Channel Selection Technique to Satisfy Secondary Users Quality of Service (QoS) Requirements in TV White Space

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***Abstract*—Growing demand of reliable and affordable wireless connectivity requires alternative solutions and television white space (TVWS) provides that opportunity. However, the biggest challenge in TV spectrum re-use is to allocate best channels for secondary user while maintaining good Quality of Service (QoS). Allocation of Secondary User (SU) channels with less interference to Primary User (PU) is still a challenge not only to academia research communities but to industry as well. We studied the spectrum selection method of geo-location database (GLDB) that provides certainty in selecting available white space spectrum in the geographical area of request. The Internet Engineering Task Force (IETF) developed a standard communication protocol between the GLDB and white space devices (WSD) in order to establish reliable communication method for WSD. In this paper, a protocol to access white space (PAWS) method combined with analytical hierarchy process (AHP) is proposed for best channel selection from the GLDB. MATLAB simulation platform was used to test the performance of the proposed technique. The results show that the algorithm using proposed AHP based method (with deterministic queuing model within WSD) selects the best operating channel based on a better global priority vector (GPV). The numerical results show that the proposed selection technique is capable of selecting the best channels that satisfy the QoS for SUs profiles as compared to existing techniques.**

***Keywords*—TV Whitespace; Smart Set-top box; Protocol to Access White Space; geo-location database; White space device; Base station;**

I. INTRODUCTION

Nowadays an enormous growth in wireless communication devices usage requires reliable and affordable broadband internet services especially in rural and urban underserved communities. Dynamic spectrum access (DSA) was found to be a promising solution for spectrum allocation inefficiency as well as to facilitate usage of white spaces [1].

The term "white space" in the context of radio frequency (RF) spectrum management refers to portions of spectrum allocated for licensed users however not utilized by the licensee at particular times in across geographical locations. These white spaces are targeted for use to provide broadband internet especially in the underserved rural and urban areas.

The biggest challenge in spectrum re-use is to allocate best white space channels for secondary users while maintaining the quality of service (QoS). The proposed DSA QoS provisioning approach case study does indicate effectiveness for, example supporting high-definition television (HDTV) streaming in television (TV) bands.

A. Current approaches

In [2] Simulated Annealing (SA) is used with multi-objective function for optimising QoS parameters for cognitive radio networks. The SA approach provided good results for the simulation; however [3] made a review or study of selecting best channel using the SA versus Analytic Hierarchy Process (AHP) and confirm that SA show latency which is making it less efficient in selecting the best channel quicker and easier. Thus [3] concludes by recommending AHP method, however, with further optimisation requirements.

A proactive method proposed by [4], Preemptive Resume Priority (PRP) M/G/1 queuing network model assess the spectrum usage and manage the connection-based multiple channel handoffs. [5] define Preemptive Resume Priority as "on-going service interrupted by arrival of higher priority. Work already done for the pre-empted job is remembered. Work-conserving Discipline". In [6] highlight the method of stochastic channel selection algorithm which is based on the learning automata technique to manage packet loss ratio because of channel switching. The difficulty with this approach is that the algorithm converges slowly and it needs more time to combine all the selection results. In [7] heuristic channel selection schemes was explored and the method couldn't run efficiently. Then [8] explores the challenge of resources allocation in TVWS by developing models for channel availability. In [9] uses Markov process to analyse QoS reliability metrics, and indicates potential performance improvement while supporting additional best-effort users without QoS deterioration.

In [10] User Cohabitation Coordinator, (UCC) was proposed while QoS requirements are considered for CR users. This proposed scheme enabled the cohabitation of CR operators demonstrating high throughput while maintaining fairness in CR networks.

Release of PAWS by Internet Engineering Task Force (IETF) as a standard protocol to access the available TVWS between a White Space Device (WSD) (for example Smart Set Top Box (SSTB)) and Geo-Location Database (GLDB), was a great way for researchers to explore different ways to test spectrum sharing [11]. PAWS addresses the method of communication between WSD and GLDB, but the selection technique is still a challenge. The major challenge to the selection of the available channels is also brought about by the dynamic status of serving the primary user (PU) while secondary user (SU) requires servicing its own users. The definition of how decisions are made in an organised fashion is to generate priorities and decompose the alternatives which eventually lead to selecting best choice based on parameters meeting requirements [12].

The remainder of this paper is arranged as follows. Section II describes the system model considered in this paper. An overview of PAWS and AHP are discussed in Section III. The proposed PAWS-AHP based channel selection is presented in Section III. Simulation environment and results analysis are discussed and presented in Section IV. The paper concludes in Section V.

II. SYSTEM MODEL

A. *Proposed Network Layout*

The proposed network layout consists of National Geo-Location Database (NGLDB), Regional Geo-Location Database (RGLDB), White Space Device (WSD), and the Smart Set-top box (SSTB) which is the end-user device acting as Access Point (AP). Figure 1 depicts the proposed network layout or system model. Components of our proposed system model are defined below as follows:

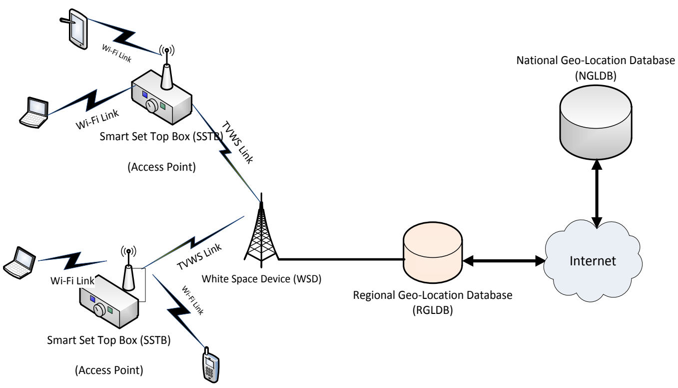

Figure 1: TV White Space System Model

1) *National GLDB*

The NGLDB which we assume have cognitive radio capabilities such as spectrum sensing and regulator policies on TVWS have made decisions on which spectrum is for white space use. The geo-database tracks and store available spectrum (in fulfilment with the rules of one regulatory domains) and ensures devices have access to it. The database manages the complexity of spectrum policy and is only used to serve the users. The NGLDB is earmarked to support national spectrum regulations and is the preferred method; since it guides accessing of dynamic spectrum. It is used by many leading telecoms regulatory countries, due to its reliability and in addition to spectrum sensing and beaconing.

The NGLDB manages holistic spectrum availability and also pass required spectrum to RGLDB to locally support the SSTB. The NGLDB manages the location of its users and other relevant parameters required by RGLDB and devices.

2) *Regional GLDB*

At the local area there is Regional Geo-Location Database (RGLDB) which is connected to NGLDB via internet cloud to allow exchange of information on sensed spectrum. Our assumption is that RGLDB have local spectrum sensing capabilities and resources management. The database relies on NGLDB for prediction of white space (WS) information. It also plays the role of verifying the predicted WS's while using very limited sensing capabilities from the local or regional Base Stations (BS).

The RGLDB is then connected with reliable link (e.g. fibre optic) as backhaul through to White Space Device (WSD) which acts as master device. The RGLDB stores and manages the spectrum locally to serve the devices connected via WSD infrastructure. The RGLDB is managing the regional-national spectrum regulators. The database provides capability of harmful interference to primary TV spectrum users, while promoting efficient radio frequency utilization and deployment.

This study uses CSIR-Meraka Institute Television White Spaces (TVWS) Geo-location Database (GLDB) for simulation. However, the depiction of the system model is such that system like RGLDB is connected via National GLDB for local and national spectrum availability. The GLDB is running on Linux platform and accessed via web services URL link: http://whitespaces.meraka.csir.co.za/ to query the available TVWS channels.

3) *White Space Device (WSD)*

The WSD can be called a "Base Station (BS)" or an "AP". This will depend on our use case (i.e. GdU, SiU or CrU). It is an approved FCC wireless device which is used for broadcasting exclusively in RF spectrum between 50 MHz and 700 MHz. In this study the WSD is capable of querying available spectrum from RGLDB, apply selection criteria through AHP process, allocate best channel to the relevant devices manage handover between expiring and newly selected channels while maintaining the QoS through a Queuing model.

In this paper we assume the WSD is setup near a school and near community centres in a village or area. The WSD acts as a master device that connects between database and SSTB with full capabilities of white spaces to serve the users and manage the spectrum resources.

III. INTERGRATED WEIGHTING

B. PAWS – AHP based channel selection

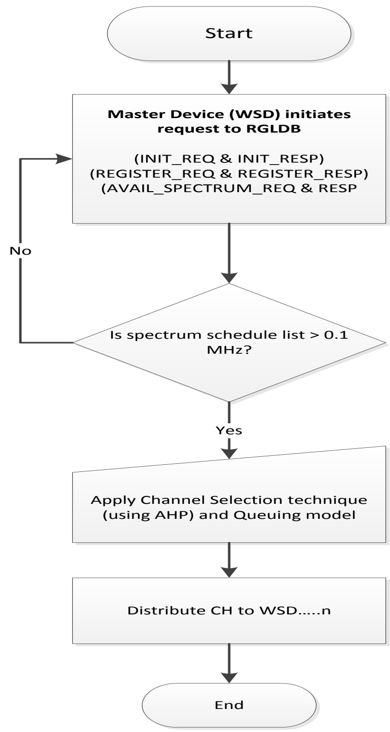

Figure 2: Proposed Channel Selection Process [11]

The channel selection technique is proposed in order to manage available spectrum resources for wireless services. In this section we review existing literature on channel selection in CRNs and TVWS. Furthermore in this paper we assume that TVWS Base Station in the system model called a "WSD" is authenticated by the Regional Geo-Location Database (RGLDB) which is clustered with National Geo-Location Database (NGLDB). The first step of the selection is to query the list of available channels using PAWS from RGLDB. The process starts with the PAWS Flow, which is broken down into four procedures namely [13]:- (i) Initial Procedure, (ii) Device Registration Procedure (DRP), (iii) Available spectrum query procedure (ASQP) and Device validation procedure (DVP).

The WSD establishes connections to RGLDB and request the available spectrum from RGLDB. The available spectrum list retrieved would contain many characteristics but key ones for decision making process will be used. The key parameter used in this paper is maxTotalBwHz which provide a trigger to apply channel mapping rules and eventually activate the decision making AHP-based channel analysis model or not. The AHP-based channel decision model is incorporating the Deterministic (D/M/1) queuing model to manage the channel handoff when PU requires so and when time has lapsed for the service. However, [14] simulated pre-emptive queuing technique PRP /M/G/1 using Poisson arrival process. If there are no available channels the WSD will query the RGLDB within the defined period to obtain at least sufficient channels as per rules to make a decision.

In [13] the parameters of white space channel profiles for AHP decision making purposes are defined. The IETF standard provides generic view of these parameters and guidelines. In [3] the AHP-based channel decision model is defined using the integrated approach with PAWS parameters.

$$\text{Bandwidth} = \text{stopHz} - \text{startHz}, \qquad (1)$$

Therefore the formula is derived from the element frequency Ranges which contains start and stop frequencies that can enable device to operate on.

The element Spectrum Schedule incorporate Event Time, which defines the time particular channels, is available for use. The EvenTime element defines the following parameter start and stop period times of event.

$$\text{Availability} = \text{stopTime} - \text{startTime} \qquad (2)$$

PAWS define and provide guideline for regulators that each available spectrum schedule be operated within permissible power level during its defined availability slot. The channels are allowed use of frequencies at highest power levels [3].

$$\text{Transmit Power} = \text{maxPowerDBM} \qquad (3)$$

The SpectrumSpec defines the parameter resolutionBwHz in hertz with permitted power spectral density. For instance [3] indicates that Federal Communications Commission (FCC) regulation requires one spectrum specification at bandwidth 6 MHz and the European Telecommunications Standards Institute (ETSI) regulation requires two specifications at 0.1 MHz and 8 MHz. The parameter maximum Total Bandwidth Hertz which is represented by:

$$\text{maxTotalBwHz} = 8 \text{ MHz} \qquad (4)$$

Where the spectrum selects returns, maxContiguousBwHz ruleset must be applied to RGLDB. The maximum spectrum size in the ETSI standard and regulation is 0.1 MHz and 8 MHz. However, for this study we assume the total bandwidth services the simulation as: 0.1 MHz, 5 MHz and 8 MHz.

Parameters described above provide minimum requirements for selecting available white space spectrum to serve as secondary user. South African research institute CISR Meraka uses Geo-Location Database authorised by ICASA to retrieve the list of available TVWS spectrum through the web services link; http://whitespaces.meraka.csir.co.za/index.jsp. Figure 2 depicts full spectrum query sequence as per PAWS process.

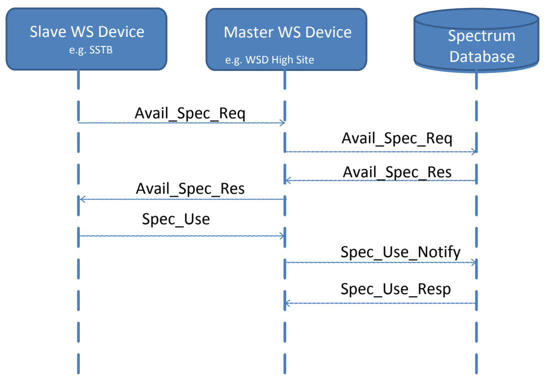

Figure 3: PAWS Spectrum Query Sequence [11]

In [11] a generic PAWS example query message AVAIL_SPEC_REQ to request the retrieval of the available spectrum list from geo-location database (GLDB):

A. Function to query spectrum

```
getSpectrum_method(){
// defining the method get spectrum
"params": {
    "type": "AVAIL_SPECTRUM_REQ",
    "version": "1.0",
    "deviceDesc": {
     "serialNumber": "your_serial_number",
     "fccId": "your_FCC_ID",
     // ...
    },
    "location": {
     "point": {
      "center": {"latitude": '$LAT', "longitude": '$LON'}
     }
    }
    "key": "your_API_key"
  },
  "id": "any_string"
 }
```

B. Display results //Example of results retrieved from database

```
"spectrumSchedules": [
 {
 "eventTime": {
  "startTime": "2016-08-31T03:28:08Z",
  "stopTime": "2016-09-02T03:28:08Z"
 },
 "spectra": [
  {
  "bandwidth": 6000000.0,
  "frequencyRanges": [
   {
   "startHz": 5.4E7,
   "stopHz": 5.12E8,
   "maxPowerDBm": -56.799999947335436
  },
  {
   "startHz": 5.12E8,
   "stopHz": 5.72E8,
   "maxPowerDBm": 15.99999928972511
  },
```

End Results

In order to ensure PAWS process provides better results this study proposed user type and roles. The three class of service profiles proposed are Gold User (GdU), Silver User (SiU) and Copper User (CrU).

The user types defined in the table 1 basically explains that GdU user has priority and serves the critical services such as Schools, Business, Library and Community Centres. CrU requires minimum bandwidth of 8MHz and time availability of the channel for SU to occupy at least 12 hours. The type of services CrU will be offering TX Power of about 36 dBm which translates to about 4W transmit power. According to WRAN [15] and [16] broadband services can operate under TVWS frequency which is capable of reaching minimum data rates of 5 Mbps to maximum data rates of 73 Mbps. Earmarking rural broadband performance connection service coverage typically can cover 33 km up to 100 km.

TABLE 1: PROPOSED USER TYPE AND ROLES

Class of Service Profiles	**Users Profile Classification**	**Required Min Bandwidth**	**Minimum Availability Time**	**Tx Power**
Gold User (GdU)	*Schools, Business, Library & community centres*	*8MHz*	*12 hrs*	*36 dBm (4 W)*
Silver User (SiU)	*Portable User's,*	*5 MHz*	*4 hrs*	*20 dBm (100 mW)*
Copper User (CrU)	*M2M, Personal Area Network (PAN)*	*1 MHz*	*1 hr*	*17 dBm (50 mW)*

The study is guided by various standards but not limited to Institute of Electrical and Electronics Engineers (IEEE) 802.22b WRAN, 802.11af WLAN and IEEE 802.15 Wireless PAN standards to define requirements per user type role [17].

Table 1 summaries the class of service profiles according to their priority rankings. In summary of the retrieval process the available list of WS channels from GLSDB, will pass the results to WSD Node which will then apply AHP process for decision making within QoS parameters as per user profile.

C. *Analytical Hierarchy Process (AHP)*

In this paper, we propose the use of AHP-based channel decision making process which criterion is defined by user type preference and conditions of the list of channels retrieved from GLSDB. According to [12] decision making in an organized manner is better decomposed into priority of choices. With proposed class of user type profile and roles defined in table 1 and list of available channels retrieved from GLSDB a multi criteria decision making method is used to select preferred channel for specific use by the user profile.

In basic terms the method according to [12] uses ratio scales from paired comparisons in order to analyse and make final decision. AHP is composed of the following steps:

- Step 1: Decompose the decision making problem into a **hierarchy**
- Step 2: Organize **pair wise comparisons** and start priorities among the elements in the hierarchy.
- Step 3: **Combine** judgements (to obtain the set of overall or weights for achieving your goal).
- Step 4: Evaluate and check the **consistency** of the judgements.

In this paper pair wise comparison is explained by an example. The paper proposed the following parameters Bandwidth, Availability and TX Power which are spectrum elements. Let us use the first two parameters Bandwidth and Availability to compare against each other in order to select the best requirements for user profile type GdU. The comparison selection makes use of relative scale to measure how much you like the bandwidth on the left (Bandwidth) compared to the (Availability) on the right. Relative Scale depicted below. However, prior we can use the relative scale the following rules must be adhered to all the time:

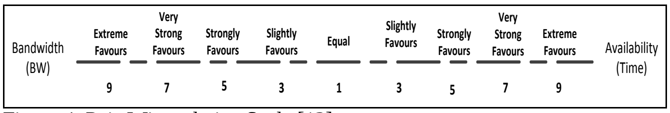

Figure 4: Pair-Wise relative Scale [12]

The pair wise relative scales uses two rule approach to manage how the comparisons are made and judged against each other [12].

Rule:

1. *If the judgement value is on the **left** side of 1, we put the **actual judgement** value,*
2. *If the judgement value is on the **right** side of 1, we put the **reciprocal** value.*

The number of comparisons illustrated by:

$$\frac{n(n-1)}{2} \tag{5}$$

Where n Number of comparisons

The pair-wise comparison output is used to make a reciprocal matrix. In comparing the Bandwidth & Availability, Bandwidth & TX Power and Availability & TX Power parameters the following matrix is created from the comparison results:

		Bandwidth	Availability	TX Power
User Profile (GdU/SiU/CrU) =	Bandwidth	1	X1	X2
	Availability	1/X1	1	X3
	TX Power	1/X2	1/X3	1

Figure 5: Matrix formula [12]

The general form of the comparisons is:

$$\text{User Profile} = \begin{pmatrix} \square & \cdots & \square \\ \vdots & \ddots & \vdots \\ \square & \cdots & \square \end{pmatrix} \tag{6}$$

Priority Vectors: (How to compute Eigen Value and Eigen Vector)

In this paper the method, using a 3 by 3 reciprocal matrix from the paired comparison is used to compute priority vectors. According to [12] step by step must be followed to compute both Eigen value and Eigen Vectors and then normalize the matrix. Normalizing the principal Eigen vectors is also known as generating the priority vector.

Priority Levels [H M H]

Goal	Gold User (GdU)			STEP 1.b 3rd root of product	STEP 1.c Priority vector (weights)
	Bandwidth	Availability	Tx Power		
Bandwidth	1.000	9.000	4.000	3.302	0.717
Availability	0.111	1.000	0.250	0.303	0.066
Tx Power	0.250	4.000	1.000	1.000	0.217
Sum	1.3611	14.0000	5.2500	4.6048	1.0000
Sum x PV	0.9760	0.9208	1.1401	3.0369	
λ-max	3.0369				
CI	0.0184				
CR	0.0318	Consistent			

Figure 6: Proposed Matrix for Gold User (Gdu) IEEE 802.22 (WRAN) [3]

So, the normalized vectors the sum of all elements in priority vector is equal to 1. In our example above on figure 5, Availability is 71.7 %, Bandwidth is 6.6 % and TX Power is 21.7 %. Best Channel Selection Cbest most preferable parameter is Bandwidth, followed by TX Power and Availability. Now, knowing their priority we can check the consistency of Cbest answer by using the following formula (7).

[12] provided proof that consistent matrix; the largest Eigen value is equal to the number of comparisons or is defined as;

$$\lambda \max = n \tag{7}$$

Then measure of consistency known as Consistency Index as deviation or degree of consistency using the following formula;

$$CI = \frac{\lambda \max - n}{n-1} \tag{8}$$

Thus in our previous computation example, we have λ_{max} = 3.0369 and three comparisons or $n = 3$, thus the consistency index is;

$$CI = \frac{\lambda \max - n}{n-1} = \frac{3.065}{3-1} = 0.0324 \tag{9}$$

The index is now calculated and [12] proposed the use the index by comparing it with the appropriate one. The appropriate CI is called Random Consistency Index *(RI)* shown in the table below

TABLE 2: RANDOM CONSISTENCY INDEX (RI) [12]

n	1	2	3	4	5
RI	0	0	0.58	0.9	1.12

$$CR = CI/RI \tag{10}$$

If the consistency ratio is less or equal to 10% then [12] proposes that the inconsistency is acceptable. However, if the consistency according to [12] is more than 10% inconsistency is not acceptable and revision of the judgement is done.

D. Proposed Channel Decision Hierarchy Technique

In this paper the proposed Channel Decision Hierarchy structure is based on the goal of selecting the best available channel. The hierarchy consists of three layers. The first is defined as layer 1 and called Level 0 – “Goal of the structure”. The goal is meant to define the purpose of the decision we are searching for. The second layer is called a level 1- criterion which is using the defined user type profiles GdU, SiU, and CrU users. The user profiles assist in narrowing down the requirements to fulfill the QoS requirements for each specific user. The third layer is called Level 2-Sub-Criteria, which is the three defined parameter properties from channel information.

The three parameters data is used to verify the QoS requirements on each channel are made available whether it can serve for broadband requirement or not. So, it is important to understand the properties of these channels to manage other related issues such as how much time its available for SU and interference with PU. The last layer is called Level 3 – Possibilities and these are list of channels retrieved from the GLSDB. The proposed AHP Hierarchy depicts how the Selection of the best available channel will take place.

In Summary, figure 7 shows how the proposed AHP works to conclude the final selection of the best channel. The analysis verifies various conditions to ensure the selected channel is based on fairness and consistency. The process of normalising the principal Eigen vector is known as “generation of the priority vector”. This process assists with obtaining the relative weights between channels that are compared. Moreover to the priority vector consistency of the selection answer can be verified by using the principal Eigen value. In paper [12] the consistency is proved, and it follows that the highest Eigen value is equal to number of comparisons made.

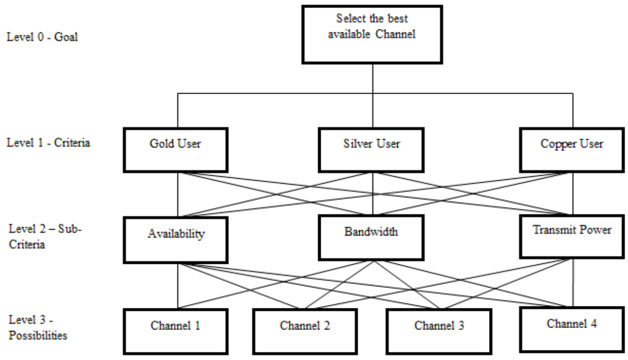

Figure 7: Proposed AHP Select Best Channel Available [12]

IV. SIMULATION AND RESULTS ANALYSIS

The simulation environment is based on the system model architecture. The simulation parameters below indicates the inputs to setup the simulation. For instance, it starts by receiving the list of available channels out of RGLDB, through WSD. The WSD in turn run the AHP Process using criteria set on user profile and SSTB facilitating the best selected channel to the end device.

The simulation environment depicted below in figure 8 explains the area of Geo-Location Database as fully simulated for this study as the required user profiles do not have similar requirements and hence simulation. The proposed user profile and role depicted in Table 1 above.

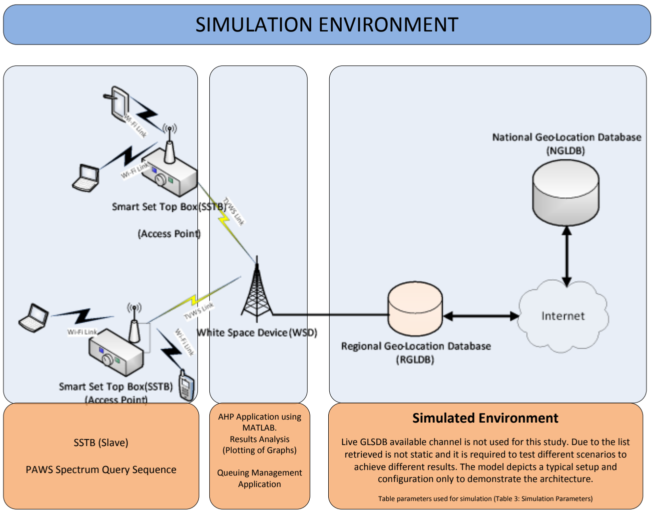

Figure 8: Simulation Environment

The WSD simulation ensures that for the received available spectrum for SU, the proper decision is made based on the profile and parameters requirements. The simulation environment uses MATLAB version R2013a to run AHP process and for this study the results are plotted on graphs for analysis (see figure 9). The AHP process uses the user profile defined as main criteria, spectrum parameters to select the best available channel for SU to occupy for allowed specified time as sub-criteria and list of available channels as level of selection possibilities.

TABLE 3: SIMULATION PARAMETERS

Simulation Parameters	
No of available whitespace channels in RGLDB (N)	12
No of white space device (WSD)	1
No of SSTB/Gold User/Silver User/Copper User	2/3/4
Typical Channel Sizes (MHz)	1/5/8
Typical Transmission (Tx) power ranges (dBm)	17/22/36
Typical available time (Min) – GdU/SiU/CrU	1440/720/60
No of RGLDB	1
GLDB query interval time (Hrs.)	30min/1hr

The spectrum selection is using PAWS technique and the queuing mechanism is proposed to manage the seamless handover, from occupied channel and not lose the workload in processing already. The spectrum list from GLSDB is based on fixed availability time and transmits power. However this paper proposed the user service profile and requirements based on IEEE standards to define each service QoS requirements depicted under Table 1. This paper further investigates to use deterministic queuing model to manage handoff during the expiry of the SU channel usage. The simulation parameters as depicted in Table 3 provide different results to verify selection performance from different user profiles.

E. Selected Available White Space Spectrum

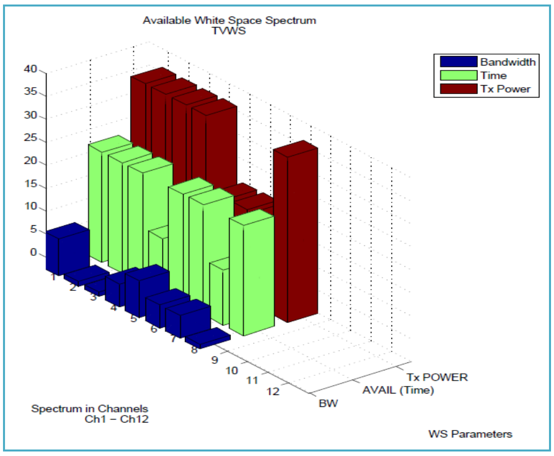

Figure 9: Selected Available TVWS Channels

Figure 8 indicates TVWS selected available channels results showing eight best channels out of twelve channels being queried from simulated geo-location database. Bandwidth with highest 8 MHz and lowest 1 MHz between channel 1 and 8 has been selected. From channel, 9 – 12 there is nothing to select hence returned zero for all three parameters. Availability of these channels for SU to use is from 24 hours and 12 hours. In figure 8 time availability is depicted in minutes the highest been 1440 minutes and lowest time been 720 minutes. The returned TX power for the eight selected channels is 36 dBm and 20 dBm.

The GLDB provides TVWS devices with operating parameters for any given location, which includes available white space channels, transmission power limits, duration for which the WS will be available for use.

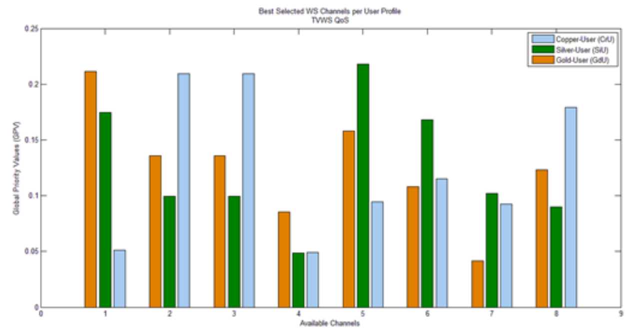

Figure 10: Best selected WS channels per user profile TVWS

Figure 9 indicates all eight selected channels meet the QoS requirements, however Channel 1 provides better QoS for GdU user profile and channel 5 gives second best QoS for GdU user profile. Channel 2 and 3 has equal QoS requirements, which are suitable as third option. For instance there is more demand for GdU these channels are able to meet the demand and fulfil the QoS without any failure.

The simulation would select channel 1 as the best channel to serve the SU, which meets QoS requirements. The GdU requires bandwidth to be high and priority vector weights indicate 0.717%, availability priority is set to be medium with priority vector weights of 0.666% and TX power priority is set to be high and its priority vector weights indicates 0.217%. The bandwidth of channel 1 is 8 MHz which meets the simulation parameter threshold, it is available for 24 hours and also it's transmit power level is 36 dBm within the protection rule of GLDB. The availability of channel 1 is more than required and makes this channel to be the best to fulfil the QoS requirements. The PU in this instance is not vulnerable to interference. The individual priority vector (weights) meets the priority criteria set in the simulation as indicated as [H M H].

V. CONCLUSION

In this paper, a selection technique based on PAWS protocol to access TVWS database and use of AHP based decision technique was proposed. The simulation used system model architecture to setup Geo-Location database using PAWS and JavaScript Object Notation (JSON) to establish the communication between the GLSDB and SSTB was proposed to act as white space access point. The simulation using PAWS algorithm retrieved twelve (12) white space channels eligible for selection based on QoS requirements as defined in the user profile table. We then introduced AHP technique multi-criteria decision-making method to select best answer out of many choices. During simulation AHP technique is eligible to select the best available channel to serve user profiles from eight white space channels out of twelve as shown in figure 9. We then use defined user profiles requirements through MATLAB simulation AHP algorithm to select best available channel which satisfy QoS needs.

The MATLAB simulation is not performing any detection or sensing of spectrum from TV broadcasting network. We make use of geo-location database instead of full cognitive functions of detecting available spectrum not the intention of this paper. In conclusion, we were able to come up with selection technique algorithm which finally uses the user profile to select best available channel to service the WS end user.

Future work includes full integration of AHP based scheme with queuing techniques; in order to proactively manage dynamic channel handovers without any harmful interference to primary users.

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REFERENCES

[1] A. Kumar, J. Wang, K. Challapali, and K. G. Shin, "Analysis of QoS Provisioning in Cognitive Radio Networks: A Case Study," *Wireless Pers Commun,* 2010.

[2] P. Vinutha and J. Sutha, 2014 "QoS Parameter Optimization for Cognitive Radio Networks," *International Journal of Advanced Research in Computer Science & Technology (IJARCST 2014),* vol. 2.

[3] M.T. Masonta, T. Olwal, F. Mekuria, and M. Mzyece, "Standard Compliant Channel Selection Scheme for TV White Space Networks," 2014.

[4] D. Venkatesan and S. Sathishkumar, "A Novel Approach to Real Time Spectrum Handoff," *IOSR Journal of Computer Engineering (IOSR-JCE),* vol. 9 pp. 36-40, Jan - Feb 2013 2013.

[5] S. K. Bose, "Priority Operation of The M/G/1 Queue," ed, 2002.

[6] W. Feng, C. Zhou, and W. Jiang, "Dynamic Channel Allocation Based on the Game Learning in Cognitve Radio Networks," vol. , 2010.

[7] J. Xiang, "Resource Management and Optimization for Cognitive Radio Networks," Philosphiae Doctor, Faculty of Mathematics and Natural Sciences, University of Oslo, 2011.

[8] F. Hessar and S. Roy, "Resouce Allocation Technique for Cellular Networks in TV White Space Spectrum," 2014.

[9] B. Ishibashi, N. Bouabdallah, and R. Boutaba, "QoS Perfomance Analysis of Cognitive Radio-based Virtual Wireless Networks," 2008.

[10] B. Canberk, I.F. Akyildiz, and S. Oktug, "QoS-Aware User Cohabitation Coordinator in Cognitive Radio Networks," presented at the Globecom 2012 - Cognitive RAdio and Networks Symposium, 2009.

[11] I. E. T. F. (IETF), "Protocol to Access White-Space (PAWS) Database," ed, 2015.

[12] T. L. Saaty, "Decision making with the analytic hierarchy process," *International Journal Services Sciences,* vol. 1, 2008.

[13] Mancuso A, Probasco S, and P. B, "Protocol to access white-space (PAWS) databases: Use cases and requirements," 2070-1721, 2013.

[14] S.F. Uddin and I. K. Khattak, "Spectrum Selection Technique to Satisfy the QoS Requirements in Cognitive Radio Network," Master Thesis, Electrical Engineering, Blekinge Institute of Technology, Sweden, 2012.

[15] Y. H. Kim, "IEEE 802.22 WRAN Overview," ed, 2010.

[16] G. Chouinard, "The IEEE 802.22 WRAN Standard and its interface to the White Space Database," ed, 2011.

[17] D. Lim, "TVWS Regulation and Standardization (IEEE 802.11af)," ed, 2013.