

Feasibility of interconnecting the University of Bangui and peripheral areas via the TVWS for e-learning in the context of COVID-19

Edgard NDASSIMBA*, Nadège Gladys NDASSIMBA*, Ghislain Mervyl KOSSINGOU*, Samuel OUYA*

* Laboratory LIRT, Higher Polytechnic School, University Cheikh Anta Diop of Dakar, Senegal

edgard.ndassimba@gmail.com, nadegegladys.ndassimba@gmail.com, skossingou@gmail.com, samuel.ouya@gmail.com

Abstract— The campuses and classrooms of the University of Bangui do not have connectivity due to insufficient network infrastructure. However, there are Dynamic Spectrum Access technologies in the unused VHF and UHF analog TV band called TV White Space that can be used to provide high-speed Wi-Fi access over wide coverage and at lower cost. Since March 2020, courses have been suspended at the University of Bangui to effectively limit and combat the COVID-19 pandemic. After a three-month period of containment, academic activities have resumed. The increase in the number of cases of COVID-19 contamination raises concerns about this resumption. Given the rules of social distancing that limit the number of students in classrooms, the risks of travelling by public transport and the lack of motivation of some students following years of war, the University of Bangui can organize distance learning as a transitional measure.

This paper is the subject of a feasibility study on the interconnection of surrounding neighborhoods and villages by TV White Space at the University of Bangui that can accommodate students and teachers for distance learning courses in the context of COVID-19.

The methodological approach consists in studying the deployment of a White Space TV network to interconnect the peripheral areas at the University of Bangui, then using the Moodle distance learning platform on which we integrate the virtual classroom plugin, deployed locally and running without Internet connectivity. The bandwidth of the White Space TV will be important to practice the educational activities without spending money to pay the Internet credits of the operators' networks. Students can connect locally via Wi-Fi in the areas covered by the platform and follow the different academic activities according to their geographical location, while others closer to the university can go to the classroom to attend classes with the professor in the rules enacted for protection against COVID-19.

Our solution initially helps to break the digital divide and then to promote e-learning at the University of Bangui in the context of COVID-19.

Keywords— COVID-19, interconnection, TVWS, e-learning, Moodle, virtual classroom

I. INTRODUCTION

Since the registration of the first case of COVID-19 in Central Africa, the pandemic is accelerating with its impacts in the field of education. The schools and the University of Bangui were closed to avoid a proliferation of this pandemic.

After more than three months of containment, the Central African government took the decision to reopen the doors of the university and primary, secondary and private vocational and university schools in strict compliance with health measures regarding physical distancing, with a relaxation of the academic calendar for the year 2020.

However, with more than 12,000 students around [1], and a capacity that does not comply with the health protocols of Covid-19, the resumption of classes at the University of Bangui could accentuate the spread of this pandemic in the university environment.

At a time when the Covid-19 pandemic is pushing most universities to innovate the way to ensure the continuity of e-learning through ICT in the face of the problem of social distancing [2], [3], the only public university of Bangui is lagging behind because it has no network infrastructure. However, the White Space TV technology based on the use of free hertzian frequencies from the television broadcasting spectrum could be used to offer broadband Wi-Fi interconnection with advantages in terms of penetration, speed, capacity and high-speed Internet access as opposed to traditional Wi-Fi [4].

Several authors have worked on TVWS. The authors in [5] discussed the effectiveness with which TVWS can be used to create very high-speed Wi-Fi and their future opportunities and unique advantages.

This work shows that the TVWS can be used to set up Wi-Fi interconnection of campus and university buildings as well as remote rural areas with difficult accessibility. With this interconnection, students could access distance learning courses via the collaborative platform using Moodle and its virtual classroom plugins BigblueButton.

The purpose of this paper is to conduct a feasibility study of interconnection of surrounding neighborhoods and villages through the TV White Space at the University of Bangui to meet the ICT needs for online courses in the context of COVID-19.

The rest of this article is organized as follows. Section II describes the state of the art of TVWS. Section III proposes the feasibility study to interconnect the villages and surrounding neighborhood to the University of Bangui through the TVWS. Section IV presents the results on our solution, and finally Section V provides the conclusion.

II. STATE OF THE ART

A. The COVID-19

In the literature, researchers in [6] have defined COVID-19 as the acronym for "Coronavirus Disease2019", a respiratory disease caused by Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), a contagious virus belonging to a family of single-stranded, positive-sense RNA viruses called coronaviridae. Like the influenza virus, SARS-CoV-2 attacks the respiratory system, causing conditions such as cough, fever, fatigue and shortness of breath. The authors in [7] introduced that the World Health Organization declared coronavirus disease 2019 (COVID-19) as a pandemic on March 11, 2020.

After several alerts, the Central African Republic registered a first case of COVID-19 which was confirmed and announced by the Ministry of Health and Population on March 14, 2020. As in other African countries, the Central African government has taken preventive measures with the temporary closure of schools and universities. However, from March 14 to August 14, 2020, there were 4,652 confirmed cases of COVID-19 with 61 deaths in the Central African Republic [8]. In spite of this figure, classes have resumed since July 29, 2020, marking the end of containment with all risks of contamination if measures are taken to prevent the spread of the disease.

B. Interconnection via TVWS

Television White Space (TVWS) can be defined as the unused TV bands between active channels in the VHF and UHF spectrum. Its advantages are twofold: they have better coverage than standard Wi-Fi and, at lower frequencies, can penetrate through obstacles and cover uneven ground with less infrastructure [9]. The harmonization of the free UHF frequency bands used are 470 to 790 MHz in Europe (ETSI standard) and 54 to 698 MHz in the United States (FCC standard) [10]. The operation of the TVWS is based on the principle of cognitive radio transmission and geographical detection [11].

Several researchers have worked on the TVWS. The authors in [12] have explored the capabilities of TVWS in rural areas and have shown that it allows Internet access with an interesting quality of service and helps to build a robust and cost-free backhaul. In [13], the authors presented a mathematical framework for the coexistence of White Space TV devices and digital terrestrial television (DTV) services in the geolocation database with interference protection in Ethiopia and Colombia. The potentialities of White Space TV have been demonstrated through the tests made by the other authors in [14] in Turkey. In [15], the authors presented the use of TV White Space in the field of education by providing broadband Internet to six high schools and the GTUC-Abeke campus in Accra, Ghana.

All these studies show that TV White Space can provide essential broadband Internet connectivity solutions. Our solution offers interconnection of peripheral areas at the University of Bangui with local Wi-Fi connectivity without Internet access.

C. E-learning

E-learning is seen as the use of electronic technology to access educational programs via the Internet [16].

Several researchers have made publications on e-learning. The authors in [17] have shown that in recent years, e-learning solutions have been gradually replacing traditional learning environments. In [18], the authors showed the effectiveness of e-learning based on the Internet of Things (IoT). While the authors in [19] showed the performance of e-learning in a cloud environment. Due to the COVID-19 pandemic around the world, other authors in [20] have shown that academic institutions have favoured distance learning which has proven to be effective.

The results of these studies show the importance of e-learning in normal times and in the context of COVID-19.

D. Moodle platform and its plugin for virtual class

The term MOODLE is an acronym for Modular Object Oriented Dynamic Learning Environment. Its development began in Australia in the 1990s by Martin Dougiamas. It is an online learning platform, licensed under the GNU Public License (GPL), accessible via a web browser and used to manage online courses (document storage space, online activities and resources with students, registration and access rights management, tutoring, etc.) [21].

The BigBlueButtonBN plugin for Moodle is developed and supported by Blindsight Networks. It is an open source web conferencing system that supports real-time sharing of audio, video, slides (with whiteboard controls), chat and screen. Instructors can engage students remotely with polls, emojis, a multi-user whiteboard and chat rooms. Presenters can record and play back content for later sharing with others [22].

Several researches have been conducted on Moodle. In [23], the authors presented the study on the impact of the training conducted by the teachers of a Polytechnic Institute of Higher Education in their practices with the Moodle Platform. Others in [24] analyzed the effectiveness of Moodle-supported undergraduate courses in English linguistics. However, the authors in [25] evaluated the user experience in online learning management systems. Moodle has plugins that are embedded or that can be developed to add functionality or appearances to the example of BigBlueButton which provides real-time sharing of audio, video, slides, chat and screen [26].

The results of this research have shown the potential of Moodle and the effectiveness of BigBlueButtonBN in facilitating e-learning.

In the context of COVID-19, Moodle has emerged as the most widespread learning environment in the world in relation to the significant growth in its use.

III. FEASIBILITY STUDY

In this feasibility study, we study the coverage and radio profiles of each TV White Space link. Below we outline the assumptions, regulatory prerequisites, frequency plan, network design, radio coverage simulation to establish the link budget.

A. Assumptions

The needs of this feasibility study are to interconnect three zones located in the outskirts of Bangui to the University of Bangui through the TV White Space network.

The TV White Space access network includes:

- a base station installed on the building housing the rectorate of the University of Bangui,
- three customer stations installed respectively at the Bégoua School, the Bimbo High School, the Rapides High School and a relay station on the banks of the Oubangui River.

The e-learning system includes:

- the Moodle platform and its plugin BigblueButton installed locally at the University of Bangui with Wi-Fi access offered by TV White Space technology without Internet connectivity,
- Wi-Fi routers at sites that offer DHCP service for DHCP clients,
- a database to manage student authentication.

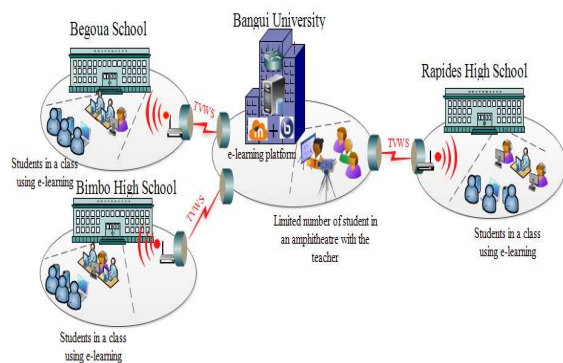


Figure 1. E-learning deployment architecture without Internet connection

In this study, we are using Gen3 RuralConnect TV White Space System equipment from Carlson Technologies with the following technical specifications.

TABLE 1. CARLSON TECHNOLOGIES GEN3 RURALCONNECT TVWS SPECIFICATIONS

Standardization	IEEE 802.11af Fully Compliant
Frequency bands	UHF 470-790 MHz (ETSI)
Channel spacing	8 MHz (ETSI)
Aggregate data capacity	96 Mbps
ACP and spectrum mask	Meets FCC and ETSI specifications
Transmitting power	21 dBm
Receiver threshold	0,75 dBm
Line loss	0,5 dB

B. The basic prerequisites

The Central African Regulatory Authority for Electronic Communications and Postal Services is in charge of regulating the available unlicensed and licensed spectrum of frequencies for use in wireless networks.

The regulatory prerequisites consist in applying for authorization to use WSD frequencies located in the "holes" of

television channel coverage, specifying the number of channels in the UHF band from 470 MHz to 790 MHz.

In our study, this request concerns 6 channels.

C. Frequency planning

We have created a frequency plan according to the following table for the base station located at the Rectorat of the University of Bangui.

TABLE 2. RADIO FREQUENCY PLANNING

Base Station Site Name	Number of Sector	Number of CPE	Number of radio per sector			Assignment of channel per BS					
			A	B	C	A1	A2	B1	B2	C1	C2
BS Rectorat	3	6	2	2	2	X1	Y1	X3	Y3	X5	Y5

D. University of Bangui TVWS network design

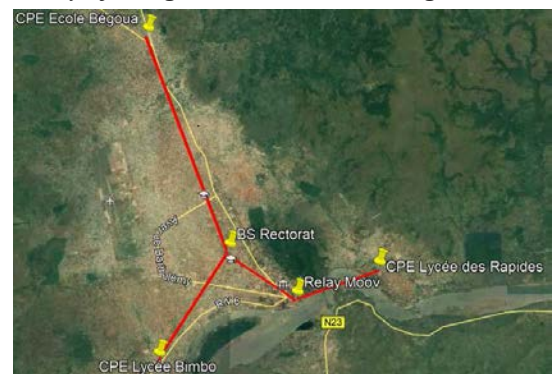


Figure 2. Design of the TVWS network using google earth

The geographic coordinates of the candidate sites are shown in the following table.

TABLE 3. SITE GEOGRAPHICAL COORDINATES

Site Name	Tower height (m)	Latitude (DD)	Longitude (DD)
BS Rectorat	45	4,377839	18,56187
CPE Ecole Bégoua	70	4,454061	18,53251
CPE Lycée Bimbo	44	4,339781	18,53718
Relay	45	4,361055	18,58561
Lycée Rapides	28	4,371514	18,61453

IV. RESULTS AND DISCUSSIONS

For the purposes of our study, we chose the outlying areas of Bangui where most of the students at the University of Bangui reside.

It extends from the bordering communes of Bégoua in the north, Bimbo in the west and Ngaragba Ouango - Kassai to the Lycée Rapides on the southern bank of the Oubangui River in the Democratic Republic of Congo.

A. Link budget



Figure 3. Base Station (BS) radio coverage single polar

Figure 3 showed the power level in dB of the radio signal emitted by the BS to the CPEs of the Bégoua school, the Lycée Bimbo and the Relay in a circle with a radius of 15km. It showed that all three sites are well covered.

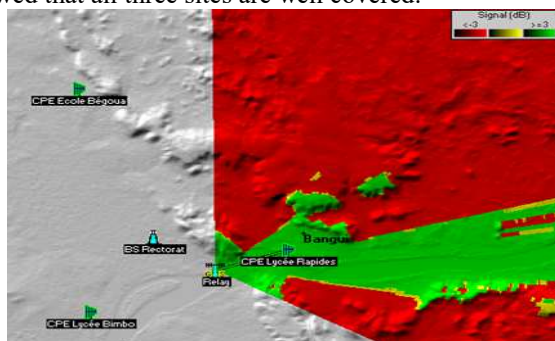


Figure 4. Relay radio coverage single polar in 0 to 120°

On fig. 4, the Relay has allowed to establish a link between the CPE Lycée Rapides and the base station thanks to a point-to-point link.

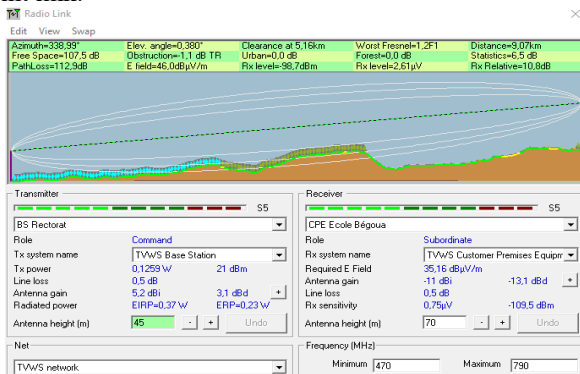


Figure 5. Profile of radio link Base Station – CPE Ecole Bégoua

The figure 5 showed the profile of the radio link between the base station and the client installed at Bégoua school.

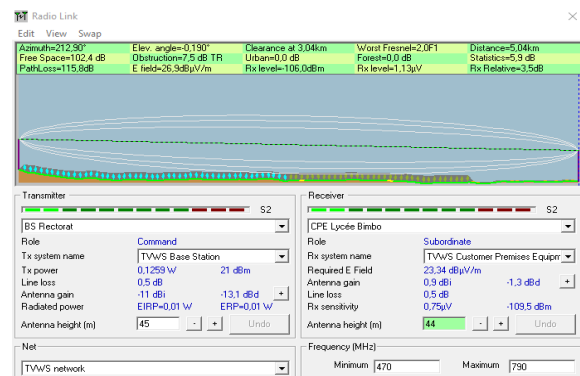


Figure 6. Profile of radio link Base Station – CPE Lycée Bimbo

The figure 6 showed the profile of the radio link between the base station and the client installed at Bimbo High School.

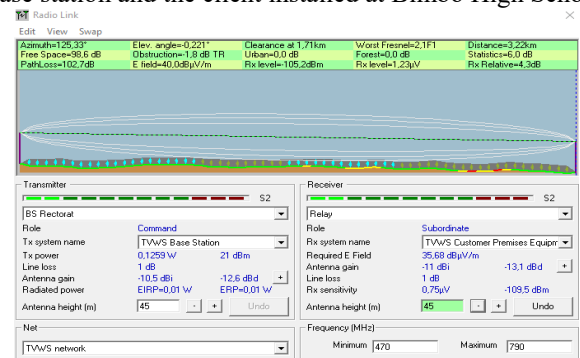


Figure 7. Profile of radio link Base Station – Relay Moov

The figure 7 showed the profile of the radio link between the base station and the relay installed at the Moov site near the Oubangui River.

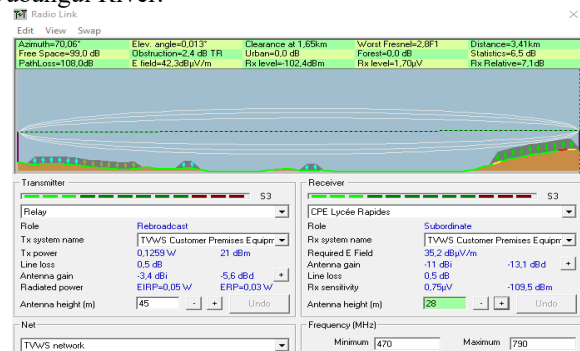


Figure 8. Profile of radio link Relay – CPE Lycée Rapides

Figure 8 showed the profile of the radio link between the relay installed at the Moov site and the client installed at the Lycée des Rapides.

All of the radio profiles in Figures 5, 6, 7 and 8 allowed us to calculate the link budget in Table 4, and then to deduce whether the link is feasible.

TABLE 4. LINK BUDGET

	Link Rectorat-Bimbo	Link Rectorat-Begoua	Link Rectorat-Relay Moov	Link Relay-Rapides
EIRP (dBm)	10	25,68	10	16,98
Free Space Loss (dB)	102,4	107,5	98,6	99,0
Antenna Gain Rx (dBi)	0,9	-11,0	-11,0	-11,0
Cable + Connector (dB)	0,5	0,5	0,5	0,5
Receive Sensivity (dBm)	-109,5	-109,5	-109,5	-109,5
Marging (dB)	17,5	16,2	9,4	16,0
Rx Level (dBm)	-106	-98,7	-104,2	-102,4

The results in Table 4 showed the link budget, specifically the margin, the received signal (Rx Level) and the receiver sensitivity (Receive Sensivity).

When the level of the Rx Level is equal to or greater than the Receive Sensivity threshold, then the link is feasible.

The results obtained in Table 4 have shown that links are feasible.

B. Scenario of e-learning through the TVWS network

In this scenario, we have students from the Faculty of Sciences Bachelor 1 in Mathematics and Computer Science. Considering their number and to respect the rules of physical distance, we have subdivided them into four groups:

- a first group at the University of Bangui in an amphitheater with the professor giving the courses in person and followed by the students located in the other zones,
- a second group at Bimbo High School in a classroom following e-learning through TVWS connectivity without Internet,
- the third group at the Bégoua school in a classroom, following the e-learning through TVWS connectivity without Internet, and
- the fourth group at the Lycée des Rapides in a classroom following e-learning through TVWS connectivity without the Internet.

All of these classrooms have been interconnected locally by the TV White Space at the University of Bangui.

Figure 9. Home screen for connection to the platform

The figure 9 showed the window used by teachers and students to connect to the platform by using the local site rca.rtn.sn

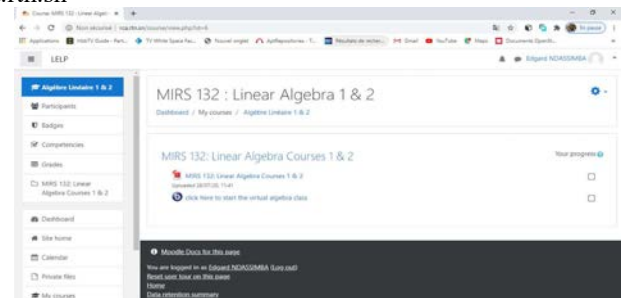


Figure 10. Accessing virtual classroom resources after login

The figure 10 showed that the teacher logged in to deliver the linear algebra 1&2 courses using the PDF format and the virtual classroom using web conferencing via BigBlueButton.



Figure 11. Virtual classroom

The figure 11 showed a virtual class session of Linear Algebra 1&2 with a real-time slide presentation of this course after teacher and students logged in.

V. CONCLUSION

In this work, we studied the feasibility of interconnecting the University of Bangui and the peripheral areas via TVWS without Internet access for online courses in the context of Coronavirus.

The Coronavirus pandemic has significantly affected the entire planet and has reduced the efficiency of administrations. The Central African Republic, with regard to the countries affected by COVID-19, has also been struck by this fragility which has completely disrupted the academic calendar of schools, training schools and the University of Bangui. The suspension of courses has hindered academic progress and disrupted the students' career path.

The feasibility study described in this article could provide an opportunity for the University of Bangui to exploit the advantages of the TVWS to provide low-cost connectivity to Internet-free distance learning platforms.

Generally, TVWS is a viable medium for broadband Internet access applications. However, our solution uses it as a WLAN (Wireless Local Area Network) to interconnect peripheral areas at the University of Bangui without Internet access. The technical advantages in terms of high bandwidth, extended reach and penetration make it possible to offer the e-

learning service without Internet access to the students at the selected sites.

The deployment of the Moodle platform and its plugin BigBlueButton locally has enabled regularly registered students to connect to virtual classes for distance learning courses in the locations covered according to the number distributed in the classrooms, and according to their geographical location, while respecting the rules of social distancing.

In future work, we will propose an independent mobile network infrastructure based on TVWS in remote rural areas of the Central African Republic with Distributed GSM/Multicast MS Lookup in Open source mobile communications and Freeswitch to provide SIP and SMS calls.

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Edgard NDASSIMBA is currently a PhD student at Computer, Network and Telecom Laboratory (LIRT) at University Cheikh Anta DIOP of Dakar. Holder a Master's degree in Teleinformatics from Polytechnic Higher School/Multinational Higher School of Telecommunications of the University Cheikh Anta Diop (UCAD) of Dakar-Senegal. His current research interests include Television White Space TVWS and applications of telecommunication's services.



Nadege Gladys NDASSIMBA is currently a PhD student at Computer, Network and Telecom Laboratory (LIRT) at University Cheikh Anta DIOP of Dakar. Holder a Master's degree in Teleinformatics from Polytechnic Higher School/Multinational Higher School of Telecommunications of the University Cheikh Anta Diop (UCAD) of Dakar-Senegal. His current research interests include Telecommunications application, e-learning.



Ghislain Mervyl Kossingou is currently a PhD student at Computer, Network and Telecom Laboratory (LIRT) at University Cheikh Anta DIOP of Dakar.
Holder a Master's degree in Engineering Sciences from Polytechnic Higher School of the University Cheikh Anta Diop (UCAD) of Dakar-Senegal.
His current research interests include Internet of Thing IoT, e-learning, e-health.



Pr. Samuel Ouya is currently the Director of Computer, Network and Telecom Laboratory (LIRT) at University Cheikh Anta DIOP of Dakar. He was from 2013 to May 2017 the first Director of Infrastructure and Information System of the first virtual university of Senegal (UVS).

Holder of a Thesis in Applied Mathematics from the Gaston Berger University of Saint-Louis in Senegal and a Telecommunications Thesis from the Cheikh Anta Diop University (UCAD) in Dakar-Senegal, he

is interested in Applications of innovative telecom services to virtual organizations.