EAI Endorsed Transactions

on Industrial Networks And Intelligent Systems Research Article ICST.ORG

Wireless Broadband Opportunities through TVWS for Networking in Rural areas of Africa

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Abstract

In this paper, we propose a new approach based on Cognitive Radio technology to address the challenges for ensuring connectivity in remote areas of Africa. Indeed, the current network coverage is concentrated around the cities with high density of population. Through the deployment of Cognitive Radio, emergency services in rural areas will benefit from low cost access networks. Cognitive Radio will be used to manage the selection/switching across different frequency UHF/VHF bands or TV White Spaces (TVWS), while avoiding interference.

Keywords: Cognitive Radio, TV White Spaces, Rural areas, Remote zone connectivity, Emergency services

Received on 25 February 2014, accepted on 21 July 2014, published on 08 May 2015

doi: 10.4108/inis.2.3.e4

1. Introduction

The use of mobile technologies and networks in Africa is growing rapidly and services are increasingly diversified. The quality of the available networks differs from one geographical area to another. In many areas, the network deliver a poor connectivity, while some areas have no connectivity. These deficiencies are related to the operators policies and the economic benefits they should derive from their investment. However, Internet or network access could considerably improve the inhabitants social condition in remote areas. Providing low cost Internet access anywhere through Cognitive Radio Networks (CRNs) and using TV White Space (TVWS) is the main objective of this contribution. In this paper, we introduce the Cognitive Radio technology, with a detailed description of its main modules in section 2. The main advantages of this technology in African context are presented in section 3 through the services that it could offer. We give an overview on the related work, referring to some works addressing the use of cognitive radio in African context in section 4. The deployment plan that we propose is considered in section 5, an experimentation idea and results are studied in 6. We open a discussion section (Section 7) before concluding this chapter in section 8.

2. Cognitive Radio networks

2.1. Definition and principle of cognitive radio networks

Cognitive Radio [1] is a paradigm for wireless networks where a node is able to automatically modify its transmitting parameters in order to communicate efficiently, while avoiding interferences with other users, the Primary Users (PU[1]). This self-configuration and self-adaptation of parameters is based on a set of modules and several factors in the internal or the external environment of the radio such as radio frequency, user behaviour and the network state.

2.2. Cognitive radio modules

Figure 1 summarizes the cognitive radio modules and details of its functions are given below.

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[1]Users that have the band-use license, the TV users.

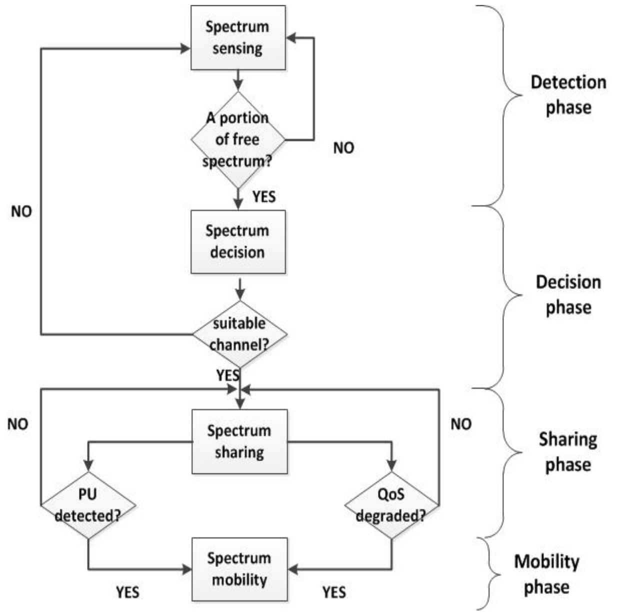


Figure 1. Operating diagram of a cognitive radio node

Spectrum sensing: The spectrum sensing is defined as the ability to measure, examine, learn and be aware of the parameters related to the characteristics of the radio channel. This module measures the availability of spectrum, the signal strength, the interferences and noise, scans operating environment of the radio, estimates the needs of users and applications, checks the availability of networks and nodes, learns about the local policies and other operators restrictions.

Spectrum decision: Decision-making is based on the appropriate communication channel choice, justifying the quality of service required for the data or the collected information transmission.

Spectrum sharing: Channel sharing has to comply with the requirement of synchronized access to the detected free-band portions. This scheduling is done between the secondary[2] users on the one hand, and between these users and the primary users on the other hand.

Spectrum mobility: Spectrum mobility reflects the fact that each transceiver, must be able to change frequency band if the initial band becomes busy. Moving to a new frequency band could happen also when the initial band fails to provide the desired quality of service to applications.

[2]Cognitive radio users, who do not have any band-use license, such as emergency services users in our context.

Channel	Spectrum	Bands
2, 3, 4	54-72 MHz	VHF Low bands
7-13	174-216 MHz	VHF High bands
5,6	76-88 MHz	VHF Low bands
14-51	470-698 MHz	UHF bands

Table 1. TVWS frequency bands [2]

Standards	Description
IEEE 802.22.1	Interferences avoidance, primary TV users protection
IEEE 802.22.2	Practice for the systems deployment and installation

Table 2. Network standards [2]

2.3. The standard for cognitive radio: IEEE 802.22

The Federal Communications Commission (FCC[3]) established the TV white spaces rules by which unlicensed devices, in our case, the cognitive radio devices, can make use of specific TV channels in the Very High Frequency (VHF) and Ultra High Frequency (UHF) bands. Table 1 summarises these frequency bands.

The use of cognitive radio approach in rural areas in Africa is based on this principle of TV white spaces (TVWS), even if the constraints and objectives are different from European and American continents. Indeed, the scarcity of spectrum resources in Europe and America led to the exploration of this new alternative. In Africa, it will provide technology services in regions with limited economic resources, often remote areas at a very insignificant cost or even free. The use of TV White Spaces in Africa to ensure a connection is a topic increasingly studied and therefore, has recently been the subject of the TV white spaces Africa Forum in Dakar (Senegal) with partners such as Google and Microsoft [3]. The 802.22 working group is developing standards for wireless regional network based on TV white spaces usage. Some specifications[4] of the standard on cognitive radio are given in table 2.

Table 2 shows the work in progress and all the interest in the use of TV bands to provide internet services.

[3] http://www.fcc.gov/

[4]IEEE 802.22-2011 Standard for Wireless Regional Area Networks, July 27th 2011.

3. Services that could be offered

Given the ability of the Cognitive Radio Networks to realize opportunistic communications, this technology could provide a set of services in rural zones, among these are:

3.1. Chronic disease patient monitoring : e.g diabetic patient

Chronic diseases such as diabetes are reaching an increasingly large proportion of the rural population. Patients in rural areas with appropriate monitoring, combine with timely hospital visits should save lives. In fact, diabetic patient fitted with glucose sensors connected to a smart-phone as a relay node to the internet allows to remotely inform the caregivers on abnormal high levels of sugar in the blood. This could avoid many painful movement of the patients from rural areas to the city (Hospital). The principle remains the same for other type of chronic conditions such as cardiovascular, cancer and respiratory diseases.

3.2. Hospital services automation : e.g for epidemic disease prevention

To accelerate treatment and diagnosis, health services in Africa should be automated. It begins with the electronic record of the patient's medical history and allows the anywhere medical records access even for people living in rural areas. The patients often helped by nurses could access, modify and control remotely their medical information or send a message on his health state to the doctors. The statistics from this automation could be helpful for early detection of health risks such as epidemics.

3.3. Emergency alerts : e.g Bushfire and accident alerts

Bushfire are often disastrous for people in rural areas and often, these people do not have the ability to call for help due to the lack of communication infrastructure. It is the same for accident occurring in very remote areas where the victims have no access networks to call the firemen. The emergency networks seem enough efficient for saving lives in similar situation with rescue arrival on time.

3.4. Internet for children

In addition to emergency centers that could benefit from Internet, the primary schools should be connected and the children in remote villages could very soon become familiar with computers and social networks. This gives them an opening to the world, an opportunity to interact with other children, thus contributing to the reduction of social and technological gap.

3.5. Improving government services : e.g births registration

Children births in villages are often not reported because of the distance to reach an administration office. This raises the problem of persons with no administrative paper for example in Côte d'Ivoire remote areas. The on-line registration of births through cognitive radio could significantly reduce the problem of undocumented persons. At the same time, several administrative services may be offered by the Internet access in villages.

4. Related Works

Researchers are increasingly interested in issues of connectivity in inaccessible areas. Projects are initiated and various technologies are considered. In this section, we first present the Loon project initiated by Google and based on the use of ISM bands before seeing the works dealing with the use of TV bands.

4.1. Example of experimental project for providing internet in rural areas: Loon project

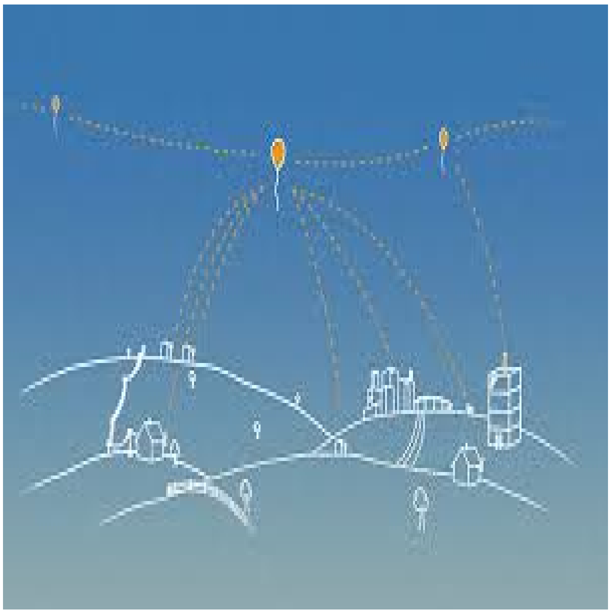


Figure 2. Google balloons for Internet in rural areas [4]

Project Loon is a network of balloons, initiated by Google company, traveling on the edge of space, designed to connect people in rural and remote areas, help fill coverage gaps, and bring people back online after disasters [4]. People are connecting to the balloon network using a special Internet antenna attached to their building. The signal bounces from balloon to balloon, then to the global Internet back on Earth as described on figure 2. This project is based on the use of 2.4 and 5.8 GHz ISM bands. However, various issues remain unanswered in this project, namely the life of the balloons in the air or in flying. This time is estimated to be ten days to the current time and this very short time could make the balloon management/redirection as a very complex process. Indeed, if the balloons can not stay long time in the air, the stability of the network will be affected and the process of change balloons or resettlement could remain very tedious for scalability needs. In addition, the principle of low cost connection is not guaranteed and this project to our knowledge does not provide mechanisms for inevitable interference management. Loon project initiated by Google, may not be of a social nature and its cost would be unbearable for impoverished populations as living in rural areas of Africa. We therefore propose the cognitive radio technology that implement interference management functions and will be based on the TV bands to provide connectivity at a lower cost in rural areas. Also, the use of the TVWS has the advantage of being long-range frequency-bands than the ISM bands used in Loon project.

4.2. Research on TVWS and Cognitive Radio for network coverage in remote areas

In developed countries, the growing number of wireless devices and the increased spectrum occupancy have resulted to the spectrum scarcity. In this context of scarce resources in traditional networks, the idea of exploring the TV bands is increasingly considered. Also, to ensure a better coexistence of technologies with efficient management of interference and better sharing of spectrum resources, Cognitive Radio technology is experienced. Cognitive Radio is considered in Europe and USA as the new wireless communication paradigm that could address the potential spectrum exhaustion problem and should be proposed for future wireless communication devices. In India, Cognitive Radio technology is seems as a real opportunity to provide wireless broadband for the applications like e-education, e-agriculture, e-animal husbandry and e-health as described by Dhope et al. [5]. Use cases for the exploitation of TV White Space for improving rural India services are discussed. Spectrum measurements of TV band in India to show the potential of frequency bands for Cognitive Radio operations have been performed by Patil et al. [6]. Geographically unused TV frequencies have been shown and this allows offering people in rural areas internet access opportunities. In the African context, this technology could mostly serve as knowledge sharing and social development tool. Cognitive Radio Networks are therefore a promising field for social networks deployment in Africa and the domain has an increasingly interest for researchers. Thus, Moshe et al. [7] have studied the White space opportunity. They have performed measurements that indicate the existence of substantial TV White Spaces available in both rural and urban areas. This work is an interesting introduction and opens up practical deployment studies which remain unexplored. Implementation of OpenBTS in rural Zambia has been studied by Jacqueline et al. [8]. This work focused on providing telecommunication system such as mobile communications in rural villages. Even if this study addresses the low cost communication issue, the solution is obviously valid and valuable for the only villages with GSM networks infrastructure. However, the African countries reality proves that the majority of villages are not covered by the existing standard networks. In fact, the economic profitability in terms of return on investment is not guaranteed for telecommunications operators. The use of Cognitive Radio technology becomes therefore necessary with its bearable costs because of the existence of TV bands infrastructure in rural areas.

5. Cognitive Radio deployment process in remote areas

Depending on the isotropic radiated power, the cognitive radio base station could connect users terminals located as far as 100 km [9] as described in figure 3. A good base stations planning could provide a network to cover two distant areas (villages) of about 100 km and greatly reduce the cost of network infrastructure. The financing by governments and the acquisition of such infrastructure and its deployment will aim to improve public services in Africa remote rural areas.

5.1. Cognitive radio networks planning scenario

Figure 3 describes the deployment scenario with a set of cities (c), villages (v) with distances estimation and the corresponding coverage plan. The cognitive radio antennas at the city allow the switching between our cognitive radio network and the existing operators networks. Also, the cognitive radio antennas set near a city, due to their sensing capability will help avoiding interferences that may be generated by the broadcasting signal of our cognitive radio networks. Relay nodes (R1) are provided to repeat the signal when the distance between two access points or base stations is greater than 100 km. Thus, it can be seen that the fundamental interest of this proposal lies in its ability to cover a large area and long distance. It should be noted that the TV band could be used only in areas lacking the standard network coverage. A proper planning and deployment will achieve a very high scope for

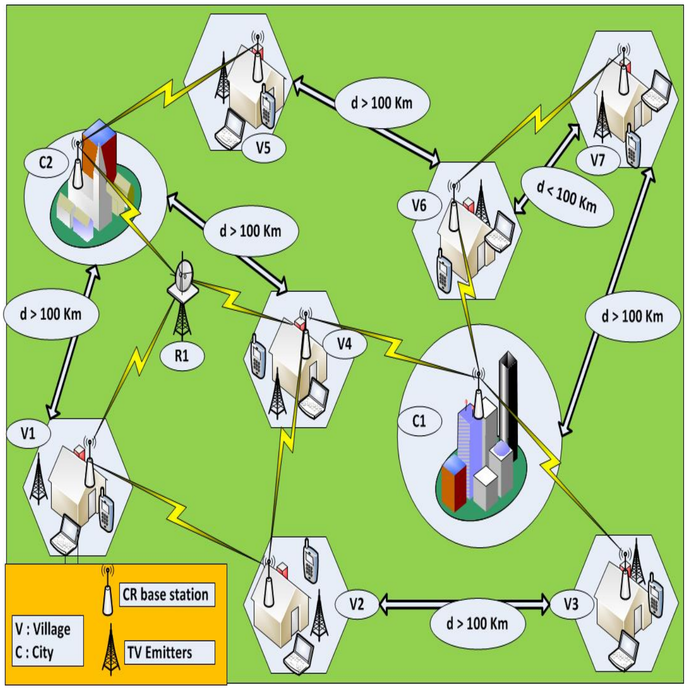


Figure 3. Planned Cognitive Radio Networks

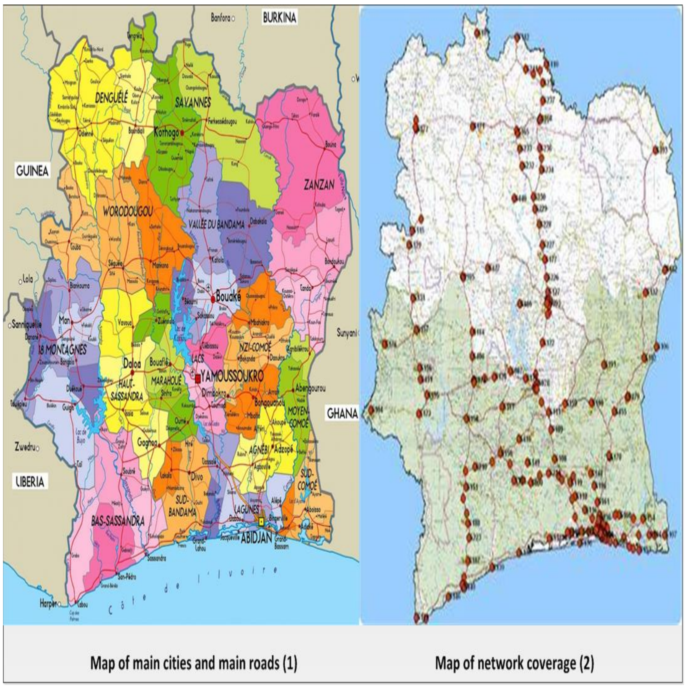


Figure 4. Network coverage map in Côte d'Ivoire [10]

possible internet access in the most remote locations. The cognitive radio is therefore an extension of network coverage anywhere and any-time even if its access must be controlled and limited to emergency services, public safety services or public services to avoid disorder in its usage. Based on a strong existing infrastructure such as TV bands (TV White Spaces), the solution we propose provides a stable network connection and facilitates its management and control. However, a number of challenges remain to make the effective deployment of this technology in rural areas in Africa.

5.2. Example of application to a geographical area

Under the National Rural Telephony Project (PNTR), the Ivorian Ministry[5] of Post and Information Technology and Communication began building a highspeed fiber optic network throughout the national territory. Thus, this country is a good example which clearly shows disparities in terms of network coverage from one area to another one and the impossibility to bring fiber everywhere and especially in more remote areas. Indeed, 6,700 km of optical fiber are considered for linking all prefectures and sub-prefectures. The first phase of the project planned will focus on the deployment of a fiber optic artery on San Pedro - Tabou and Man - Odienné - Korhogo - Ferkessédougou city-axis, along 1,400 km on one hand and on Abidjan Bondoukou - Bouna city-axis, along 549 km on the other hand. The cost of this project is estimated to 163 million euros for 6700 km. Despite all these efforts and its significant financial cost, this project will not be enough to cover remote areas. The figure 4 confirms that the deployment policy focuses on the main arteries or main road connecting the large agglomerations, the densely populated areas. This map shows the deployment of BTS antennas from operator COMIUM in Côte d'Ivoire which is almost similar to all other operators. In this context, cognitive radio and TVWS usage will help ensure connectivity for emergency services with low cost in these remote areas. However, the deployment of cognitive radio technology must take into account radio-environmental constraints.

[5]http://www.telecom.gouv.ci/main.php

6. Contributions and main results

6.1. Constraints analysis

To provide network access in remote areas, it will be deployed the cognitive radio technology in rural areas but also find a link between this technology and traditional networks (i.e. Backbone). This link is the point of connection or switching between traditional networks and the newly deployed cognitive radio networks. Although the impact in terms of interference on the TV users is minimal in rural areas due to the very low number of TV, signals from cognitive radio transmitters could cause enormous interference around the connecting areas near cities and most populated zones. We therefore performed simulations to assess the importance of these disturbing noise

Parameters	Values/description
Reference frequency	VHF Low bands
Receiver bandwidth	1 Mhz
Sensitivity	-110
Antenna height	30 m
Emitter transmit power	35 dBm
Event generation(sample)	10000
Coverage radius	30 km
Density of TV users	$20/km^2$
Environment	Rural/outdoor

Table 3. Simulation parameters

through the network simulator SEAMCAT. SEAMCAT is a free of charge integrated software tool based on the Monte-Carlo simulation method. It permits statistical modelling of different radio interference scenarios for performing sharing and compatibility studies between radiocommunications systems in the same or adjacent frequency bands[6].

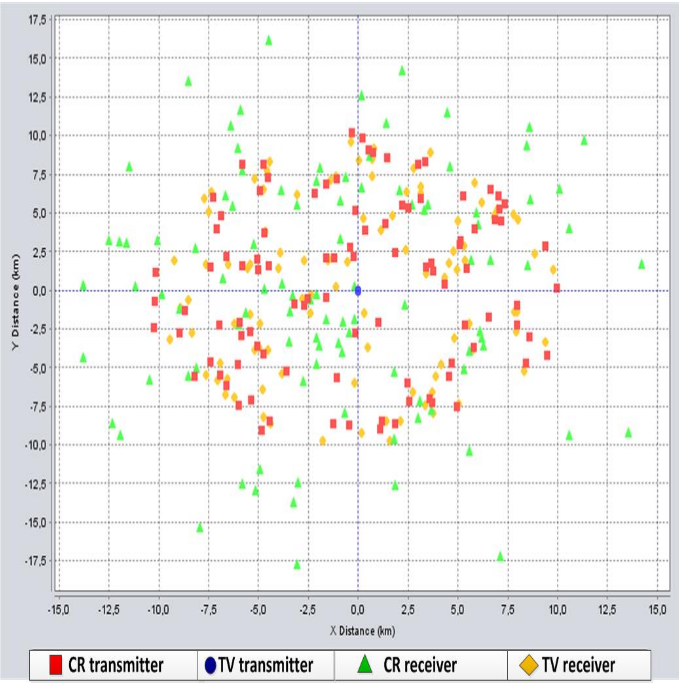


Figure 5. TV users and CR transmitter distribution scenario

Figure 5 shows the scenario of simulation and the description of the selected parameters are given in table 3.

Operating in the band of 54-72 MHz, our statistical Monte-Carlo simulation using SEAMCAT are based on uniform random distribution of TV users in the cognitive radio transmitter disk-coverage. Table 3 details the parameters of simulations where the more important variables are the transmission power and the number of potential TV users. The simulations are performed in a rural environment and it should be noted that the attenuation related to obstacles such as forests, mountains or the atmosphere have not been taken into account. In practice and in cognitive radio real deployment process, all of these factors and other environmental factors should be taken into account. The attenuation taken into account in this simulation is based on the free space model [11]. It is important to note that for free space model, the path loss in decibels between the transmitter and the receivers is given by [12]:

$$20log_{10}(d) + 20log_{10}(f) - 147.55 \quad (1)$$

Where f represents the frequency in use and d the distance between transmitter and receiver. In this scenario, the distance between the cognitive radio transmitter and the TV users is in the range of $]0; 15km]$ and all nodes (TV users and CR transmitter) are assumed to be fixed. This characteristic looks realistic because TV users are not mobile. The execution of this simulation has generated a signal which in principle should create the communication link for cognitive radio terminals. This signal expected for providing connectivity between a cognitive radio node (e.g. node offering emergency services) is interference factor for TV users with the noises it generates as shown in figure 6.

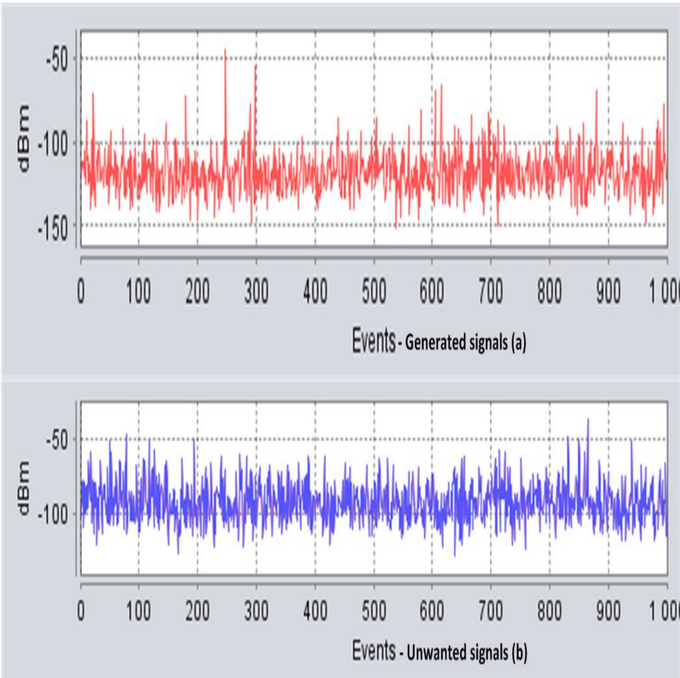


Figure 6. Unwanted signal and interference induced

[6]http://www.seamcat.org/

In figure 6, the generated signal for cognitive radio communications (Sub-figure a) is almost equivalent to the noise suffered by the TV users (Unwanted signals: Sub-figure b). The tests performed through these simulations have shown that at least 92.25% of TV users in the coverage of the CR transmitter and sharing the same frequency band are affected by the generated noise in a radius of 1 km. The distance and position of TV users are then appeared as very important factors because when the distance between the transmitter and TV users increases, the proportion of affected nodes decreases to 22% for a distance of 15 km as example. These probabilities of high interference provided by the simulation results seem unbearable in rural areas and these emissions from cognitive radio transmitters could be catastrophic for TV users around the cities and densely populated areas. This allows us to note that any deployment of cognitive radio technology to provide emergency services in rural areas, will inevitably take into account the positions of the TV users in cognitive radio base station's planning process.

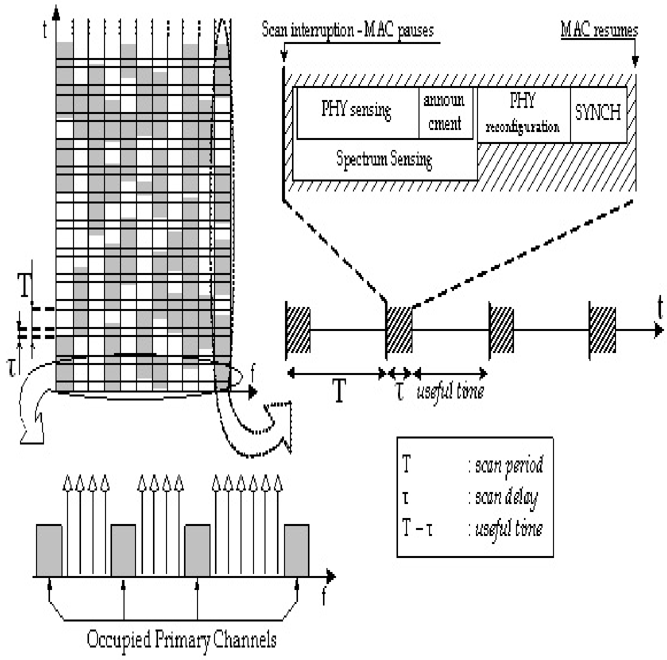


Figure 7. Spectrum analysis for the cognitive users access [12]

6.2. Engineering and deployment

For better reduction of costs, a proper study should be conducted, that enables efficient deployment of network infrastructure. Thus, must be taken into account the best locations for cognitive radio base stations and relay nodes in order to minimize the infrastructure's cost while maximizing the network coverage area. This planning process could also take into account the transmission power of the emitter, based on the area population density. Indeed, the choice of the transmission power, the intensity and frequency sensing will differ from one zone to another. As an example, a control/management of interference by cognitive radio nodes nearby cities will be highly increased compared to less populated areas and the deployment process should take into account the transmission parameters (Transmission power) and their possible values for better planning of the emitters. Indeed, each cognitive radio node must implement functions and algorithms for interference avoidance.

6.3. Interference avoidance with TV users

The deployment of cognitive radio networks creates a new type of opportunistic users whose major constraint remains achieving transmissions or communications without interfering with the TV users as shown in section 6.1. Figure 7 shows the general principle used by the cognitive radio Medium Access Control (MAC) protocols for collisions mitigation. This figure illustrates the different steps performed by a cognitive radio node before the frequency band access. There is a sensing period (scan), a period of reconfiguration and synchronization before any transmissions on the detected free channels (useful time). Occupied primary channels denote in this case, the occupation of the frequency band by TV users and useful time are periods that can be exploited by the cognitive radio users for their transmissions. To avoid, for example, interfering with the TV users, we define a set of actions that will be implemented on the cognitive radio base station (or cognitive radio relay antenna). In general, these functions allow antennas to react to various changes that can impact the radio environment such as changes in the air index (medium wave propagation) because of the rain for example, or following the arrival of TV users. Currently, we have defined two functions. The objective of the first function (decreaseTrPower) is to adjust the transmission power of the antenna. As for the second one (moveToBand), it allows antennas to change their transmission channel. Each of the defined two functions was expressed by the rules of logic programming which are then translated to one computer programming language. So, a function is composed of an action which is executed when a set of conditions are satisfied. We recall that 'Actions' are operations performed in order to change the state of a CR base station transmission parameters. To each 'Action', we associate a set of 'Preconditions' (REQUIRE) and another set of 'Postconditions' (ENSURE). Preconditions includes the conditions that must be satisfied for the action execution. The Postconditions describe the new state that some parameters must satisfy after the action execution. In this paper, we provide two examples of functions (actions implementation) aiming at changing the transmission power (Algorithm 1) and to change the transmission central frequency/bandwidth (Algorithm 2). Algorithm 1 enables the adaptation of the transmission power to meet the requirements concerning the interference limit and the air index. Algorithm 2 allows two base stations to execute a frequency hopping when the minimum transmission power (minPowerAccept) required for ensuring better transmissions is no longer guaranteed. Experimentation demonstrating the interest as well the good functioning of the frequency change algorithm will be described in section 6.4.

Algorithm 1 $Action :: DecreaseTrPower(P_i, W_i, F_c, P_j)$

$initFreq \leftarrow F_c; bandwidth \leftarrow W_i;$
$threshold \leftarrow \lambda_i; channelEnerg \leftarrow E_i;$
$minPowerAccept \leftarrow P_{min}; transmitPower \leftarrow P_i;$
$newTransmitPower \leftarrow P_j.$
while $channelEnerg(E_i) > threshold(\lambda_i)$ **do**
  if $(P_i) > (P_{min})$ **then**
Require: $(E_i \leq \lambda_i) \wedge P_j > P_{min}$
Ensure: $\neg(P_i) \wedge (W_i) \wedge (P_j)$
  else
    $Action :: MoveToBand(W_j)$
  end if
end while

Algorithm 1 describes the strategy which leads to an adaptation (*decrease*) of the transmission power to meet the requirements of the interference limit (*threshold*), compared to the detected energy on the channel (*channelEnerg*). It is important to note that the minimum acceptable power P_{min} must meet the needs of the transmissions quality. This value (P_{min}) must be chosen taking into account the constraints of the environment, vegetation (mountainous area, forest area, free space) and weather conditions (rain, air).

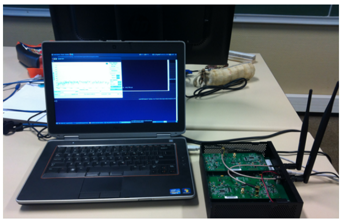
Algorithm 2 $Action :: moveToBand(F_i, W_i, F_j, W_j)$

$initFreq \leftarrow F_i; initBand \leftarrow W_i; newFreq \leftarrow F_j$
$threshold \leftarrow \lambda_i; channelEnerg \leftarrow E_i;$
$transmitPower \leftarrow P_j; numberOfDevice \leftarrow N;$
$newBandwidth \leftarrow W_j; tvDeviceSensitivity \leftarrow S_i.$
Require: $\forall_i \in N, notOverlap(F_j, W_j, P_j, S_i)$
if $E_i \leq \lambda_i$ **then**
Ensure: $\neg(W_i \wedge F_i) \wedge W_j \wedge F_j$
end if

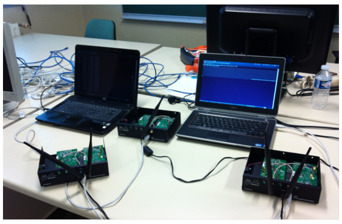
Algorithm 2 shows the frequency hopping when the minimum transmission power (*minPowerAccept*) required for ensuring better transmissions is no longer guaranteed. Also, the function *notOverlap* ensures that the new frequency band chosen complies with the overlap constraints and therefore generates no interference to TV users (*tvDeviceSensitivity*) in this area. Section 6.4 gives an idea of how these proposed algorithms could be implemented in practice.

6.4. The proposed algorithms experiment idea using the cognitive radio platform

We perform experiments of the frequency hopping scenario on cognitive radio platform acquired under the ANR[7]-LICORNE project.



(a) A CR node



(b) 3-nodes connected

Figure 8. Cognitive Radio platform

This platform is composed of five nodes and each node is composed of a USRP-1 box, two daughter-boards for transmission/reception (Tx/Rx) operating in GSM (RX/TX 900) and in WiFi (RX/TX 2400) accompanied with the corresponding antennas. A laptop with GNU software is interconnected to the USRP box as presented in figure 8a. This platform allowed us to do an experiment of transmission/reception on WiFi and GSM bands and to test the frequency hopping with the setup shown in figure 8b. This experiment demonstrates the functioning of the algorithm 2 implemented on a cognitive radio node. To test the frequency hopping, we generate a disruptive AWGN (Adds White Gaussian Noise) signal to create interferences on the transmission channel.The signal thus generated is seen as a transmission of a primary node. This then triggers the process of frequency hopping to avoid interferences as seen in figure 9. This experiment in GSM and WiFi bands remains valid for mitigating interferences to TV band users with cognitive radio networks deployed in rural areas. In addition, the transmission power adaptation model

[7]The French National Research Agency-ANR (Agence Nationale de la Recherche en France).

proposed by Ouattara et al. [13] and tested through the LICORNE platform, represents another strategy for mitigating interferences in cognitive radio networks and therefore for TV white spaces.

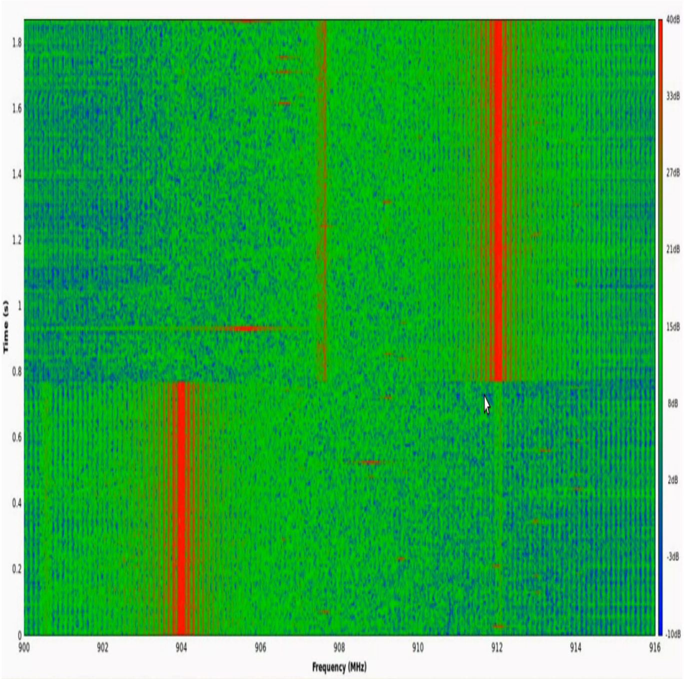


Figure 9. Frequency hopping for interferences avoidance

6.5. Other framework for test and experiments: The CREW project platform

The CREW platform [14] facilitates experimentally-driven research on spectrum sensing and sharing in licensed and unlicensed bands (TV bands). It offers test-bed capabilities to TV frequency bands experimenters. It combined indoor and outdoor installation deployed in the city of Logatec at Slovenia. The test-bed remote access portal[8] allows to show node status, choose particular cluster for performing an experiment remotely as shown in figure 10.

We worked on this platform during the CREW training days[9] and made tests remotely to validate the TV frequency bands potential in terms of data transmissions and interferences awareness as seen in figure 10. The transmitters radio coverage calculation and visualisation is expressed through the figure 10. The different colors (green, blue, red) and the characteristic of energy detected from one zone to another one, allows to confirm the presence or the absence of a transmission based on the measured power.

[8]www.log-a-tec.eu

[9]CREW Training Days is the day which took place on February 2013 at Brussels

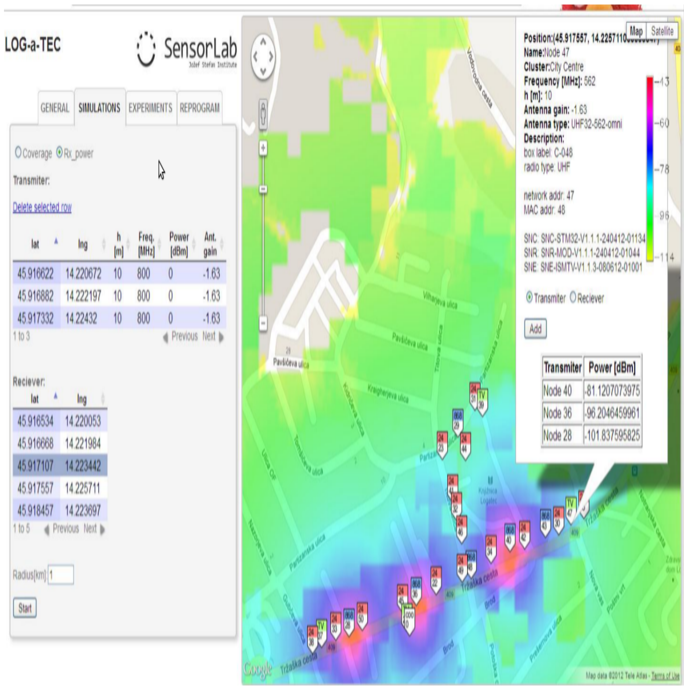


Figure 10. Platform for remote test on the TV bands

Also, this platform (CREW) allows for various tests such as the multi-hopping scenario that remains a very important aspect for transmissions reaching remote areas.

6.6. Other significant challenges

Network performance enhancement: A better network performance in terms of throughput and available bandwidth is an important interest in ensuring quality of service to users. Performance is thus linked to the availability of channels and the quality of these free bands. The work proposed by Ouattara et al. [15] on modelling the behaviour of primary users (TV users in this context) shows how to improve the process of detection of free bands and reduce latencies due to the frequency hopping induced by a primary user probable appearance. Umamaheswari et al. [16] works shown the capacity of cognitive radio technology to provide high throughput and good quality of service for users. In addition, Ouattara et al. [17] propose a best effort on-the- fly resource reservation, carrying the data flow end-to-end with a new scheduling plan that reduce latency and improve throughput with cognitive radio networks. This technology is therefore well suited for offering high quality of communication to emergency services in rural areas.

Energy for powering equipments and maintenance: The access to a source of energy to power the equipment to be installed is a real challenge for the deployment of cognitive radio networks in rural areas. In fact, rural areas in Africa are devoid of electric networks. However, there are alternatives such as solar energy increasingly used. Generators are also used as power source for electronic equipment and research continues to provide solutions to electricity problems in areas with limited resources (rural area) [18] . The energy problem can not therefore constitute an obstacle to the deployment of cognitive radio technology in remote areas.

7. Discussion

The sensing, with TV users detection and strategies experimented (frequency hopping) allow reducing the interference risks. However, it should be noted that these detection/strategies occur after a minimum of interference already suffered by the devices (TV). This could be an important problem in case of large-scale affected devices and could deteriorate the overall performance or the suitability of the general solution. Building a knowledge base that provides equipments geolocation information in accordance with the principle suggested by Thao et al. [19] is an appropriate solution to overcome this issue.

8. Conclusion

In this work, we have shown that cognitive radio is a real opportunity for network coverage in rural areas through the use of TV band. We have proposed a scenario for the deployment of this technology, noting its expansion capacity over long distances for ensuring network access in remote areas. The interference avoidance mechanism provided by cognitive radio makes this technology more suitable in this context (rural) with various constraints. The set of services (Section 3) that can be offered through the cognitive radio networks demonstrates its importance in African context. This next generation network is promising to improve life of many people living in remote and often inaccessible regions in Africa. In the future, we will propose a communication architecture based on cognitive radio networks to improve health services in rural areas. Health centers to be interconnected, medical applications to develop and install, patient to be remotely monitored are some challenges [20] for our future proposal in the context of rural areas in Africa. The platform of CREW project will be an additional framework for our experiments and testing considering the fact that the provided results will be based on a natural environment.

Acknowledgment

This work is partially supported by the LICoRNe project, funded in part by the National Agency for Research in France ANR (Agence Nationale de la Recherche).

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