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A Novel Channel Selection Algorithm in Cognitive Radio Networks

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Abstract: Cognitive radio networks (CRN) are smart communicating networks, where the spectrum is shifted to different **white holes**, without disturbing the communication. Opportunistic Spectrum or Dynamic Spectrum Access has been applied for spectrum rarity thereby increasing energy efficiency and throughput. The basic concept in the proposed work is Route selection and channel selection among the available channels. In our work we propose a novel optimal channel selection algorithm, Enhanced Channel Selection Algorithm (ECSA), by considering interweave approach of Cognitive users among the Primary users. By using Matched filter detection method, all free channels are identified and Kalman filter has been applied to identify the optimal channel among the identified ones. Numerical results of the work have been plotted by implementing the proposed work and compared with state of the art algorithms using NS2.

Keywords: Cognitive radio networks, Opportunistic Spectrum Access, Channel Selection, Kalman Filter, Update Phase, Predict Phase

1 Introduction

Wireless Networks emerged to a greater extent where the nature of a radio device is expected to support the bandwidth issues and Quality of Support (QoS) issues as well [1]. As per [2], Radio Spectrum a priceless technology that uses the concept of radio waves of the range 3Hz to 3THz. In India, as mentioned in [3], though the availability of spectrum is in the range from 9 kHz to 1000 GHz, much of spectrum (less than 100 GHz) is not exploited due to lack of scalability and inadequate equipment. Few applications of the radio spectrum are public telecommunication services, military services [4], seismic surveys, radars, natural calamities forecasting, etc.To deal with a policy document on the spectrum, National Frequency Allocation Plan (NFAP) has been developed, to advertise the small amount of spectrum for few geographical locations. Fig.1 gives the general spectrum band usage globally [5]. Currently, we live in the era of Ultra High Frequency (UHF) and Super High Frequency (SHF) i.e 4G. Frequency is not the only characteristic of a spectrum [6], user environment; time and space are also considered during spectrum sharing. Since telecommunications works on frequency, enormous research and introduction oi cognitive radio are bring given in [7]. Spectrum sharing are classified in various patterns such as spectrum leasing and trading, in band sharing, reusing licensed spectrum either by low power radios or ultra-wideband radios(UWB) [3]. In latter case, its an unlicensed technology which works in the absence of licensed basd. This leads to the new and next generation of networks called Cognitive Radio (CR) technology. CR was recommended by J. Mitola in his paper [8], by defining CR as *Radio resources and further computer-related communications as per user's needs can be determined intelligently by the Wireless Devices in all layers of Communication protocol.*

Haykin in his paper [9] worked on the lower layers of protocol stack using the concept of Mitola, in Wireless networks and classifies spectrum band into three forms: Black Spaces, Gray Spaces, and White Spaces. White spaces are spectrum free band whereas the other two suffers interference. CR uses this white spaces for detecting the 'empty space' for dynamic access, hence the name '**Spectrum Holes**' [10].

Radios of Cognitive network astutely alter their frequency according to situations like fading, interference, etc. Interference occurs due to the location of radios, signal power, channel gain, etc. Generally two

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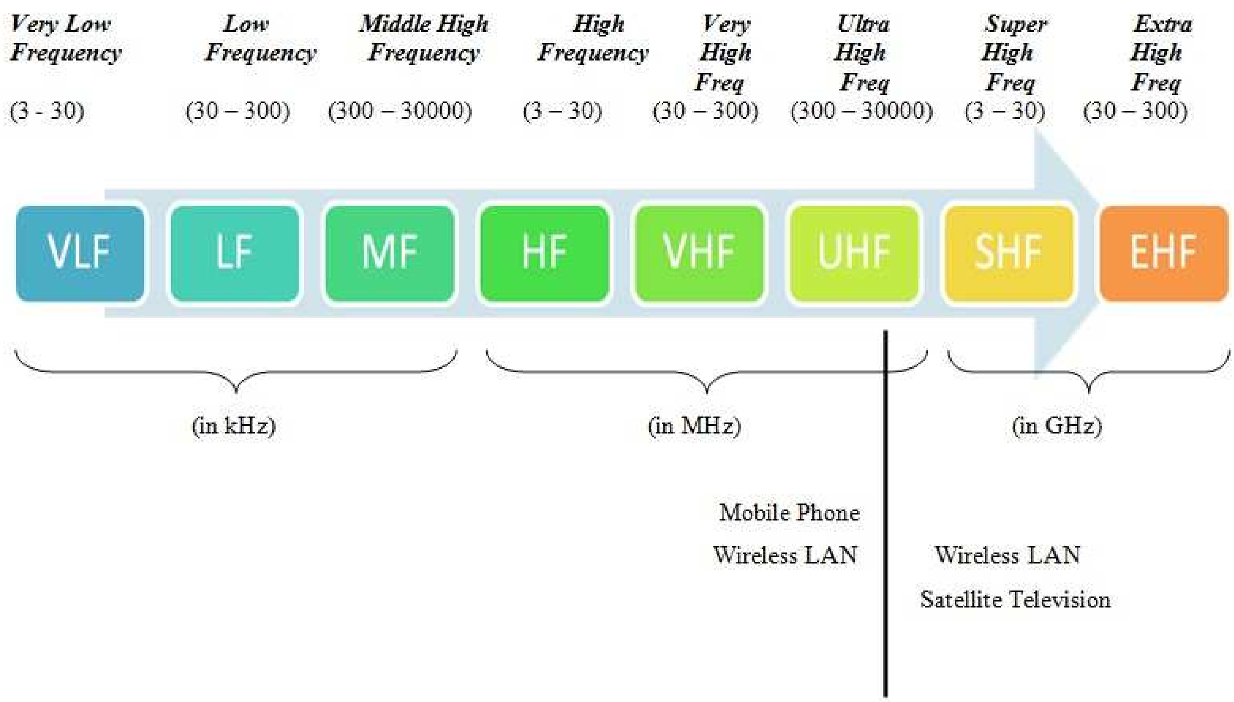

Fig. 1: General Spectrum Band Usage

forms of users available in CR networks namely Primary user (PU) add Secondary user (SU). PUs are licensed users who can operate in their allocated spectrum band. SUs are unlicensed users who can tap a spectrum without disturbing PU [11]. Therefore, SUs (also called as CR users) should functionalize more in either licensed oc unlicensed network. Cognitive radio networks are constructed on the basis of Opportunistic spectrum access (OSA) a.k.a Dynamic Spectrum access (DSA). Numerous research on MAC techniques, elements, and a classification for OSA has been discussed [12], in detail.

Exploiting of spectrum bands by the SUs in a cooperative fashion has been discussed in [13]. PUs spectrum band can be shared with SUs without disturbing it through spectrum sharing techniques like underlay, overlay and interweave [10].

Fig.2 describes the underlay, overlay, interweave spectrum sharing techniques with Frequency in X axis and Power density in the Y axis. PUs is mentioned in curved lines and SUs are in the rectangular box.

The cognitive radio network follows a spectrum cycle that includes four operations namely Sensing, Analysis, Reasoning and Adaptation.[14] [Figure 3]

Sensing Operation: Discovery of empty slot spectrum holes to avoid i.e Detect and avoid (DAA) [3] interference with PU. An effectual way to discover empty slot is by means of detecting the PU movement. Several spectrum

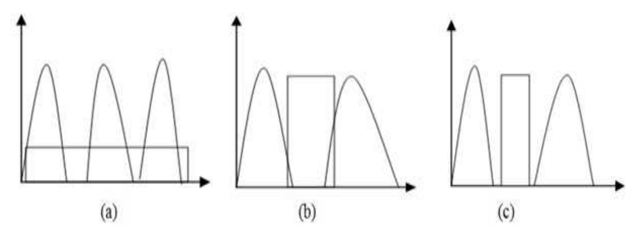

Fig. 2: (a) Underlay (b) Overlay and (c) Interweave Spectrum sharing technique
Frequency in X axis and Power density in Y axis; PU Curved line, SU Rectangular box

sensing methods like energy detector, matched filter detector, etc can be used to detect PU movement. [15]

Analysis Operation: Finding of all available spectrum based on the spectrum sensing are considered. This operation is also called as ′orientation operation′

*Reasoning Operation:*Based on user’s requirements, one which is the best spectrum band that meets the QoS has been decreed for usage.

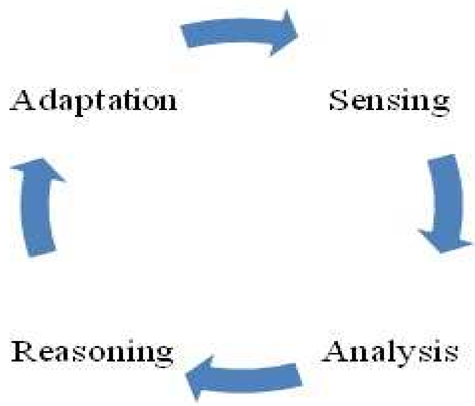

Fig. 3: Spectrum Cycle in a Cognitive radio [14]

Adaptation Operation: Any CR device has to integrate with dynamic characteristics like frequency, modulation, transmission power, communication technology, etc. [11]

2 Applications of Cognitive radio networks

In [8], as mentioned by J. Mitola, Cognitive Radios have the knowledge to alter its antennas position according to their available environment. Due to this capability, CRs has its own applications in many fields like Medical Body Area networks, military communications and authentication purpose. WBAN contributes an intelligent way of tracking the medical records and details of a patient remotely through Cloud Computing, [16] are possible through CR technology. Remote observation of patients health condition is possible for a doctor who is in far place.

Wireless networks may get disconnected due to natural calamities like earthquakes, land sliding, etc., that leads to nil communication to the outside world. During such scenarios CR technology creates an instant emergency network despite of location [4]. Multimedia applications like audio, video or live streaming requires high bandwidth. Networks either wireless or sensor, embedded with CR technology utilizes bandwidth and provides a faster access of data [4]. Voice recognition plays a vital role in authentication.

Voice recognizer after acquiring the signals, are encoded with VoCoder and transmitted. [15] Authenticity of an individual is performed by the CR radio which is embedded on the recognizer. Vice versa works at the receiver end. Apart from [15], CR radio plays an important role for military soldiers in warfield [17]. This article [17] discusses in detail about difficulty of the soldiers who battled with radios of high interference and non scalable single radio. The big solution was Software Defined Radio and Cognitive Radio.[17] [4]

The rest of the paper is organized in the following manner. Section 3 comprises about the Literature review of various interweaving algorithms of Cognitive radio networks. Section 4 discusses about the comparison of algorithms. Section 5 concludes the work and the references used for the work are presented.

3 Literature Review

Various research has been proposed for interweave channel assignment schemes and Asifuddola et al., [18] were the first authors to propose the idea of Vacate on Demand (VD) algorithm in CR networks. Hopping algorithm has been used for allocating channels for CR users based on the ranking table in a minimal time. Each CR users have their own secure hopping sequence which is used during data communication among other CR users. So, whenever the PUs arrives at its respective spectrum then CRs ought to be cleared and a new spectrum location will be allocated to it instantly to a channel. e.g channel id N/2. If N/2 is busy, CR hops to its ascending and descending direction, till it finds an empty space. (i.e +3N/4 to -3N/4). Based on the occurrence of PUs, sensing results are calculated and a further ranking table is built headed with shortest PU movement towards fullest occurrence. Working of [18] has been implemented and compared for various PU loads, whereas in [19] adaptive multiple rendezvous control channels (AMRCC) introduces varying frequency hopping sequence based on the PU movement has been arranged in a ranking table. The advantage of this method [19] is synchronization of sender and receiver by exchanging SYNC packets and able to accept new users at any time.

In [20],like OSA, where harmonizing and to amend the radio spectrum, Spectrum Load Balancing (SLB), which uses OSA scheme in order to support non-interference of PU channels. SLB uses integration technique, where every user has to know other users spectrum, before allotting for themselves. Proposal of Channel ranking based channel hopping scheme (CRCH) given in [21] which uses linear optimization and channels are ranked based on the movement of both SUs and PUs.

One of the most popular sensing technique - Cooperative Spectrum Sensing is used in [22] to detect the idle spectrum bands. Moreover, a channel with less collision/contention based on probability has been proposed in this work. Scenarios based on all channels busy or single idle channel available are discussed for SU users. Availability of channels using a three state spectrum sensing model has been introduced in [23] hence we can conclude that whether PU occupies the channel or SU from other network occupies it. Justification of throughput in the work is done by using Markov chain model in a co-existing cognitive radio network.

From [18] [23], prior information about the movement of primary users is required to access a channel by an SU. In [24], superior information about the PU channels is not required and by using the intuitive spectrum sensing, SUs access the PU free channels. Also from [25], optimal stopping rule is used to increase the throughput of SUs, in which the state of SUs can be stopped and resumed depends on the Markovian channel gain. In Cognitive Radio Ad Hoc Networks (CRAHNs), channel with less colliding level has been selected as the "best channel " from the collection of unused primary channels [26] that uses cooperative spectrum sensing for figuring out the number of SUs occupying the spectrum holes, thereby increasing the throughput by 70 %.

4 Proposed Model

In Cognitive radio networks, to achieve the Dynamic Spectrum access (DSA) and channel estimation, states of the channel are estimated under several ways. Few of them are Bayesian Estimation, Markov Model, Gaussian Probabilities Model, Kalman Filter, etc. [27]. In our proposed work, exploration for empty spectrum holes is performed by using Kalman filter. Since PUs and SUs are infrastructure less, there is a possibility for interference among them which leads to Noisy signals. For filtering such noisy signals and also to predict the next available spectrum band in a short duration, we use Kalman Filtering. The proposed network is a nonlinear one i.e not continuous, with varying measurements. To measure such varying values, Extended Kalman Filter has been used to support the varying input and output [28]. It uses covariance matrix for correlating the channels/values to each other.

In our proposed work, Matched filter detection (MFD) has been used since information about the PUs is already known by SUs [29]. QoS parameters of PUs are also known and passing those parameters through a filter and hence interference is minimized and signal noise ratio is maximized. The below equation defines the matched filter detection [30]

$$Y(n) = \sum_{i=-\infty}^{\infty} Im[n-i]z[i] \tag{1}$$

where Y(n) is the output of the signal; z[i] unknown signal depends on the impulse response of the matched filter Im(n) and to achieve a perfect SNR, values may be compared with a reference signal. The following notations are used throughout the work.

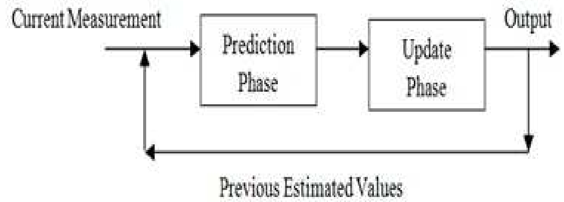

Fig. 4: Kalman Filter Cycle

The two main operations or phases of Kalman filter are: Predict and Update [28]. Predict phase refers to the present state of a node, at a particular time. The current measurement and previously estimated values are given as input, in this phase. This phase is also called as "prior " state estimate since previously estimated values are known before computing the next value. In Update phase, a finely tuned value of a state which is a combination of predict and present state are taken part for calculating Kalman gain at a given time. It is also called as "posterior " state estimate whose calculated values are circulated as feedback for prediction. Fig. 4 describes the Kalman Filter cycle.

SU users sense the radio environment for satisfying the QoS requirements (like delay, interference, noise, etc). Each SUs senses the channel to detect any spectrum hole (i.e spectrum which is available and free from PU) [13]. Various spectrum sensing techniques like energy detection, matched filter detection, cyclo-stationary feature detection; etc can be used for sensing the spectrum. Spectrum sensing is described in the following equation:

If s(t) is absent

$$X(t) = n(t) \tag{2}$$

If s(t) is present

$$X(t) = s(t) + n(t) \tag{3}$$

where s(t) is the primary user signal and n(t) is the Additive White Gaussian (AWGN)noise signal received along with the PU signal and X(t) is the total signal received at the receiver.

Notations Used:

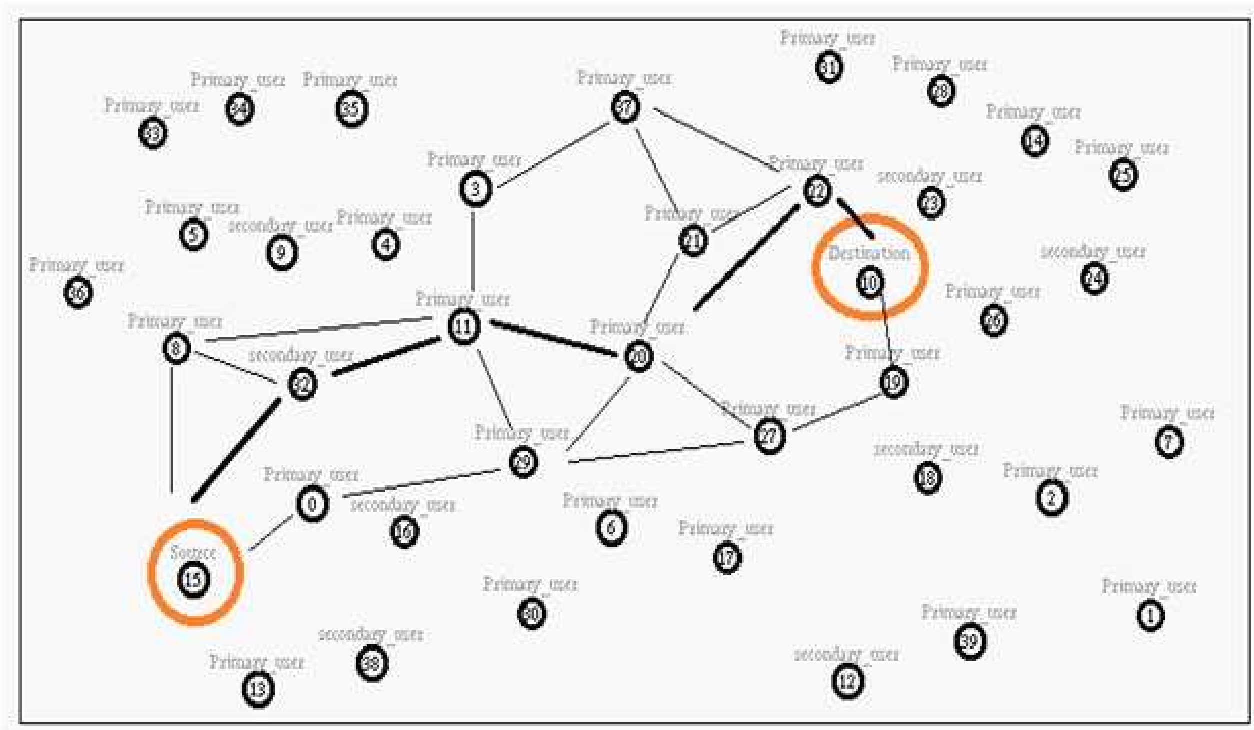

Fig. 5: Optimal Route after using Kalman Filter is: $15 - 32 - 11 - 20 - 22 - 10$

$x_t \rightarrow$ Current Value at time t

$y_t \rightarrow$ Estimated Value at time t

$\alpha_t \rightarrow$ Time variation at time t; n dimensional vector

$P_t \rightarrow$ Estimate Error Covariance

$R \rightarrow$ Covariance matrix, of white noise

$K_t \rightarrow$ Kalman Gain at time t

$z_t \rightarrow$ Estimation of available BW at time t

$M \rightarrow$ Measurement matrix

$v_t \rightarrow$ Measurement White Gaussian Noise with Zero mean and covariance R

Corresponding equations of Predict and Correct/Update phases as given in the following (4) and (6)

Predict Phase:

$$x_t = x_{t-1} \tag{4}$$

$$P_t = P_{t-1} + \alpha_{t-1} + R \tag{5}$$

Update Phase:

$$x_t = x_t + K_t(z_t - x_t) \tag{6}$$

$$P_t = (1 - K_t)P_t \tag{7}$$

$$\text{where } K_t = \frac{P_t}{P_t + R} \tag{8}$$

$$\text{and } z_t = M(x_t) + v_t \tag{9}$$

The state transition matrix is a matrix, T , which is given as follows:

$$T(t) = {}^{\partial\alpha_t}\!/_{\partial x_t} \; \left| x = x'_{i-1} \right\rangle \tag{10}$$

where x'_{i-1} is the state estimate identified from kalman filter after the update phase.

Table 1: Simulation Parameters

Channel Type	Wireless
Propagation Model	Two Ray Ground Model
MAC Type	802.11
Antenna Model	Omni Antenna
Max. Packet Length	50
No. of Mobile Nodes	40
Routing protocol	VD/CAC/ECSA
Source Node	15
Destination Node	10

After estimating the possible free channels (Ch_{est}), to find the optimal channel among the idle channels are given as input to the Kalman filter for assigning the best channel under noise channel $(Ch(i)_{no})$ which is explained in the following algorithm.

Enhanced Channel Selection Algorithm

Input: Possible idle channels (Ch_{est})

1. Ch (i) = Ch $(i)_{no}$
2. If Ch(i) = = Ch$(i)_{no}$
   Kalman_Prediction of Ch$(i)_{no}$
   Else
   Kalman_Update (Current, Previous)
   Estimate the frequency of Channel Ch(i)
   Store Ch_{est}
3. Repeat step 1 to step 2 until one Ch_{est} is received

Output: Optimal Channel for particular timeslot is selected

5 Simulations and Performance Evaluation

Here we present the simulation and the performance evaluation of the proposed work. The performance of the proposed ECSA protocol is evaluated using NS2 simulator. The QoS parameters considered for evaluation are: Energy consumed, Delay, Throughput, Expected time to get an optimal free channel. [31]

The simulation parameters are tabulated in Table 1. The simulation consists of 40 mobile nodes in which few nodes are assigned as Primary Users and others as Secondary Users. The routing protocols: Vacate on Demand (VD), Contention Aware channel selection and Enhanced Channel Selection Algorithm are used for forwarding the data packets from Source 15 to Destination 15. Three different routes are identified from source to destination and the one given in dark lines are the optimal route based on the proposed work given in Figure 5. The evaluation parameters like Energy consumption, delay, throughput etc are calculated on using an interface as shown in Figure 6.

Fig. 6: QoS evaluation parameter interface

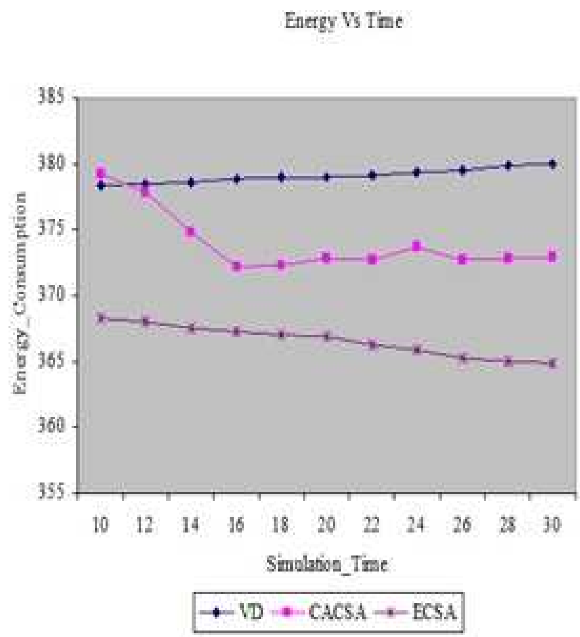

Fig. 7: Energy Consumption Vs Simulation Time

Figure 7 describes about Energy consumption in cognitive radio, which is defined as [32], is the amount of energy required to find a new channel and the amount of energy to search for this new channel. The energy consumed by VD, CAC and ECSA are plotted (in seconds) using trace file and given in Table 2.

Delay in cognitive radio occurs due to the spectrum sensing of radio environment. The delay values are plotted (in seconds) using trace graph, which is described in Figure 8 and given in Table 3.

In CR network, Throughput may be defined as the number of data packets that reach the destination in a given time.

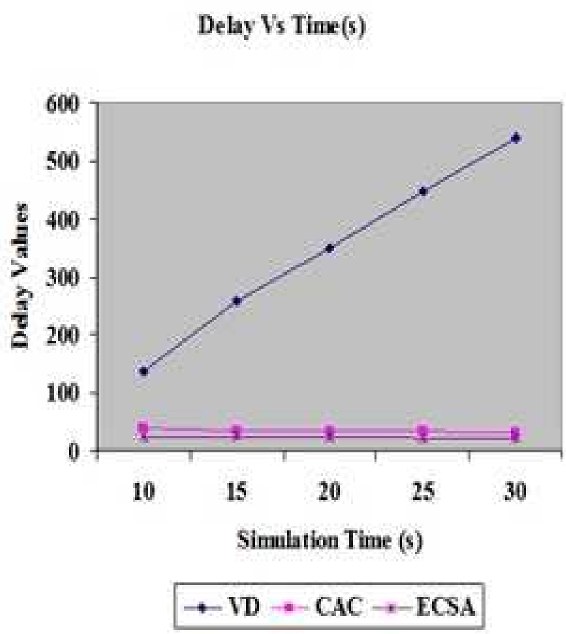

Fig. 8: Delay Values Vs Simulation Time

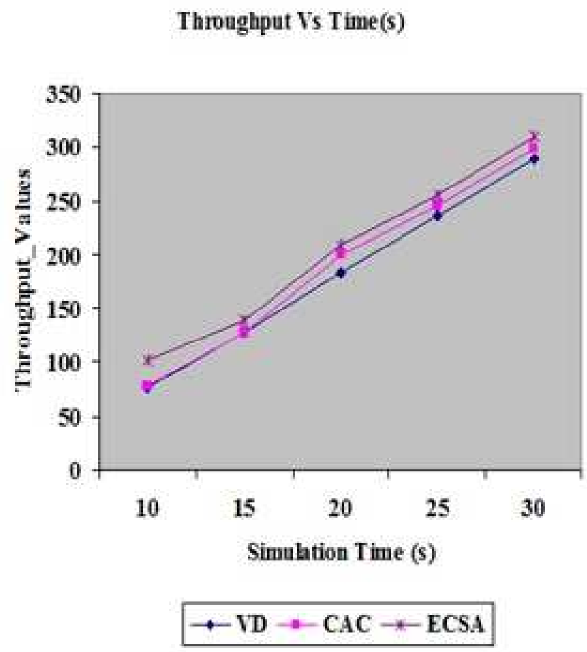

Fig. 9: Throughput Values Vs Simulation Time

[13]. The throughput values are plotted (in seconds) using trace graph, which is described in Figure 9 and given in Table 4.

Expected time to get a free channel [18] in a given time has been calculated and plotted (in seconds) using trace graph, which is described in Figure 10 and given in Table 5.

6 Conclusion and Future Direction

In this work, we proposed an optimal channel selection algorithm for assigning the channels to a secondary user. It uses Kalman filter for identifying the best channel among all the feasible channels. Either predict or update phase is considered for the input channel values in a noisy environment. Simulation results show QoS metrics like delay, throughput, energy efficiency and the estimated time to get a free channel for the proposed work are better when compared to VD and CAC algorithms. As an extension, the proposed channel assignment algorithm can be applied.

A comparison of Vacate on Demand(VD), Contention Aware channel selection (CACSA)and Enhanced Channel selection Algorithm(ECSA) are given in Table 6.

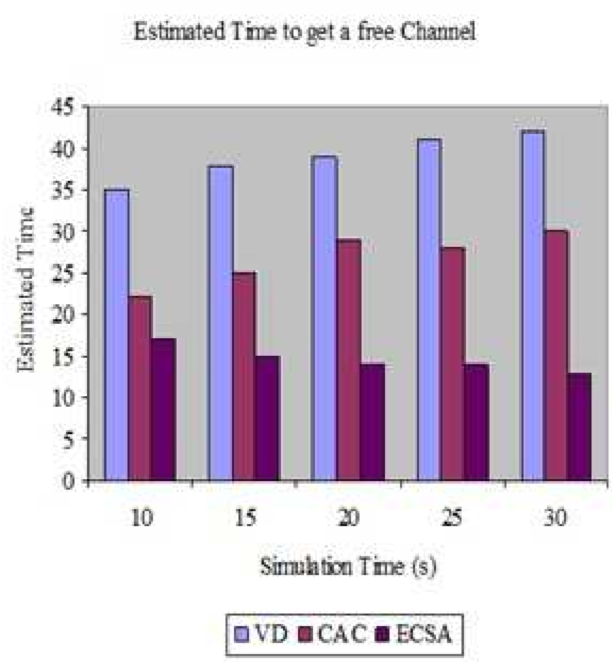

Fig. 10: Estimated Time to get a free channel Vs Simulation Time

Table 2 Energy Consumption Values Vs Simulation Time (seconds)

Simulation Time (seconds)	Vacate on Demand (VD)	Contention Aware Channel Selection (CAC)	Enhanced Channel Selection (ECSA)
10	878.301	879.339	868.339
15	878.669	879.252	867.252
20	879.038	872.679	866.679
25	879.406	872.406	865.406
30	879.775	872.775	864.775

Table 3 Delay Values Vs Simulation Time (seconds)

Simulation Time (seconds)	Vacate on Demand (VD)	Contention Aware Channel Selection (CAC)	Enhanced Channel Selection (ECSA)
10	138.096	41.0373	26.0373
15	257.796	34.6561	25.6561
20	351.638	33.444	24.444
25	448.702	33.723	23.723
30	538.311	32.234	22.234

Table 4 Throughput Values Vs Simulation Time (seconds)

Simulation Time (seconds)	Vacate on Demand (VD)	Contention Aware Channel Selection (CAC)	Enhanced Channel Selection (ECSA)
10	76.77	78.12	102.12
15	128.24	128.44	138.44
20	183.26	199.26	209.26
25	236.73	245.72	255.72
30	289.98	299.34	309.34

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References

[1] K.P Joshi, S.Y. Nam, S.W Kim, Cognitive radio wireless sensor networks: Applications challenges and research trends, Sensors, **13(9)**, 11196-11228, 2013.

[2] United States Department of Commerce, National Telecommunications and Information Adminstration, Spectrum Wallchart, NTIA, 2016.

Table 5 Expected Time to get a free channel Vs Simulation Time (seconds)

Simulation Time (seconds)	Vacate on Demand (VD)	Contention Aware Channel Selection (CAC)	Enhanced Channel Selection (ECSA)
10	35	22	17
15	38	25	15
20	39	29	14
25	41	28	14
30	42	30	13

Table 6 Comparison of VD, CAC and ECSA algorithms

S. No	VD	CAC	ECSA
Algorithm	Vacate on Demand	Contention Aware Channel selection Algorithm	Enhanced Channel selection Algorithm
Technique used	Channel Hopping Mechanism; Blind Estimation of channels	Optimal Spectrum sensing rule; Stopping and Continuing using Bellman Equation	Extended Kalman filter for prediction and updation
Advantage	No. of hops to get a free channel is less if PU traffic is less than 50%	Multi Channel Design	Optimal Channel selection in a noisy environment
Disadvantage	Searching of free channel in the ranking table increases time	Threshold value increases if the next estimated channel is free hence waiting time increases	Uses the basic channel estimation techniques; can be further extended to other estimation channels.

[3] Department of Telecommunications, Wireless planning and Coordination Wing,National Frequency Allocation Plan report, WPC and DoT, 2013.

[4] R. Bhojray, R. Dash and S. Patra, Cognitive Radio: An Intellectual Network for Future Wireless Communication Systems, International Journal of Computer Networks and Wireless Communications, **6(4)**, 38-45, 2016.

[5] T. Rappaport, R.W Heath, R.C Daniels and J.N Murdock, Millimeter wave wireless communications: Systems and circuit, Prentice Hall, 2015.

[6] M. Altamimi, M.B.H Weiss and M. McHenry, Enforcement and spectrum sharing: Case studies of federal commercial sharing, 2013.

[7] A. Foster, Spectrum Sharing, 8th Global Symposium for Regulators, 2008.

[8] J. Mitola and G.Q Maguire, Cognitive radio: Making software radios more personal, IEEE Personal Communications, **6(4)**, 13-18, 1999.

[9] S. Haykin, Cognitive radio: Brain-empowered wireless communications, IEEE Journal on Selected Areas in Communications, **23(2)**, 201-220, 2005.

[10] S. Kandeepan, G. Baldini and R. Piesiewicz, UWB Cognitive Radios, Novel Applications of the UWB Technologies, Dr. Boris Lembrikov (Ed.), InTech, 2011.

[11] L. Khalid and A. Anpalagan, Emerging cognitive radio technology: Principles, challenges and opportunities, Computers and Electrical Engineering, **36(2)**, 358-366,

2010.
[12] A. Sultana, Fernando Xavier and Zhao Lian, An Overview of Medium Access Control Strategies for Opportunistic Spectrum Access in Cognitive Radio Networks, Springer Peer-to-Peer Networking and Applications,1-20, 2016.
[13] S. Selvakanmani and M. Sumathi, CRCN CORMEN An on demand opportunistic routing protocol for mobile cognitive radio ad hoc networks, ICCCS14, Chennai: Proceedings of IEEE International Conference on Computer Communication and Systems, 265-270, 2014.
[14] A. Khattab, D. Perkins and M. Bayoumi, Cognitive radio networking preliminaries, Cognitive Radio Networks: From Theory to Practice, Springer Science + Business Media New York, 11-20, 2013.
[15] J. Polson, Cognitive radio applications in software defined radio, Proceedings of the SDR Forum Conference, San Francisco, 2004.
[16] S. Selvakanmani, Suresh, Umashankar and Vignesh, Dynamic Monitoring system for patient diagnostic records, International Journal for Scientific Research and Development, **4(1)**, 676-679, 2016.
[17] J. Keller, SDR and Cognitive radio: the new horizons of military communications, Military and Aerospace Electronics: Executive Briefing, 2011.
[18] M.Asifuddola, S. Ram, G. R. Begh and G. M. Rather G M, Vacate on demand algorithm in cognitive radio networks, 2013 IEEE International Conference on Signal Processing, Computing and Control (ISPCC), Solan, 1-5, 2013.
[19] C. Cormio and K.R. Chowdhury, Common control channel design for cognitive radio wireless ad hoc networks using adaptive frequency hopping, Ad Hoc Networks, **8(4)**, 430-438, 2010.
[20] A. Chronopoulos, M. Musku, S. Penmatsa and D. Popescu, Spectrum load balancing for medium access in cognitive radio systems, IEEE Communications Letters, **12(5)**, 353-355, 2008.
[21] A. Hossain and N. Sarkar N, Cross layer rendezvous in cognitive radio ad-hoc networks, 2015 International Telecommunication Networks and Applications Conference (ITNAC), Sydney, NSW, 149-154, 2015.
[22] A. Mesodiakaki, F. Adelantado, L. Alonso and C. Verikoukis, Performance analysis of a cognitive radio contention-aware channel selection algorithm, IEEE Transactions on Vehicular Technology, **64(5)**, 1958-1972, 2015.
[23] Y. Zhao, M. Song and C. Xin, FMAC: A fair MAC protocol for coexisting cognitive radio networks, Proceedings IEEE INFOCOM, Truing, Italy, 1-9, 2013.
[24] H.T Cheng and W. Zhuang W, Simple channel sensing order in cognitive radio networks, IEEE Journal on Selected Areas in Communications, **29(4)**, 676-688, 2011.
[25] V. Vaid, A. Patel and S.N. Merchant, Optimal Channel Stopping Rule Under Constrained Conditions for CRNs, 2014 Twentieth National Conference on Communications (NCC), Kanpur, India, 1-5, 2014.
[26] A. Mesodiakaki, F. Adelantado, L. Alonso and C. Verikoukis, Energy-efficient contention-aware channel selection in Cognitive Radio Ad-Hoc Networks, Barcelona: IEEE 17th International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD), 46 - 5046-50, 2012.
[27] D.M Yan, and J. Wang, Sensor Scheduling Algorithm Target Tracking oriented, Wireless Sensor Network, **3(8)**,295-298, 2011.
[28] J. Haught, K. Hopkinson, N. Stuckey, M. Dop and A. Stirling, A Kalman filter-based prediction system for better network context-awareness, Baltimore: Proceedings of the 2010 Winter Simulation Conference, 2927-2934, 2010.
[29] S. Senthilkumar and C. Geetha Priya C, A review of channel estimation and security techniques for CRNS, Automatic Control and Computer Sciences, **50(3)**, 187-210, 2016.
[30] M. Shahnawaz Shaikh and K. Gupta, A review of spectrum sensing techniques for cognitive radio, International Journal of Computer Applications, **94(8)**, 1-5, 2014.
[31] H. Zhao, E. Garcia Palacio, Y. Xi and J. Wei, Estimating resources in wireless ad-hoc networks: A Kalman filter approach, 2010 7th International Symposium on Communication Systems, Networks and Digital Signal Processing(CSNDSP 2010), Newcastle, 71-75, 2010.
[32] V. Namboodiri, Are cognitive radios energy efficient? A study of the Wireless LAN scenario, Phoenix, Arizona, USA, 28th IEEE International Performance, Computing, And Communications Conference (IPCCC) 437-442, 2010.

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