A Method for Identification of White Spaces in the VHF/UHF Band for the Future Deployment of Cognitive Radio Networks in the City of Loja

Juan Ochoa Aldeán, Edison D. Troya Chanta

Abstract— This project aims to carry out the identification of White Spaces within the VHF / UHF, corresponding to the range of frequencies ranging from 54 to 686 MHz, for possible use in cognitive radio systems bands. The methodology consisted of a spectrum monitoring performed in order to know their spectral occupancy in six parishes of the City of Loja. For that, a spectrum analyzer system was used, in order to evaluate the implementation Cognitive Radio Networks (CRN's).

Index Terms— Spectrum, Wireless Communication, Cognitive Radio, White Spaces, National Frequency Plan.

I. INTRODUCTION

According to the National Frequency Plan (NFP) issued by the Agency for Regulation and Control of Telecommunications, we can see that the frequency bands used for radio communications are saturated, however, recent studies show that the use of spectrum is not efficient. So while some bands are congested, there are other regions of the spectrum that are underused. As a solution to the growing demand for radio spectrum and its inefficient use, the cognitive radio technology has been identified as a promising solution to counteract the imminent saturation of this resource. The fundamental idea of this technology is basically allow unlicensed users (secondary) to access certain spectrum bands that are available or temporarily vacated by licensed users (primary), as long as transmissions do not cause any interference with the primary [1] users. In recent years, cognitive radio has been gaining great importance in the field of wireless communications mainly due to its multiple potentialities. In general, cognitive radio is a technology that can dynamically adapt to your operating environment and combine different kind of information to make intelligent decisions about the spectrum that can be used without interfering with the primary users. [2] Nowadays, no study in the city of Loja in the field of telecommunications has showed the current state of the radio spectrum mainly in the range frequencies between 54-686 MHz. In this context, this paper identifies the available frequencies (White Spaces) within the VHF and UHF bands, these frequencies are intended for the transmission of analogue broadcasting and television in the city of Loja. For this study, it was made a different levels of radiated energy monitoring within the studied band for each of the six parishes of the city of Loja, and finally establish the percentages of spectral occupancy to assess implementation of CRN's.

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This work is organized as follows: In (II) an analysis of the spectrum is performed in the band 54-686 MHz, in (III) a method of measuring spectrum utilization is proposed, the results of the studies are shown in (IV) and analyzed in (V) to finish with the conclusions in (VI).

II. SPECTRAL GRANT FOR THE LOJA CITY WHITIN 54 MHZ – 686 MHZ

According to the NFP in Ecuador [3], the distribution of telecommunications services in the band between 54 and 686 MHz are shown in Tables 1 and 2:

TABLE I. RADIO STATIONS CONCESSION IN THE LOJA CITY. [4]

CATEGORY	RADIO STATION	FREQUENCY (MHz)	SITE
FM	Boquerón	93,7	Loja
FM	Caravana AM	101,3	Loja
FM	Cariamanga FM	104,5	Loja
FM	Ecuasur FM	102,1	Loja
FM	El Cisne	91,3	Loja
FM	Radio Universitaria	98,5	Loja
FM	J.C Radio	107,3	Loja
FM	Kocodrilo Radio	98,1	Loja
FM	La Hechicera	88,9	Loja
FM	La voz del Santuario	99,7	Loja
FM	Loja 97.7 FM	97,7	Loja
FM	Luz y Vida	88,1	Loja
FM	Matovelle	100,1	Loja
FM	Misión San Antonio	94,9	Loja
FM	Mix FM	105,7	Loja
FM	Municipal FM	90,1	Loja
FM	Ondas de Esperanza	94,1	Loja
FM	Planeta Estéreo	106,1	Loja
FM	Poder	95,3	Loja
FM	Radio Corporación	97,3	Loja
FM	Radio de la Asamblea	95,7	Loja

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FM	Radio Pública FM	90,5	Loja
FM	RS Musical	89,3	Loja
FM	Rumba Stereo	106,9	Loja
FM	Satelital	100,9	Loja
FM	Semillas de Amor	89,7	Loja
FM	Sociedad FM	99,3	Loja
FM	Sonorama FM	103,7	Loja
FM	Vilcabamba Estéreo	102,5	Loja
FM	Zapotillo FM	96,1	Loja
FM	Cañaveral	96,5	Loja
FM	Radio Vigia FM	93,3	Loja
FM	Súper Láser	104,9	Loja
FM	WG Milenio	92,5	Loja

TABLE II. TV CHANNELS CONCESSION IN THE LOJA CITY. [4]

CATEGORY	TV STATION	FREQUENCY (MHz)	SITE
TV Abierta	Ecuavisa	2- (54-60)	Loja
TV Abierta	UV Televisión	4- (66-72)	Loja
TV Abierta	Teleamazonas	5- (76-82)	Loja
TV Abierta	Ecuador TV	7- (174-180)	Loja
TV Abierta	Cadena Ecuatoriana de Televisión	8- (180-186)	Loja
TV Abierta	Red Telesistemas (RTS)	9- (186-192)	Loja
TV Abierta	Televisión del Pacífico	11- (198-204)	Loja
TV Abierta	Telerama	24- (530-536)	Loja
TV Abierta	Canal Uno	26- (542-548)	Loja
TV Abierta	TV Legislativa	28- (554-560)	Loja
TV Abierta	Teleatahualpa (RTU)	30- (566-572)	Loja
TV Abierta	Tropical TV	32- (578-584)	Loja
TV Abierta	UCSG TV	34- (590-596)	Loja
TV Abierta	Oromar TV	36- (602-608)	Loja
TV Abierta	El Ciudadano TV	49- (680-686)	Loja

From the above tables it can be seen that a total of 34 Radio stations and 15 TV stations are open concession for the city of Loja.

III. METHODOLOGY FOR MEASURING

A. *Scheme*

The scheme was carried out in order to perform the measurement is shown in Figure 1. It is composed of a spectrum analyzer ANRITSU model MT8212B, type Discone DX-D130, PL-BNC pigtail antenna, RG58 coaxial cable 50 ohm RF connectors.

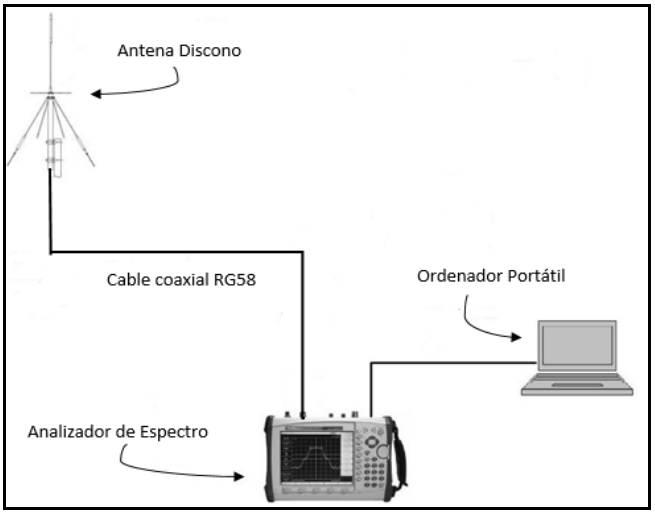

Fig. 1. Measurement scheme

B. *Process*

In order to give a chance to the process of measuring the spectrum, a sub division of the frequency range to be evaluated (54 - 686 MHz) was established. This division considered sub bands of application and use of the spectrum according to the NFP. The total number of sub bands obtained by the division is four, as shown in the following table.

TABLE III. DIVISION OF THE FREQUENCY BAND 54 MHZ – 686 MHZ.

	BAND			
	54 MHz		686 MHz	
	Sub Band 1 (MHz)	**Sub Band 2 (MHz)**	**Sub Band 3 (MHz)**	**Sub Band 4 (MHz)**
Range	54 – 88	88 - 108	174 - 216	512 - 686
Bandwidth BW (MHz)	34	10	42	96
Service	TV VHF	Radio FM	TV VHF	TV UHF

C. *Spectrum occupancy metrics*

The main feature presented by cognitive radio networks (CRN's) is the ability to detect the emission of radio signals corresponding to primary users in order to not to cause any interferences and find White Spaces, which improves the performance of these networks for data transmission. [2] The techniques can be used for evaluating the spectrum are: power detection, matched filter detection and cyclostationary detection [5]. To perform measurements, the energy detection method was used as a metric, thus you can compare the signal strength measurements, the same that have been produced by the various telecommunications services. The main part of this method is determining a threshold decision which will discriminate if the signal is there. According to the provisions of cognitive systems, detection thresholds are:

a) Digital Terrestrial Television (DTT): -116 dBm.
b) Analog Television: -94 dBm. [5]

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Currently in the city of Loja there are no DTT broadcasting, consequently it is established as a threshold value -94 dBm.

IV. RESULTS

Once collected the measurements of radio spectrum in the bands of interest, the processing of all data for getting to know the percentage of spectrum occupancy according to the following equation (1) is performed:

$$\%\ occupied\ spectrum = \frac{used\ BW}{BW\ Sub\ Band\ (SPAN)} x100 \quad (1)$$

Thus, it will be identified what percentage of sub-utilization of the radio spectrum within the city of Loja is.

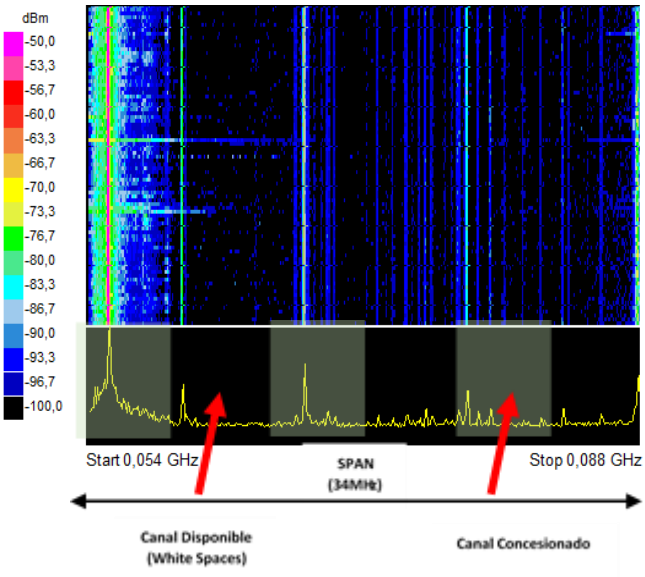

Fig. 2. Spectrum Analyzer display

For the percentage of spectral occupation that exists in each of the sub bands analyzed, it must be taken into account that the total bandwidth which is occupied in each sub band corresponds to the sum of all the frequency ranges being used by television or radio broadcasting systems and maintains a concession within that sub band in the city of Loja.

This can be seen on the screen of the spectrum analyzer in figure 2. The following percentage values have been obtained by spectrum measurement for each of the sub-bands and are presented throughout this paper. In addition, based on the selected method the number of Tv channels or radio stations available and the number of White Spaces in the six parishes of the city of Loja was determined.

In Table IV we can observe the results obtained for the range of frequencies comprised between 54 MHz to 88 MHz.

As we can see in Table V, the range of frequencies ranging from 88 MHz to 108 MHz, corresponds for FM radio broadcasts.

As we can see in Table VI, the range of frequencies ranging from 174 MHz to 216 MHz, corresponds to TV VHF broadcasting.

According to the National Frequency Plan (NFP), this frequency range is designated to TV UHF broadcasting except the range between 608 MHz to 614 MHz, which has been dedicated to radio-astronomy applications.

It can be seen in table VII that the spectral occupancy rates are low in all parishes.

V. TECHNICAL FEASIBILITY FOR THE IMPLEMENTATION OF CRN´S IN THE LOJA CITY

This paper has assessed and analyzed the state of the radio spectrum, from the measurements made in the six parishes of Loja city, in order to determine the feasibility of implementing new technologies to use more efficiently the available spectrum in the city, such as the CRN's. The percentages of the spectral evaluation of each of the sub bands are shown in Fig. 3.

The data presented in the previous figures represent the bandwidth in MHz and the percentage based on the available bandwidth in each parish. Overall, these data give a clearer idea of what the sub bands of saturated frequencies and what areas of the city of Loja are.

Table VII displays the frequency averaged data that is used within Loja and the bandwidth sub-utilized (available) comprised within the range of frequencies between 54 MHz to 686 MHz.

VI. CONCLUSION

The expansion of wireless systems in recent years, and the need to use communication as a fundamental tool to the development of society, have led to question the regulatory model for the use of radio spectrum, leaving result in shortage of frequencies available for the implementation of new wireless systems.

Cognitive radio appeared as a new paradigm of radio spectrum management and like a promising solution to the problem of the scarcity of radio spectrum, mainly due to its growing demand for wireless systems and current sub-utilization.

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TABLE IV. RESULTS OF THE SPECTRAL OCCUPANCY OF SUB-BAND 1.

SUB-BAND 1: VHF (54 MHz – 88 MHz)							
Parish	**Sector**	**Channels Concession / Busy**	**BW Busy MHz**	**SPAN MHz**	**BW Available MHz**	**Spectrum Concession / Used**	**Spectrum Available**
Carigán	**Carigán**	**3 / 2**	**12**	**34**	**22**	**52.94 % / 35.29 %**	**64.71 %**
	Sauces Norte	**3 / 2**	**12**	**34**	**22**	**52.94 % / 35.29 %**	**64.71 %**
El Valle	**Amable María**	**3 / 3**	**18**	**34**	**16**	**52.94 % / 52.94 %**	**47.06 %**
	San Juan del Valle	**3 / 3**	**18**	**34**	**16**	**52.94 % / 52.94 %**	**47.06 %**
Sucre	**Obrapía**	**3 / 2**	**12**	**34**	**22**	**52.94 % / 35.29 %**	**64.71 %**
	El Pedestal	**3 / 3**	**18**	**34**	**16**	**52.94 % / 52.94 %**	**47.06 %**
	Turunuma	**3 / 2**	**12**	**34**	**22**	**52.94 % / 35.29 %**	**64.71 %**
El Sagrario	**Barrio Central**	**3 / 3**	**18**	**34**	**16**	**52.94 % / 52.94 %**	**47.06 %**
	Zamora Huayco	**3 / 2**	**12**	**34**	**22**	**52.94 % / 35.29 %**	**64.71 %**
Punzara	**La Argelia**	**3 / 2**	**12**	**34**	**22**	**52.94 % / 35.29 %**	**64.71 %**
	Daniel Alvarez	**3 / 2**	**12**	**34**	**22**	**52.94 % / 35.29 %**	**64.71 %**
San Sebastián	**San Sebastián**	**3 / 3**	**18**	**34**	**16**	**52.94 % / 52.94 %**	**47.06 %**

TABLE V. RESULTS OF THE SPECTRAL OCCUPANCY OF SUB-BAND 2.

SUB-BAND 2: FM (88 MHz – 108 MHz)							
Parish	**Sector**	**Channels Concession / Busy**	**BW Busy MHz**	**SPAN MHz**	**BW Available MHz**	**Spectrum Concession / Used**	**Spectrum Available**
Carigán	**Carigán**	**33 / 29**	**5.8**	**20**	**14.2**	**33% / 29%**	**71 %**
	Sauces Norte	**33 / 30**	**6**	**20**	**14**	**33% / 30%**	**70 %**
El Valle	**Amable María**	**33 / 30**	**6**	**20**	**14**	**33% / 30%**	**70 %**
	San Juan del Valle	**33 / 30**	**6**	**20**	**14**	**33% / 30%**	**70 %**
Sucre	**Obrapía**	**33 / 30**	**6**	**20**	**14**	**33% / 30%**	**70 %**
	El Pedestal	**33 / 30**	**6**	**20**	**14**	**33% / 30%**	**70 %**
	Turunuma	**33 / 30**	**6**	**20**	**14**	**33% / 30%**	**70 %**
El Sagrario	**Barrio Central**	**33 / 30**	**6**	**20**	**14**	**33% / 30%**	**70 %**
	Zamora Huayco	**33 / 29**	**5.8**	**20**	**14.2**	**33% / 29%**	**71 %**
Punzara	**La Argelia**	**33 / 30**	**6**	**20**	**14**	**33% / 30%**	**70 %**
	Daniel Alvarez	**33 / 30**	**6**	**20**	**14**	**33% / 30%**	**70 %**
San Sebastián	**San Sebastián**	**33 / 30**	**6**	**20**	**14**	**33% / 30%**	**70 %**

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TABLE VI. RESULTS OF THE SPECTRAL OCCUPANCY OF SUB-BAND 3.

SUB-BAND 3: VHF (174 MHz – 216 MHz)							
Parish	**Sector**	**Channels Concession / Busy**	**BW Busy MHz**	**SPAN MHz**	**BW Available MHz**	**Spectrum Concession / Used**	**Spectrum Available**
Carigán	**Carigán**	**4 / 3**	**18**	**42**	**24**	**57.15% / 42.85%**	**57.15 %**
	Sauces Norte	**4 / 3**	**18**	**42**	**24**	**57.15% / 42.85%**	**57.15 %**
El Valle	**Amable María**	**4 / 4**	**24**	**42**	**18**	**57.15% / 57.15%**	**42.85 %**
	San Juan del Valle	**4 / 4**	**24**	**42**	**18**	**57.15% / 57.15%**	**42.85 %**
Sucre	**Obrapía**	**4 / 4**	**24**	**42**	**18**	**57.15% / 57.15%**	**42.85 %**
	El Pedestal	**4 / 4**	**24**	**42**	**18**	**57.15% / 57.15%**	**42.85 %**
	Turunuma	**4 / 4**	**24**	**42**	**18**	**57.15% / 57.15%**	**42.85 %**
El Sagrario	**Barrio Central**	**4 / 4**	**24**	**42**	**18**	**57.15% / 57.15%**	**42.85 %**
	Zamora Huayco	**4 / 4**	**24**	**42**	**18**	**57.15% / 57.15%**	**42.85 %**
Punzara	**La Argelia**	**4 / 4**	**24**	**42**	**18**	**57.15% / 57.15%**	**42.85 %**
	Daniel Alvarez	**4 / 4**	**24**	**42**	**18**	**57.15% / 57.15%**	**42.85 %**
San Sebastián	**San Sebastián**	**4 / 4**	**24**	**42**	**18**	**57.15% / 57.15%**	**42.85 %**

TABLE VII. RESULTS OF THE SPECTRAL OCCUPANCY OF SUB-BAND 4.

SUB-BAND 4: UHF (512 MHz – 686 MHz)							
Parish	**Sector**	**Channels Concession / Busy**	**BW Busy MHz**	**SPAN MHz**	**BW Available MHz**	**Spectrum Concession / Used**	**Spectrum Available**
Carigán	**Carigán**	**8 / 6**	**16**	**174**	**138**	**27.59% / 20.69%**	**79.31 %**
	Sauces Norte	**8 / 5**	**30**	**174**	**144**	**27.59% / 17.25%**	**82.76 %**
El Valle	**Amable María**	**8 / 7**	**42**	**174**	**132**	**27.59% / 24.14%**	**75.86 %**
	San Juan del Valle	**8 / 7**	**42**	**174**	**132**	**27.59% / 24.14%**	**75.86 %**
Sucre	**Obrapía**	**8 / 7**	**42**	**174**	**132**	**27.59% / 24.14%**	**75.86 %**
	El Pedestal	**8 / 8**	**48**	**174**	**126**	**27.59% / 27.59%**	**72.41 %**
	Turunuma	**8 / 5**	**30**	**174**	**144**	**27.59% / 17.25%**	**82.76 %**
El Sagrario	**Barrio Central**	**8 / 8**	**48**	**174**	**126**	**27.59% / 27.59%**	**72.41 %**
	Zamora Huayco	**8 / 5**	**30**	**174**	**144**	**27.59% / 20.69%**	**79.31 %**
Punzara	**La Argelia**	**8 / 8**	**48**	**174**	**126**	**27.59% / 27.59%**	**72.41 %**
	Daniel Alvarez	**8 / 6**	**36**	**174**	**138**	**27.59% / 20.69%**	**79.31 %**
San Sebastián	**San Sebastián**	**8 / 7**	**42**	**174**	**132**	**27.59% / 24.14%**	**75.86 %**

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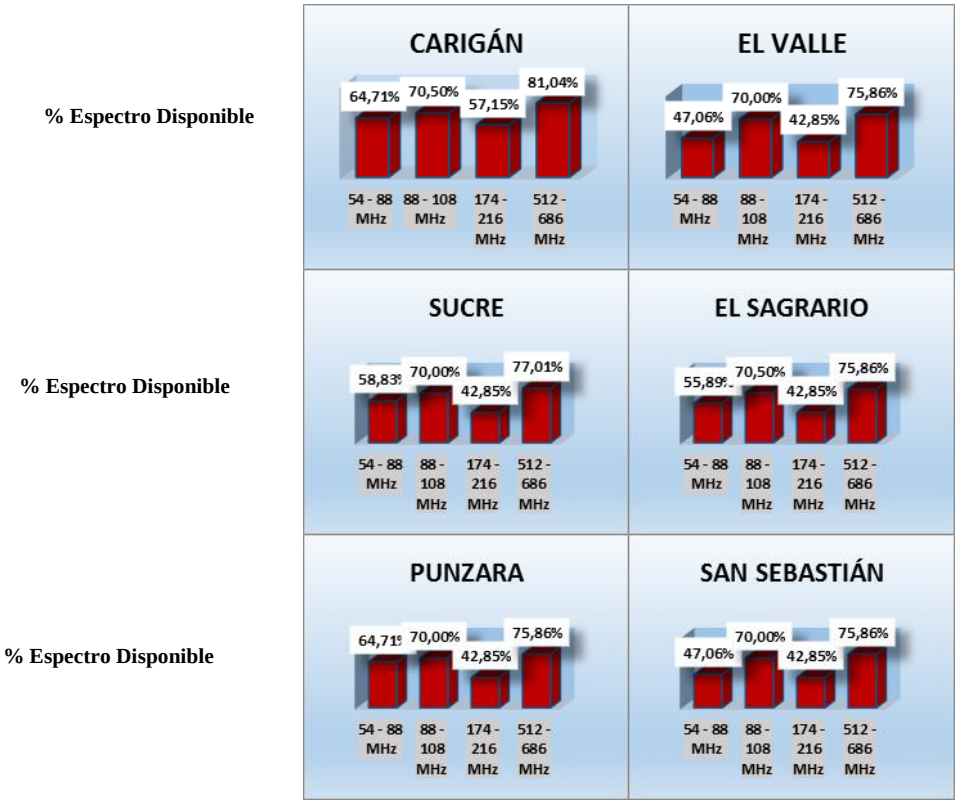

Figure 3. Percentaje Spectrum available in each sub band for each parish in the city of Loja.

TABLE VIII. AVAILABILITY OF SPECTRUM IN THE LOJA CITY.

Average Values		
	BW Occupied	**BW Sub-utilized**
Sub-Band VHF (54-88MHz)	14,5 MHz	19,5 MHz
Sub-Band FM (88-108MHz)	6 MHz	14 MHz
Sub-Band VHF (174-216MHz)	23 MHz	19 MHz
Sub-Band UHF (512-686MHz)	39,5 MHz	134,5 MHz
TOTAL	**83 MHz**	**187 MHz**

Its main feature is based on the dynamic allocation of frequencies allowing users to reuse the unused spectrum without interfering with legitimate users, ie, it has the skill to change its operating parameters according to the communication needs that are required, thus optimizing the use of radio spectrum. The results of the spectral evaluation made in the frequency band of FM radio and VHF / UHF (54MHz - 686MHz) television in different parishes in the city of Loja, show that within the spectrum that is allocated to TV channels there are channels available for use by cognitive radio networks. The average value of the amount of spectrum available in the city of Loja is 187 MHz, which represents 69.3% of the frequency band being assessed. Therefore, the possibility of applying cognitive radio networks in parishes in the city of Loja is promising. Within the different sub bands evaluated in the present work, we realize that the sub band in which there is a greater chance for a future application of cognitive radio networks within the city of Loja, is the UHF television band, and that within this band there is an average value of about 134.5 MHz that is underutilized allowing for the deployment of a WRAN system based on the IEEE 802.22 standard to provide rates up to 1.5 Mbps in downlink and up to 384 Kbps in uplink. In summary, the implementation of cognitive radio networks within the city of Loja is feasible. However, this study focused on the identification of White Spaces of the radio spectrum, therefore further work should analyze the deployment of these cognitive systems, as well as the location of transmission systems and infrastructure.

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