AWGN}} = \frac{1}{2\pi\sigma} e^{-(x-\mu)^2/2\sigma^2} \tag{2}$$

2.3 Spectral detection model & sensing spectrum method

Generally, the technique allowing unlicensed users to dynamically access unused licensed tapes in order to minimize unused spectral bands or blanks is known as a dynamic spectrum access scheme. In this scheme, unlicensed users essentially use unused licensed frequency bands at no charge. When the licensed user begins to use the frequency band, the unlicensed user must release the group and move to another idle band. That is, the CR technique and the dynamic spectrum access scheme are major solutions for increasing spectrum utilization in cognitive radio smart sensor networks. The goal of spectrum pooling is to improve spectral efficiency by overlaying a new mobile radio system on an existing system without the need to modify the licensed system. Cognitive radio (CR) has been identified as an enabling technology that will significantly mitigate the effect of under-utilization of spectrum and mitigate spectrum scarcity. But for this to happen, a fast and accurate detection technique must be developed. A number of spectrum detection techniques are available in the literature, but these have no shortcomings.

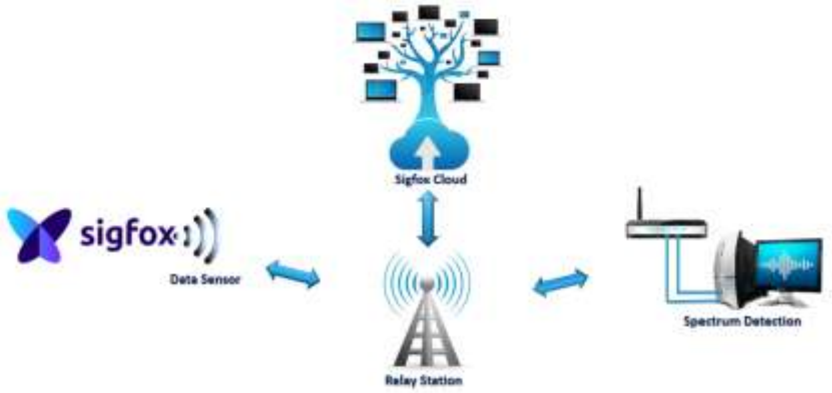

Figure 4: Configuration of the spectral detection method

According to the detection technique, there is a compromise between the detection delay and the accuracy of the detection. The technique that takes a long detection time has more precision with the cost of delays and conversely. Basically, there are two types of detection techniques: (a) signal processing techniques such as matched filter detection, energy detection, waveform detection, cyclostationary characteristic detection etc ... ; and (b) cooperative detection techniques: centralized spectrum detection, decentralized spectrum detection and hybrid spectrum detection. But in our research, we will focus on the cyclostationary detection method. This method is used to detect the primary user by exploiting the cyclic characteristics of the signal and used for signals in the spectrum and is able to identify the AWGN noise of the primary user [5]. The cyclostationary characteristics are caused by the periodicity of the signal. x (n) is cyclostationary with a mean m: = E {x (n)} and a covariance Cxx (n; τ): = E {[x (n) - m (n)] [x (n + τ) - m (n + τ)]}. An almost cyclostationary process is defined if its mean and its correlation are almost periodic sequences.

For x (n) with mean and real cero, cyclic and time-varying correlations are defined as the generalized Fourier pair in (1). The correlation model proposed as follows:

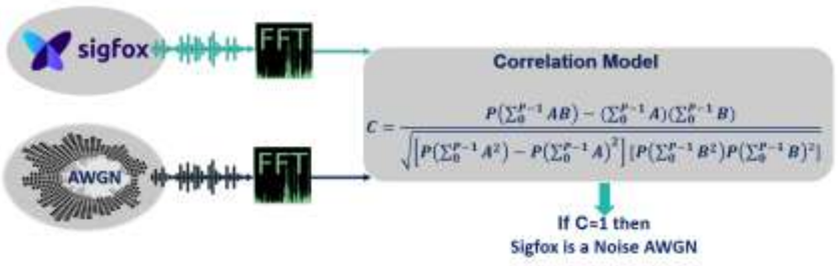

Figure 5: Model of correlation

Detection system that uses spectral correlation algorithms showing spectrum components and radio background noise in the SigFox frequency band.

III. METRICS NETWORK THEORETICAL ANALYSIS

In traditional WSN networks, the Quality of Service is typically characterized by four parameters: bandwidth, delay, jitter, and reliability. To avoid the dangerous consequences in critical applications, local storage networks must maintain an adequate level of quality of service. Quality of Service support is a complex issue due to resource constraints, such as processing power, memory and power sources in wireless smart sensor nodes. Quality of Service (QoS) is a management concept that aims to optimize the resources of a network or process and to ensure good performance for critical applications for the organization. Quality of Service offers users differentiated rates and response times by application according to the protocols implemented at the structure level. Different objective functions for measuring communication quality metrics in the network [15]. Three objective functions of wireless communication performance are considered in this paper: Maximize throughput (3), Minimize power consumption (4) and minimize Bit Error Rate (BER) (5):

$$f_{\max\_\mathrm{debit}} = \frac{log_2(\overline{M})}{log_2(M_{\max})} \tag{3}$$

$$f_{\min\_energy} = 1 - \frac{\overline{P}}{P_{max}} \tag{4}$$

$$f_{\min\_BER} = 1 - \frac{log_{10}(0.5)}{log_{10}(\overline{P_{BER}})} \tag{5}$$

We will also study the Signal-Interference-Noise Ratio (SINR) that is used to measure the quality of communications. In link transmissions, SINR can be thought of as the received signal power at the receiver divided by the sum of the received powers of unintended signals (interference) from other links on the same spectrum channel [16]. For a link (i; j) on the spectral channel c, its SINR ratio can be calculated as follows (6):

$$SINR_{\mathrm{ij}}(c) = \frac{G_{ij}p_i}{\sigma^2 + \sum_{(a,b)\in I(c),(a,b)\neq(i,j)} G_{aj}p_a} \tag{6}$$

With Pi: the transmission power of the sender i. In this paper, we assume that the transmit power of all links is at the fixed level. Gij: the gain of the channel between the transmitter i and the receiver j, which can be denoted $k/(d_{ij})^{\alpha}$; K: the path loss constant; dij: the distance between i and j; α: the exponent of path loss; σ^2: the thermal noise that can be considered a constant and the sigma notation presents the global interference to the receiver j, which is generated by the links transmitting concurrently on the current spectrum channel; I (c): the set of links sharing the spectrum channel c. To ensure the effective transmission of the link, each intended signal must be decoded successfully at the receiver. For the SINR, there is a desired value designated by, which indicates the successful decoding threshold [16]. the constraint is satisfied as follows:

$$SINR_{ij}(C) \geq \beta \tag{7}$$

With β is the threshold of successful decoding.

IV. SIMULATION EVALUATIONS

In this project, we proposed a new irrigation system to improve and to promote Apricot-Peach and Olive production in Tunisian middle west area. An Automated Irrigation Biological Agriculture system and a new irrigation management system are developed. An agriculture irrigation platform architecture is proposed and we developed the ecosystem stages of cloud computing of things for remote control and supervision of agricultural parcels irrigation and their identification –supervision through a distanced interface via cognitive radio. Wireless smart sensors network, Internet of Things, Cloud Computing, SigFox,- LORA Wan, Waspmote plug and Probes data logger, … The visualization interface was put in place and cloud computing offer us the characteristic of each parcel type of plants, surface area, soil condition, irrigation system based on smart sensors [17]-[19].

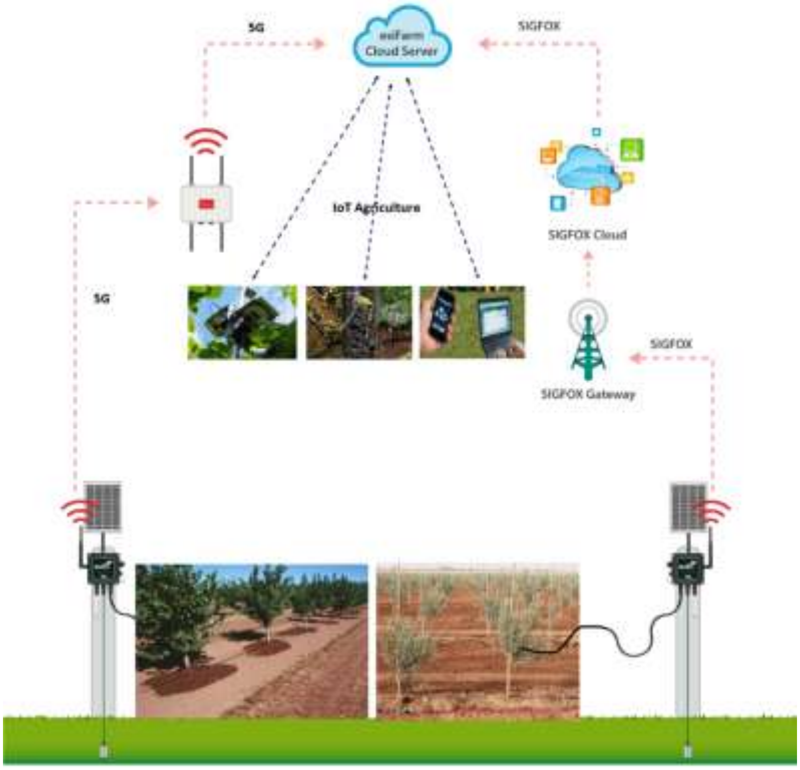

Figure 6: Application for IoT Intelligent Agriculture

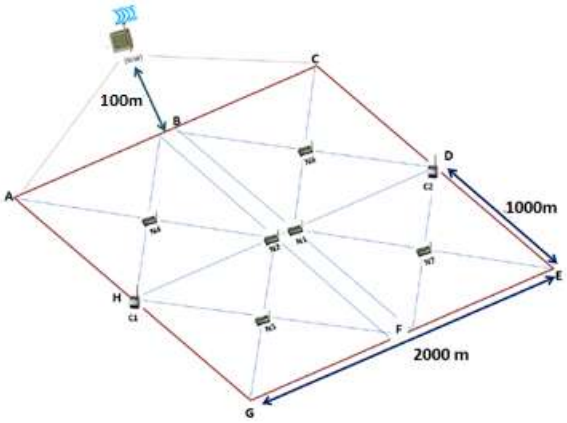

Figure 7: Network topology of application IoT Intelligent Agriculture

The topology of the cognitive-radio IoT in the simulation of the intelligent farming application is shown in the following figure (7) where 100 nodes are randomly deployed over an area of 2000m to 1000m. Each smart sensor node is mounted with a single TRX. There are several streams of data simultaneously in the network. The transmission power of each link is set at 13 dBm and the thermal background noise σ^2 is equal to -100 dBm. The gain of the channel is defined as $h\,ij = k/(d_{ij})^{\alpha}$,where dij is the distance between two smart sensors. We adopt the path loss constant k = 1 and the path loss exponent α = 5.

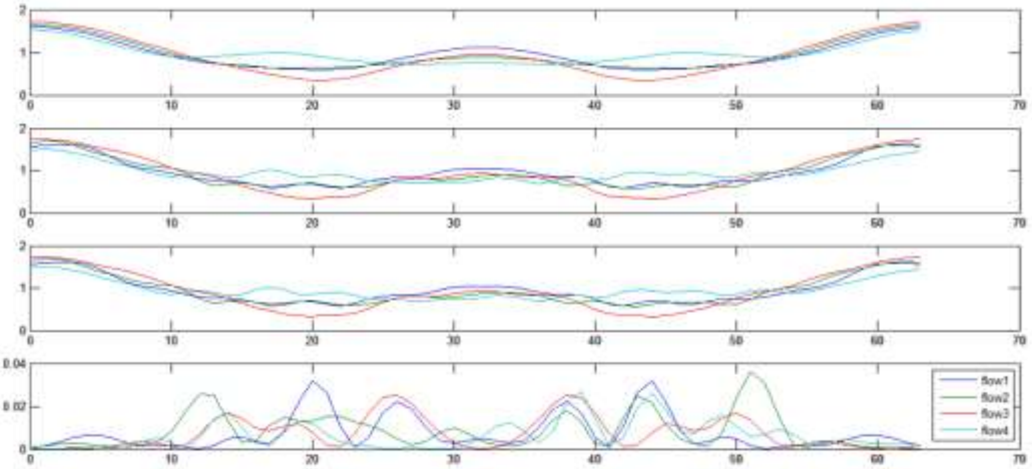

Figure 8: MIMO simulation

BER performance analysis of Binary PSK modulation technique with AWGN channel

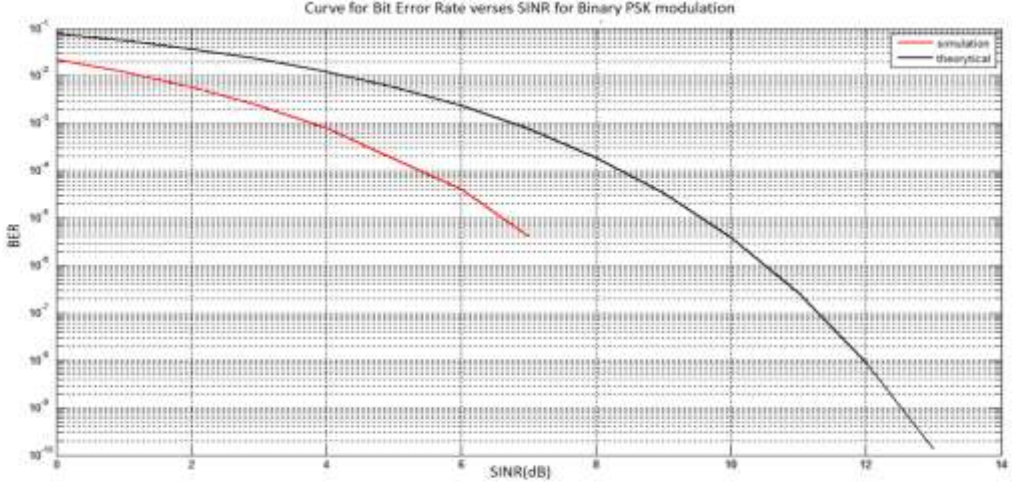

Figure 9: simulation of BER metric

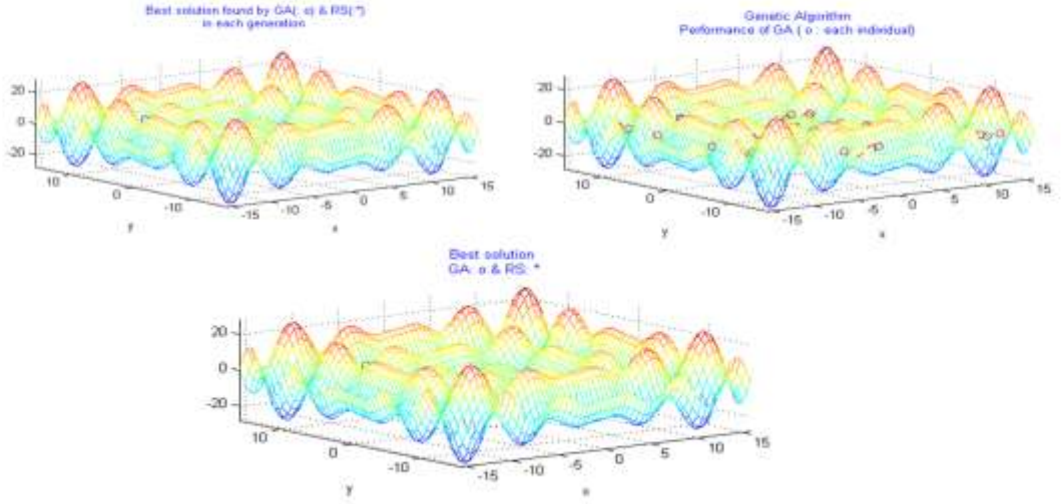

Figure 10: simulation of SINR with algorithm genetic

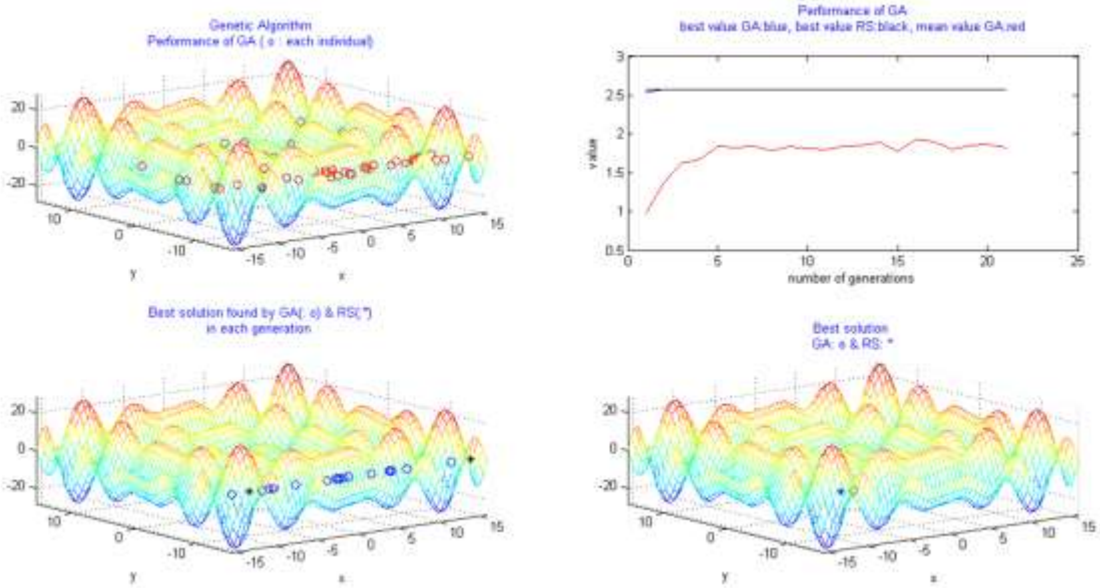

Figure 11: Power consumption metric simulation

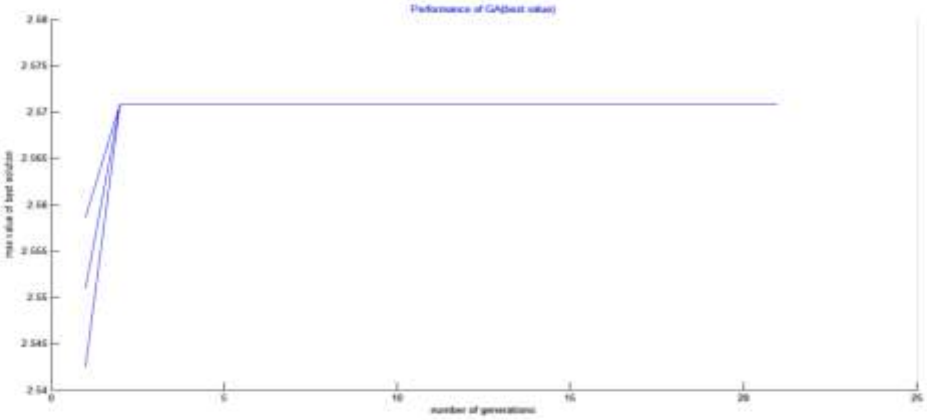

Figure 12: Performance of GA power consumption simulation

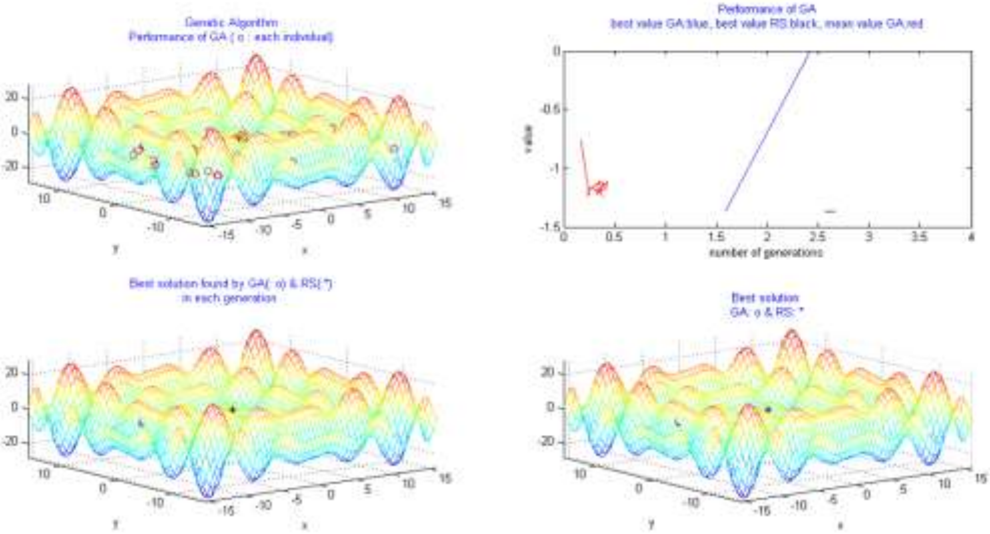

Figure 13: Throughput metric simulation

V.CONCLUSION & PROSPECTS

A work in progress of the multiple notions combination of a Spectral Sensing & Multi-objective Spectrum Allocation over MIMO-OFDMA based on 5G cognitive WSSNs for IoT Intelligent Agriculture application was presented in this paper. The work addressed the necessity of sensing the spectrum of characterizing unlicensed bands where several IoT services will be deployed. The channel availability of likelihood distribution is computed using continuous-time Markov chain considering primary transmitting users, temporal channel usage, channel pattern and spatial distribution. In the other hand, we proposed the heterogeneous statistical QoS driven resource allocation scheme by applying the MIMO-OFDMA based cognitive radio WSSNs. In this paper, we investigated the optimal spectrum allocation with respect to network throughput and spectrum utilization in cognitive radio WSSNs based IoT Intelligent Agriculture application. Because the available limited frequency spectrum is not enough to cater the increasing in traffic demand, the cognitive radio WSSNs technology plays an important role in such a scenario by opportunistically accessing the licensed spectrum. Among the cognitive tasks, spectrum sensing is found to be the most energy consumption. The simulation is conducted to evaluate the performance of proposed model in terms of collision and throughput efficiency by varying network density size. The outcome shows significant performance improvement. An improvement of 26.3% is achieved in terms of collision reduction and an improvement of 40.8% in terms of throughput is achieved. An optimization of channel availability is considered to further analyze and improve the performance of cognitive radio WSSNs.

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