The Impact of Using TVWS in the Field of Health in Countries in Conflict : The Case of Central African Republic

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

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

edgard.ndassimba@gmail.com, skossingou@gmail.com, nadegegladys.ndassimba@gmail.com, keba.gueye@esp.sn, samuel.ouya@gmail.com

***Abstract*— Since the rebellion of December 2012, Central African Republic government controls only 20% of the national territory. Most of health and telecommunications infrastructure are destroyed. Operators are not ready to reinvest; doctors are deserting these conflict zones. This has the consequence of increasing the mortality rate due to frequent diseases such as hypertension and diabetes.**

This article proposes, on the hand, the use of free spaces in television broadcasting channels called television white space (TVWS) to allow the establishment of broadband Internet network and on the other hand e relevant e-health solution for remote patient monitoring that operates this high-speed network. This solution based on Internet of Things (IoT) allows caregivers to collect data on patient's blood pressure, blood glucose level, electrocardiogram and body temperature in conflict areas and transmit them to a specialist doctor in the capital Bangui for better interpretation and indication. In our study, the monitoring and the data collection of the patients based on Internet of Thing is required because it allows the doctor located in Bangui than nursing staff located in conflicts areas to remotely get access to the vital parameter of the patient in real time and support the processes of making a decision regarding the need of the patient. The Internet of Thing solution is more efficient and flexible for real time data transmission between the doctor and the patient than the data also that can be collected from the existed devices and send to the doctors in the remote sites.

This proposal contributes to the improvement of health services in countries in conflict and reduces mortality rates in areas not covered by conventional operators.

***Keywords*— TVWS, Broadband, IoT, e-health, Countries in conflict**

I. Introduction

In Africa, in conflict zones, particularly in the Central African Republic, rural areas are emptied of doctors and health workers fleeing armed groups. The crisis has significantly weakened the health care system. The monitoring and management of certain diseases, such as diabetes and hypertension, in the 80% of the national territory occupied by the rebels are not insured. The minimum health service is provided in these areas by humanitarians and studies have revealed that there are around 2,000 qualified health personnel missing [1].

Peace agreements have been signed between the Central African government and the rebels; but this did not push conventional operators to redeploy telecommunications network in these areas, fearing the sabotage of their infrastructure.

Without an appropriate telecommunications infrastructure, it is difficult to envisage the use of information and communication technologies to meet the health care needs of the population.

Several articles have already shown the relevance of using TVWS to build a broadband network at lower costs [2, 3].

Other articles have also proposed solutions that exploit a broadband network to improve health care.

In [4, 5], the authors propose the remote collection of the vital parameters of the patients to send them to be treated and the use of the connected objects on the web for the taking of the type 1 diabetic patients.

In most articles on e-health, the authors assume that they already have a broadband network that can support their solutions. This is not the case in the context of the CAR where the telecom operators are hesitating the deployment despite the encouragement of the state.

The rest of this article is organized as follows. Section II describes the state of the art. Section III proposes a network architecture based on TVWS and an architecture of the e-health solution. Section IV presents the performance results for both the network and the proposed e-health solution. Section V provides the conclusion.

II. State of the Art

A. The conflict in the Central African Republic

Since December 2012, the CAR has been going through an unprecedented military, political and social crisis, enriched by two rival groups, the seleka and the anti-balaka. The root causes are multiple, and the factors of conflict are political, economic and result in ethnic, religious and inter-communal tensions and their instrumentalization for political ends [6].

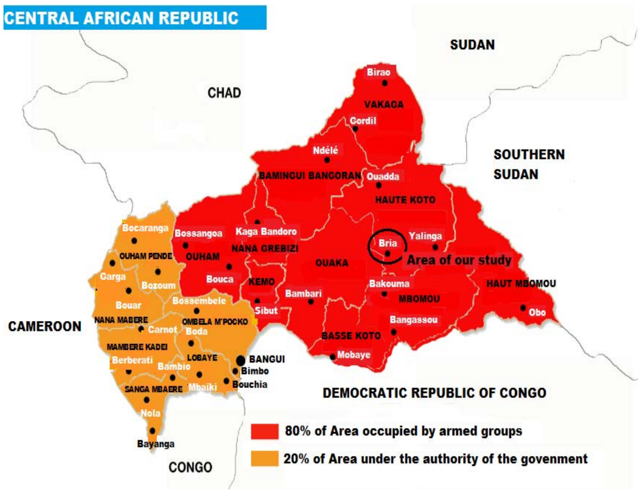


Figure 1. Security situation in the Central African Republic

The map in Figure 1 shows in yellow the part of the territory controlled by the Central African Republic government, and in red the part controlled by the different armed groups [7].

B. The impact of the crisis on health

In the Central African Republic crisis, the health sector is one of the areas that has suffered heavy losses.

Indeed, all technical and administrative platforms are destroyed in the affected areas and the equipments are vandalized. The direct consequences are the lack of care for emergency care and the monitoring of chronic diseases [8]. Humanitarians are trying to remedy this, but they are generally limited in refugee camps protected by the United Nations Blue Helmets. People who are trying to return to their towns and villages as a result of peace agreements have no health care structure despite the willingness of health personnel from the occupied areas.

C. E-Health

Telemedicine is a solution that many countries have adopted to improve health care and alleviate the desertification of medical specialists in remote areas. The Telemedicine is defined as a sub-domain of e-health through a remote medical practice using information and communication technologies.

The authors in [9], showed the positive impact of e-health used to reduce the consultation rate of patients suffered from lifestyle-related diseases and which make their health conditions unstable.

In [10], the authors proposed and studied the performance of a portable health telemonitoring system in India. The results they obtained allowed physicians to remotely intervene on the patients in their home before being received in the structures of health thus allowing the patients and the doctors to save time.

D. State of the art of TVWS deployment

White Space TV or "white space" is a technology that allows the use of free TV frequencies to offer broadband Internet in rural areas. The UHF free frequency bands used are 470 to 790 MHz in Europe and 54 to 698 MHz in the United States. The use of white space is based on secondary unlicensed Dynamic Spectrum Alliance (DSA) access under the principle of non-detrimental interference to television operators operating in the area.

Several researchers have been working on the relevance of using TVWS in both developed and developing countries, and have reported the satisfactory results they have had. This is the case of the authors in [11], who showed that the deployment of the TVWS network did not bother television operators who used channels close to the space used by the TVWS and authors in [12] made measurements 24 hours a year in Botswana and showed that TVWS services can coexist with conventional television services without significant interference. The results in terms of performance and means showed that their TVWS network could reach a bitrate of 4Mbps.

These results show that a well-designed TVWS network can be used to deliver e-health services.

E. Simulation tools

To study the reliability of the TVWS network to offer in our study area in CAR, we opted for the radio simulation and predilection software (Mobile Radio). This choice is justified by studies of other similar products and the fact that the software is free. The open access to the code of this software has allowed many researchers to continue to improve their performance [13].

This software uses the Irregular Field Model (IFM) radio propagation model approved by the ITU (International Telecommunications Union) and makes it possible to calculate the attenuation of the radio transmission taking into account the irregularities of the ground like the well-known model " Okumura-Hata " [14, 15].

III. PROPOSED ARCHITECTURE

The study area is located in CAR in the prefecture of the haute-kotto (Bria) as shown on the map of Figure 1. The feasibility of deployment of a wireless network is very important, we will describe the three main phases to follow, namely:

- Radio planning ;
- Network planning ;
- Deployment of the network.

A. Feasibility study

1) Radio planning : *it* consists of choosing the sites BS and CPE TVWS with objectives in terms of coverage, performance by performing the calculations of coverage to calibrate the propagation models.

The steps start are:

a) Identification of the area *:* where we want to develop e-health.

b) The survey : it consists in searching and recognizing potential condidate sites, noting their geographical coordinates called Global Positioning System (GPS).

c) Propagation prediction and radio coverage : *it* consists in determining the parameters of the base station (BS) and customer Premises Equipment (CPE), to define the constraints.

2) Network planning : this consists in determining the maximum flow rate that the base station can provide.

3) Deployment : is done following the radio and network planning which is a critical phase of such a project.

The results of radio planning are presented in section IV of this article.

The study made it possible to propose a network architecture including :

- A TVWS base station (BS) with an omnidirectional antenna installed in the humanitarian room in the city of Bria, and
- Three clients antenna located in three villages.

The base station is connected to an Internet access point for humanitarians in the Bria area.

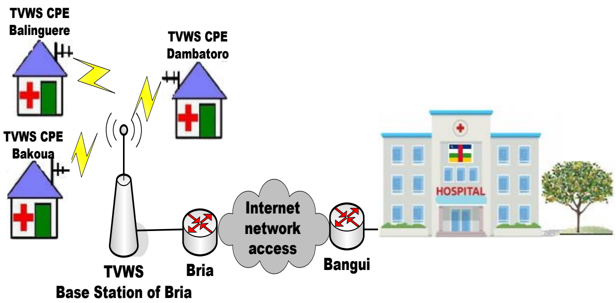


Figure 2. Proposed TVWS architecture

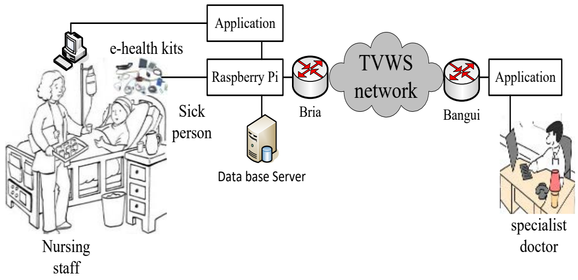
B. *Proposal of the e-health service deployment architecture*

The telemedicine system includes:

The Internet of Things **:** Each endpoint is considered a gateway to its set of smart objects. In addition, each user has control over these objects. The aggregation node (Raspberry Pi) is not responsible for reading the sensors. It simply provides a gateway between the user and the TVWS network and then performs data analysis. The sensor node is the lowest level of a sensor network. It is responsible for collecting information from sensors, performing user actions, and using communication mechanisms to send data to the aggregation node.

The API part: We have developed a REST API capable of retrieving information collected by a connected medical device (biometric sensor) and storing it in a MongoDB database.

Web Application: To set up the web application we use NodeJS technologies and a WebRTC (Kurento) multimedia server. This platform allows doctors and patients on the sites of the displaced to register and authenticate in order to access the features of the media server. Once connected, the medical specialist can view the sensor data and the patient's multimedia streams. The application also collects information from the database and display it.



IV. Results

We chose the Bria area because it was the most affected by this crisis and was occupied by the different armed groups from the three neighboring countries (Chad, Sudan, Democratic Republic of Congo).

A. *Feasibility of the network*

We did our radio simulation using the technical specifications of the Carlson Wireless Technology brand TVWS RuralConnect-Gen3-ETSI solution. The height of the towers, technical specifications and geographical coordinates of the base station and the three villages of displaced people were recorded in the following table:

TABLE 1. SITES COORDINATES

Site Name	Tower height (m)	GPS Coordinates Latitude (DD)	Longitude (DD)	Altitude (m)	Distance BS to CPE (km)	Transmitting Power (dBm)	Reception theshold (µ v)	Loss of Line (dB)	Antenna Gain (dBi)
TVWS_BS_Bria	70	06.536097	21.988825	582,5		21	0,75	1	7,8
TVWS_CPE_Dambatoro	20	6.5974056	21.998647	575,7	06,90	21	0,75	1	10,3
TVWS_CPE_Balinguere	20	6.5504778	21.899969	633,7	09,94	21	0,75	1	10,3
TVWS_CPE_Bakoua	20	6.4668944	21.999805	583	07,79	21	0,75	1	10,3

The network topology is shown below:

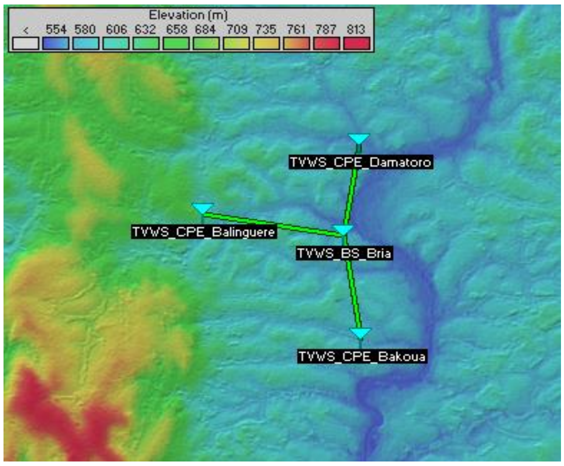


Figure 4. Topology of the Base Station and CPE network

Simulations of single pole radio coverage within a 15km radius of the base station in Figure 5 have shown that the dB power level of the radio signal transmitted by the base station is greater than or equal to 3dB. This means that the client equipment deployed on the sites of the displaced people of Dambatoro, Balinguere and Bakou are well covered in relation to the radiation field of the base station. This demonstrated that simple polar radio coverage depends on the transmitting power of the base station.

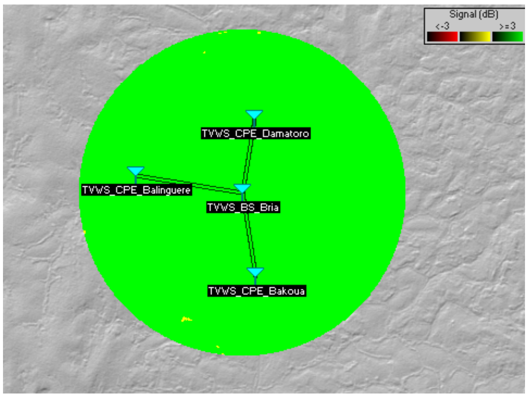


Figure 5. Single polar radio coverage within a 15km radius

The link budget was automatically calculated by the software on the profiles of the three links in Figures 6, 7 and 8. This link balance is composed of the Equivalent Isotropic Radiated Power (dBm) and the margin (dB).

TABLE 2. LINK BUDGET

	(Link number 1) Base station to CPE Balinguere	(Link number 2) Base station to CPE Dambatoro	(Link number 3) Base station to CPE Bakoua
Transmitting Power (dBm)	21	21	21
Cable + Connector (dB)	1	1	1
Antenna Gain Tx (dBi)	7,8	7,8	7,8
EIRP (dBm)	**27,8**	**27,8**	**27,8**
Free Space Loss (dB)	118,8	122,6	121,0
Antenna Gain Rx (dBi)	10,3	10,3	10,3
Cable + Connector (dB)	1	1	1
Receive Sensivity	-109,5	-109,5	-109,5
Margin (dB)	**27,8**	**24**	**25,6**

The Equivalent Isotropic Radiated Power (EIRP) from the base station to the customer equipment for a frequency of 470 - 790 MHz was identical for the three links (27,8 dBm); while the margin varied according to the link parameters such as total propagation losses, gains of the transmitting and receiving antennas, receiver sensitivity.

Figure 6 gives the parameters for calculating the margin of the link between the base station and the Balinguere site customer.

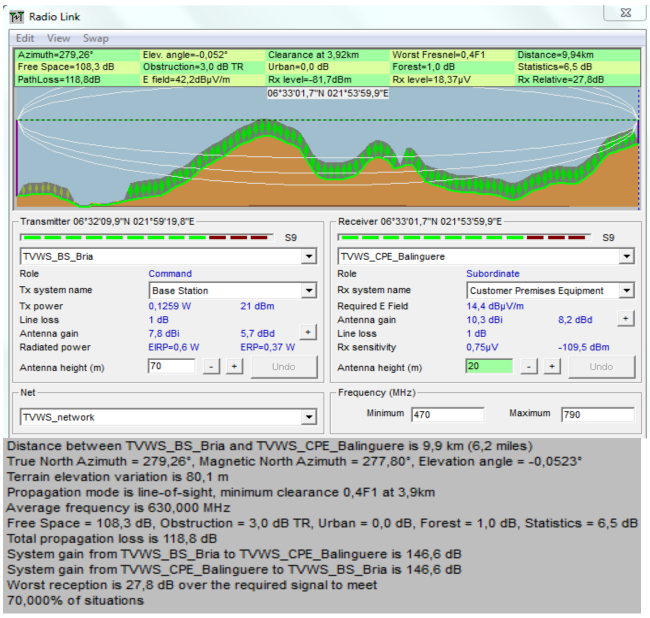


Figure 6. BS – CPE Balinguere radio profiles

Figure 7 shows the parameters for calculating the margin of the link between the base station and the Dambatoro site customer.

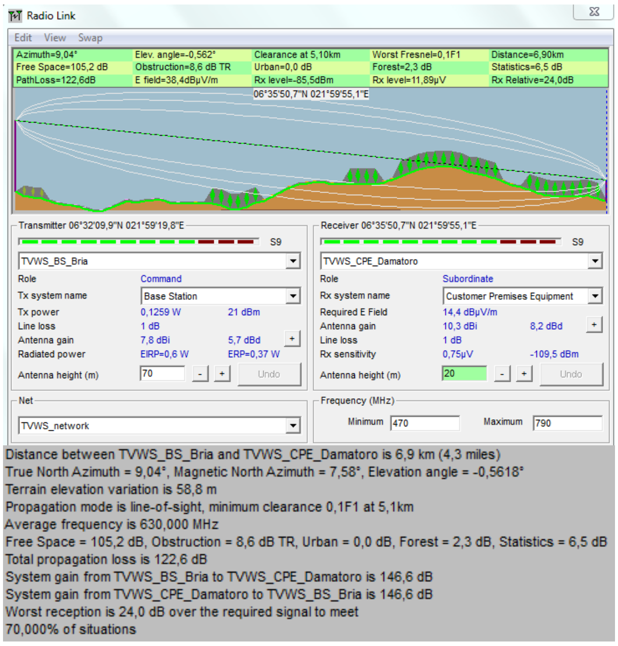


Figure 7. BS – CPE Dambatoro radio profiles

Figure 8 gives the parameters for calculating the margin of the link between the base station and the Bakoua site customer.

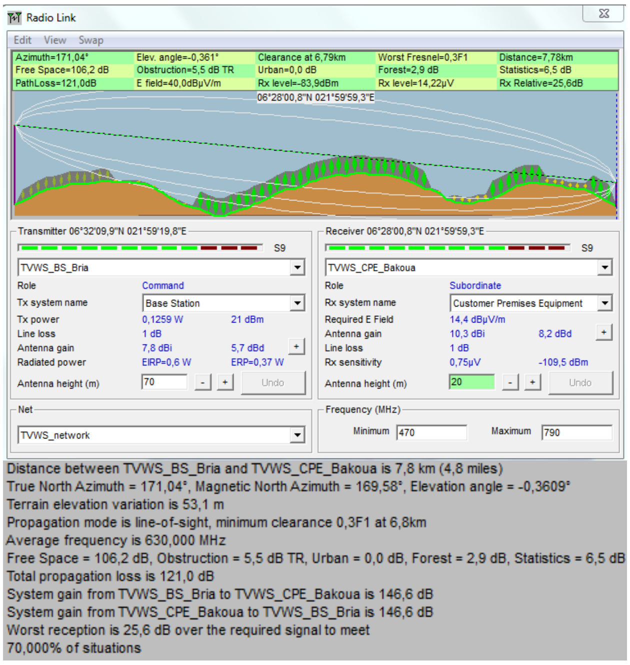


Figure 8. BS – CPE Bakoua radio profiles

B. Testing with e-health sensors

To show the relevance of our solution we used a set of humidity and temperature sensors attached to a WiFi gateway (NodeMCU ESP8266) as shown in Figure 9.

Figure 9. Implementation of e-health with the NodeMCU module

Figure 10 shows that access to the platform requires registration and authentication.

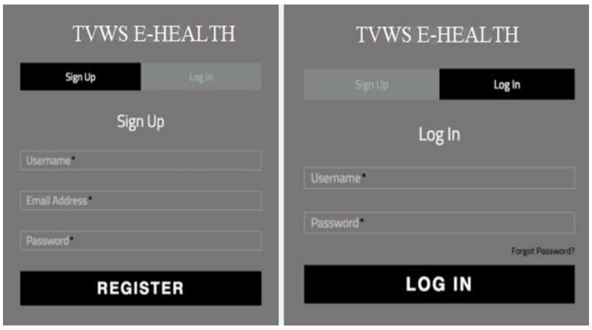


Figure 10. Patient registration and connection to the platform..

Figure 11 shows that actors can access information from temperature and humidity sensors that can be replaced by biometric sensors.

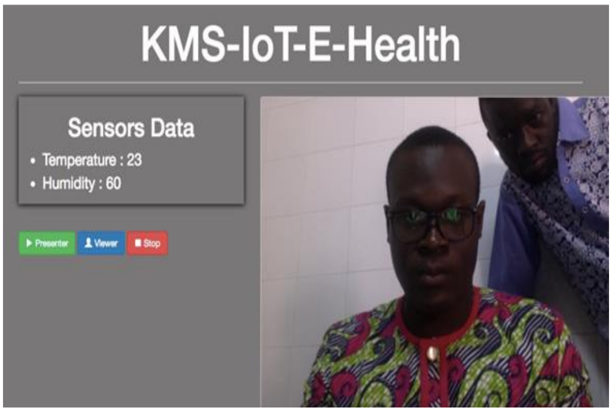


Figure 11. Measuring the temperature and humidity using sensors

V. Conclusion

The results of our work have shown that a well-designed broadband network can be used by specialists for remote monitoring of patients with chronic diseases.

The e-health platform that we have proposed, integrating biometric sensors, aggregation nodes and an API, allows specialists to access patient data, on the one hand, and on the other hand, to communicate in real time via the Web with patients in conflict zones thanks to WebRTC technology.

Patient follow-up is almost as if the actors were not geographically dispersed.

This proposed e-health solution cannot be effectively implemented without an easily deployable broadband network such as TVWS.

The result of our study can be extended to several conflict areas in countries in the sub-region such as Mali, Burkina Faso, Nigeria, Cameroon and Chad.

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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 Teleinformatic 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.

Ghislain Mervyl Kossingouis 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.

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 Teleinformatic from Polytechnic Higher School/Multinational Higher School of Telecommunications of the University Cheikh Anta Diop (UCAD) of Dakar-Senegal.
His current research interests include Telecommunicaions application, e-learning.

Kéba GUEYE 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 physics and applications "Electronics Systems and Telecommunication" from the University Cheikh Anta Diop (UCAD) of Dakar-Senegal.
His current research interests include Internet of Things IoT and Intelligent System, VoLTE, CoAP, MQTT.

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.