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Network Selection and Spectrum Handoff based on Adaptive Weights in Cognitive Wireless Networks

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Abstract - *ICT (Information and communication technologies) have revolutionized the way of life and its innovative, efficient and effective use is becoming increasingly a potent factor in the growth of society and economy. Explosive surge in the demand for wireless mobile communications services expects that communication to a mobile device anywhere, anytime and anyplace on the globe will be accessible in the near future. The increased demand of channel and thus effective utilization of spectrum can be solved by using the technique where unlicensed spectrum user may be allowed for using licensed spectrum. Bands of fixed licensed spectrum are limited and very precious resource therefore a new technique designated as CRN (cognitive radio network) is able to solve problem related to scarcity of fixed spectrum for unlicensed users. This technique is recently being deployed with wireless networks for thwart limitations of conventional wireless networks. CR (Cognitive radio) is becoming potent technique in upcoming versions related to wireless communications system. Wireless Delay Tolerant Networks (WDTNs) are used in Intelligent Transportation System (ITS). The number of wireless devices has been increased tremendously on the roads now. Cognitive Radio (CR) has been used by WDTNs. They allow the other wireless devices to use the unutilized spectrum. An innovative technique depended upon PSO (Particle Swarm Optimization) is proposed having minimized handoff delay and increased throughput. Simulation results shows that proposed protocol have better results using PHSCR algorithm. GRA method is used to select the network that is optimal when users' preferences are not considered in CR vehicular networks. In this method relations are established using analysis of availability of spectrum of licensed spectrum with minimum handoff delay. The results obtained prove that the any MADM techniques may be used in selection of optimal network. GRA method helps CR for unused spectrum for the selection of the optimal network for spectral handoff.*

Key Words: Cognitive radio, Delay Tolerant, Spectrum Handoff, MADM and Particle swarm optimisation.

1. INTRODUCTION

Wireless communication networks which pave the way for always connected communication are probably most important means in global ICT strategy, spanning to almost all other industries. Explosive surge in the demand for wireless mobile communications services expects that communication to a mobile de-vice anywhere, anytime and anyplace on the globe will be accessible in the near future. The increased demand of channel and thus efficient use of spectrum can be solved by using an array of antennas mounted on base stations, vehicles, satellites, ships and aircraft.

Significant rise in wireless communication and its applications has led to overcrowding for spectrum bands, degraded communication efficiency as demonstrated by Wang et al (2014) and Zhang et al (2015). Cisco estimated that, World's yearly IP traffic expected to attain 4.8 ZB (Zettabytes) / year or 396 EB (Exabyte's) / month by 2022 depicting a CAGR of 26% for five years (2017-2022). As per Cisco Global Mobile Data Traffic report, expectation is that Global IP traffic will increase threefold over the next 5 years. As far as India is concerned, it witnessed overall mobile data traffic growth by 109 percent in 2018 which is estimated to grow by 11 times from 1.3 EB to 14 EB till 2023. Further, monthly GB/month data usage with each Smartphone in India may observe increment five times starting from 3.9 GB by 2017 to 18 GB in 2023. 'Source: Cisco Visual Networking Index: Forecast and Trends, 2017–2022'.

Intelligent transportation system primarily requires always best connected anywhere wire-less services and thus needs improving the vehicular communication. Increasing number of vehicles on road is causing substantial growth in vehicular communication applications. Consequently, overcrowding of the spectrum bands is posing challenges with regard to quality issues of transport communication. Recently, cognitive techniques are being deployed upon wireless networks for thwart limitations of conventional wireless networks. CR (Cognitive radio) becoming potent technique in subsequent generation related to wire-less

communications system. Cognitive technique (CT) is a process in which knowledge is gained through perception with reasoning as well as regularly upgrading and updating using previous learning.

CR enables to find out the underutilized spectrum contained in license and unlicensed band of spectrum so that underutilized spectrum can be used more realistically. The primary users (PU) who own the license have exclusive right for using spectrum anytime as per their wish, while secondary users (SU) can utilize spectrum if it is vacant and not being using by primary user. In CR wireless communication networks, an idle is selected to be used by the unlicensed user and it is vacated when any licensed user upon channel was detected. CR technique of radio is expected to be a promising processes to improve efficiency of wireless communication networks.

This improves spectrum utilization by achieving the end-2-end goal by increasing efficiency of network. CR proved to be new paradigm regarding wireless communication networks which uses resources of spectrum efficiently and flexibly regarding bursty traffic and reduces packet loss, power waste along with it offers high degree regarding buffer management with improved quality of communication. Today, demands of spectrum is increasing so, use of fixed and available spectrum is not performed. Further, requirements of spectrum is increasing as a result of growth in systems of mobile communication. Barja et al (2011) demonstrated the the cognitive radio techniques to solve this issue. This technology allows secondary users for using licensed bands, in a manner that interference may be neglected. According to US FCC (federal Communication Commission)'s rules and regulations that secondary users may be able to using frequency bands in limited manner.

Technology of Cognitive Radio includes four types of processes. They are 'sensing of spectrum, decision regarding spectrum, mobility of spectrum, and sharing of spectrum'. Spectrum sensing includes the sensing related to all available spectrums. It is crucial in this regards. In selection for best band in using the secondary user's hence minimal interference been present. As a result, secondary users get the related band and transmission gets started. It is the possibility for primary user immediately arrives for occupying its related band. In present situation, secondary users forced for vacant its owned spectrum to primary user and moved towards different vacant and available band. Zekri et al (2012) expressed that handoff spectrum plays an important role for avoiding interference of primary users and it allows use of underutilized spectrum dynamically. Before switching into different spectrum, handoff mechanism is required to gather required information regarding availability of spectrum, most suitable spectrum and prepares in reference to handoff process.

In the case if unlicensed spectrum bands are utilized, handoff strategy required for retaining data transmission. Idle frequency channel is discovered for conducting handoff process. It primarily depends on spectrum sensing. It contains two alternatives in which spectrum sensing may take place. Akyildiz et al (2009) deliberated about before and after triggering of handoff event occurs.

Depending upon triggering time related to handoff, three schemes related to handoff takes place. These includes 'proactive, reactive and hybrid schemes' of handoff. Proactive scheme related to handoff, secondary users continuously checks activity related to primary users. Takagi and Walke (2008) demonstrated for making decision regarding data transmission. Present handoff scheme reflects very less delay of spectrum handoff in case secondary user selects channel which has highest probability, regarding not been in use for definite time. As and when primary user arrived, at that time secondary users be able to sense another channel in idle condition. It is designated reactive scheme related to handoff. Takagi and Walke (2008) mentioned, however this scheme has disadvantage in terms of handoff delay. Hence, by merging these two schemes viz- proactive and reactive, hybrid scheme has been propounded. Obviously, the hybrid scheme is equipped with the advantages related to proactive sensing regarding spectrum and activity of reactive handoff. It is understood that primary users arrive to access their allocated channels quite often and thus the secondary users have to explore other vacant channels and their communication get interrupted. This poses an issue of spectrum mobility and continuous SU data communication. Therefore, hybrid handoff technique is considered as a method to achieve better spectrum handoff time due to absence of spectrum sensing time when handoff process takes place. Takagi and Walke (2008) and Nardis and Guirao (2010) mentioned this concept.

Intelligence techniques containing computation e.g. fuzzy logic as mentioned by Wang et (2010), PSO (Particle Swarm Optimization), ACO (Ant Colony Optimization), etc. may be implemented for improving handoff spectrum for providing uninterrupted connectivity. These are also applied in idle channel's selection required in handoff mechanism.

The selection of optimal network to handoff the spectrum is a difficult task for the CR devices. It can be done through different multiple attributes decision making (MADM) methods like SAW as mentioned by Christian et al (2012), TOPSIS as reported by Ahmed et al (2013), Modified TOPSIS as demonstrated by Afshari et al (2010), GRA as expressed by Hwang and Yoon (1981), PROMETHEE as explained by Deng et al and VIKOR as deliberated by Wei (2011) as different methods.

Mareschal et al (1984) mentioned that some bands of electromagnetic spectrum are heavily loaded while others are unutilized. The license to operate in certain frequency band will be provided by the international or government agencies. Since, nearly entire spectrum band has been already allocated for licensed users, so it is difficult to provide new license or improve the current services. Yu (1973) reported that sometimes usage of frequency bands in a specific region is also minimum.

Users of spectrum can be categorized in two types: primary users who are also designated licensed users and secondary users who are also designated unlicensed users. Licensed users are the one who have the authorization to access the specific frequency band while unlicensed users donot have any authorization for access any spectrum band. CR checks for the available spectrum band and if found available, allocate the available band to the unlicensed user.

The optimized results can be given by the MADM methods which reduces the complexity in making handoff decision of spectrum. A technique for spectrum handoff which uses one of the MADM method had been modeled. This scheme is well modeled with CR vehicular networks. The spectrum hole knowledge is already known prior to spectrum handoff; hence its nature is proactive.

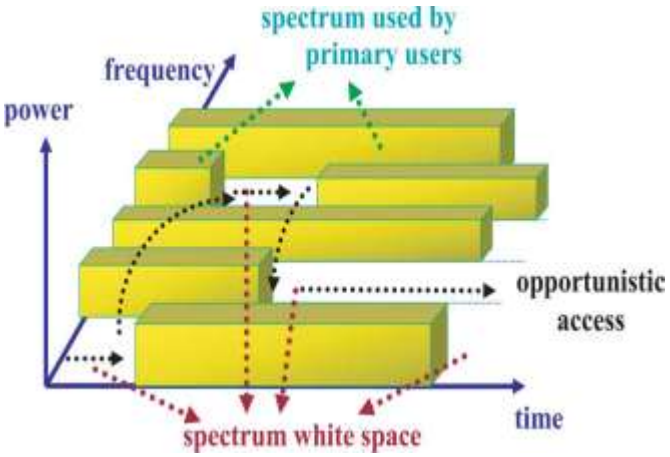


Figure1: Spectrum white space or spectrum hole

2. CR NETWORK ARCHITECTURE

The basic architecture of CR network is presented in Fig. 2. This is evident from fig. that it includes two networks types. They are primary network and CR network. As it is clear that the primary network being the licensed one having special right for using the allocated frequency band. Primary network base stations are termed as the base stations while PUs are identified as different nodes in the primary network.Figure shows that PUs of the primary network possess a special permission for using the allocated band I and II of licensed spectrum. CR network may further be split into CR network based on infrastructure and CR network without infrastructure. A central controller is the part of a CR network based on infrastructure similar to base station into cellular network.

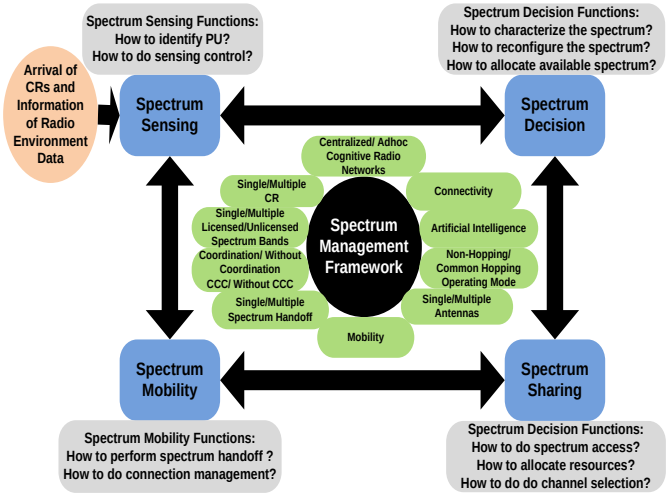


Figure2: CR Network Architecture

On the other hand, no central controller is found in infrastructure less CR network and therefore no user's communication facility is available in infrastructure less CR network. This necessitates the users to facilitate themselves for all the processes in the network.

Heterogeneous CR network is a network comprising a heterogeneous wireless network and CR network. Similarly, heterogeneous CR adhoc network is a combination of wireless network of heterogeneous type and adhoc CR network. The base station and node are termed like CR base station and CRs respectively. In this arrangement, the licensed bands vacated by PUs are utilised by the CR network without having license.

Spectrum is electromagnetic resource of importance and government agencies regulate it, regarding managing the complex issues. Currently, spectrum allocation takes place according to firm allocation policy which includes transmission power regulation and allocation of several frequency bands regarding various services and applications. In last decade huge growth in wireless users and applications take place. Total worldwide users in 2009 were 3.2 billion and it is expected an increment by 100 folds in 2013.Huge spectrum allocation is needed for new applications and it is tough for finding unallocated spectrum due to maximum spectrum bands are allocated according to firm allocation policy. Due to this policy artificial scarcity situation takes place regarding spectrum. According to a survey by FCC (Federal Communications Commission) as mentioned by Zhang and Yeo (2014) that according to task force of spectrum provided report that demand for allocated spectrum will increase 15% to 85% and follows the function related to space and time. A different conducted measurements related to spectrum occupancy represented that New York City average

utilization to be 5.2% whereas in Chicago be 17.4% as mentioned by Alrabaee et al. (2012).

The required technology for DSA includes CR (cognitive radio). With reference to Haykin as mentioned by Alemseged et al. (2013), the CR (cognitive radio) described as a communication system of intelligent wireless which is attentive regarding the surrounding environment i.e., outside world, and apply methodology containing understanding by building for learning from environment and adapts its contained states for the variations statistically regarding incoming (RF) stimuli by applying related variations regarding some operating parameters e.g., 'transmit-power, carrier frequency, and modulation strategy in real-time', considering two main objectives:

- Highly reliable communications whenever and wherever needed.
- Efficient utilization of the radio spectrum.

CR (Cognitive radio) contains two essential capabilities, Cognitive capability and reconfiguration. Cognitive capability is used to enable (CR) for sensing its radio environment for finding spectrum holes. Spectrum holes may be used for communicating in the case of need, hence observes increment in utilization of spectrum.

Re-configurability deemed as capability for adjusting the operating parameters used in transmission for fly without modifications in components included in hardware hence, activates CR (cognitive radio) for adapting conveniently for radio environment of dynamic type. Re-configurable parameters include 'operating frequency, modulation and transmission power etc.

2.1Handoff Requirements

Temporary service disruption takes place at the time of handoff and further effects QoS regarding communication. Important needs for reducing adverse effects related to handoff are as below:

- The latency of the handoff should be very low. The transfer from the current band of communication to new band should be very fast so that the disruption period is reduced to minimum.
- There should be minimum effect on the QoS. The functions of spectrum sensing, analysis and decision should be performed quickly in order to minimize the call dropping probability.
- The number of handoffs/unit time (or handoff rate) should be minimum. The hand-off process disrupts the communication temporarily so reduction in number of hand-offs per unit time will reduce the overall disruption period.
- The additional signalling during the handoff process should be minimum.

2.2Handoff Issues in Cognitive Radio Networks

Further problems contained in handoff related to another wireless networks, CR (cognitive radio) faces different challenge related to spectrum mobility. Hence, existing solutions according to literature related to different wireless networks is not possible to apply in CR (cognitive radio) as it is not spectrum allocation of fixed type. Another challenge corresponds regarding availability of spectrum of very-wide range in transmission. Characteristics of channel changes according to operating frequency which further depends upon found idle-band.

The Challenging issue regarding modelling spectrum handoff having multiple interruptions as a result of appearance of primary users is analysed by Zheng et al. (2014), Wu et al. (2008), Aghajani and Ghasemi (2013), Yin et al. and (2012). In analysing for spectrum handoff, two different methods are described according to research literature which depends upon selection timing of channels for using on instant regarding handoff. First approach includes proactive decision approach expressed by Fahimi and Ghasemi (2016) and Xian et al. (2012 which includes the decision for future channel used in handoff, before practical handoff. Selection of channel is depended upon prediction techniques use. Second method includes reactive decision approach as illustrated by Takagi and Walke (2008), Jo and Cho (2009) and Yoon and Ekici (2010) which includes the selection of channels after handoff request takes place with spectrum instantaneous sensing. Comparison study related to these approaches is presented by Liu et al. (2011) which discussed their advantages and disadvantages. Bicen et al. (2013) presented hybrid spectrum handoff algorithm which includes the switching of algorithm in-between proactive and reactive approach which depends on primary arrival rate aiming the reduction of SU service time.

Ileri et al. (2007) presented the switching between overlay-to-underlay mode using method of transmission power reduction on arrival of PU's in constraint of non-interference and also presented spectrum including multi-cell handoff for reducing issue of coverage regarding underlay mode while final decision regarding staying or changing the channels at the time of handoff depends upon the requirement related to flow with delay bound is also recommended. Presented algorithm makes a use of cumulative probability which is depended upon measurements of past backlog for taking handoff decision.

3. PARTICLE SWARM OPTIMIZATION

PSO (particle swarm optimization) is search algorithm which is population-based algorithm and based upon social behaviour simulation of birds in flock. First objective related to concept of particle swarm includes graphical simulation of unpredictable and graceful, bird flock choreography as reported by Liu et al. (2008) aiming

the discovering patterns which governs ability of synchronously birds fly, as well as quickly change of direction in the case of regrouping into optimal formation. With this objective, a concept development took place for efficient and simple optimization algorithm.

Figure3. An optimization technique based on bird flocking behaviour
(Image courtesy: http://www.turingfinance.com)

According to PSO, 'individuals', designated as particles, are "flown" into search space of hyper dimensional type. 'Changes to the position of particles within the search space are based on the social psychological tendency of individuals to emulate the success of other individuals. The changes to a particle within the swarm are therefore influenced by the experience, or knowledge, of its neighbours. The search behaviour of a particle is thus affected by that of other particles within the swarm (PSO is therefore a kind of symbiotic cooperative algorithm). The consequence of modelling this social behaviour is that the search process is such that particles stochastically return toward previously successful regions' in search space.

Individuals in a particle swarm follow a very simple behaviour: to emulate the success of neighbouring individuals and their own successes. The collective behaviour that emerges from this simple behaviour is that of discovering optimal regions of a high dimensional search space.

A PSO algorithm maintains a swarm of particles, where each particle represents a potential solution. In analogy with evolutionary computation paradigms, a swarm is similar to a population, while a particle is similar to an individual. In simple terms, the particles are "flown" through a multidimensional search space, where the position of each particle is adjusted according to its own experience and that of its neighbours.

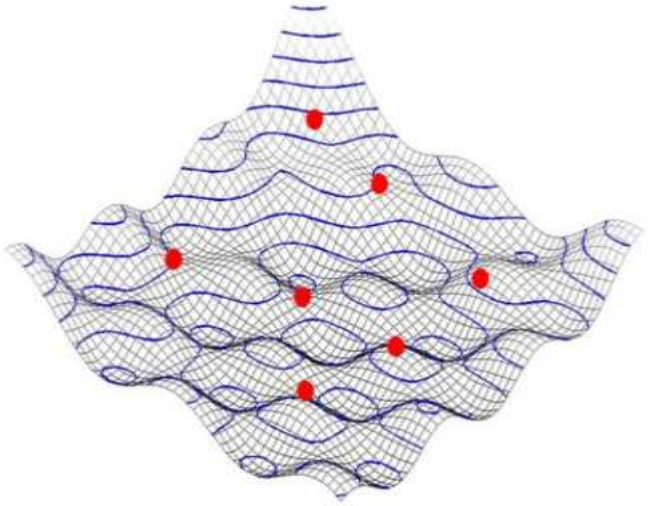


Figure 4:(Animation courtesy: University of Stuttgart): Simulation

3.1Multiple attributes Decision Making (MADM) methods

How to select a suitable option from a set of predetermined options which have multiple attributes? The process of making this decision is referred as Multiple Attributes Decision Making (MADM). These approaches are used to estimate the objective weights as depicted.

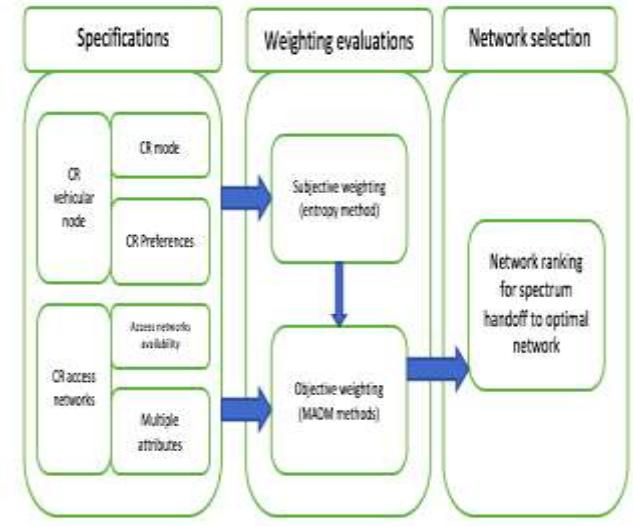


Figure5: Methods used to estimate the weight

A multiple attributes matrix 'D' is created to provide handoff for spectrum for the selection of optimal network. These can be given as:

$$D = \begin{array}{c|cccc} \text{Options} & \text{Multiple Attributes} & & & \\ & w_1 & w_2 & \ldots & w_n \\ \hline O_1 & O_{11} & O_{12} & \ldots & O_{1n} \\ O_2 & O_{21} & O_{22} & \ldots & O_{2n} \\ . & . & . & . & . \\ . & . & . & O_{ij} & . \\ . & . & . & . & . \\ . & . & . & . & . \\ O_m & O_{m1} & O_{m2} & \ldots & O_{mn} \end{array}$$

where, O ij denotes the matrix element. It is the attribute value j w.r.t option i.

4. GREY RELATIONAL ANALYSIS METHOD

A theory was commenced to analyze the grade of a number of different options and to select the best option. When uncertainty is present then this method is used to study. In this theory, as per the information degree, 'white system is the system where information is entirely known and black system is the system where information is unknown. When information is partially known then this system is known as grey system'. When there is a complicated relationship between different variables and factors then this GRA (Grey Relational Analysis) method, part of theory of grey system is used. Hence, current method is extensively used. Following steps are present in the GRA method:

a) Classification of the network parameters.
b) Definition of upper and lower bound related to parameters.
c) Normalization of parameters.
d) Calculation of the GRC (grey relational coefficients).
e) Ranking of network as per the GRC values.

4.1Proposed Technique

The proposed technique makes use of one of the MADM method namely, GRA method. The proposed technique consists of several steps. They are as follows:

The handoff of spectrum starts as soon as CR vehicular node arrives.

- CR remains in the present network if other services not required, else spectrum sensing starts.
- If any network is available, then it checks for well modelled networks among the available networks.
- If network is well modelled, then discretionary action is taken else impulsive action for spectrum handoff takes place.
- If impulsive action for spectrum handoff takes place, then preparation of the spectrum handoff is done.
- If discretionary action for spectrum handoff takes place, then following steps are to be followed:
- The multiple attributes are gathered.
- Multiple attribute matrix is created.
- Subjective weights are calculated using entropy method.
- GRA is applied for the selection of the spectrum handoff optimal network
- If optimal network found having different from present network, then
- Reconfiguration of the hardware is done,
- Spectrum handoff to optional network.

Table -1: Multiple attributes of different access networks

	Multiple Attributes			
	TL (%age of users)	**D (ms)**	**Dir (Degree)**	**J (ms)**
Network1: WLAN	10	55	45	15
Network2: LTE	83	15	6	6
Network3: WiMAX	40	58	9	9

Entropy method is used for the calculation of the weights of each attributes and the result is shown in figure. These are the subjective weights and weight is equal to 1. With the help of these weights, when vehicular node preference is not taken into consideration then selection ranking for spectrum handoff is depicted in figure 4.

It can be concluded from the figure that SAW selects WLAN while our proposed technique GRA selects LTE related to spectrum handoff. It is the static method for selection of spectrum handoff optimal network. It is seen from table 1 that traffic load becoms highest within LTE so; it becomes unsuitable network during busy hours related to spectrum handoff. The delay becomes high in WiMax and WLAN as compared to LTE.

Here the secondary user can use an idle channel in communication only in the case of primary user band become idle. Here it is not specified about the comprehensive communication protocols, due to research be focused upon probability for finding the idle channel, which provides the performance limit of the communications. It also focussed on number of iterations for finding idle channel during spectrum handoff delay when swarm size is large. For considering this some simulation parameters are taken and applied to through the PHSCR algorithm and measured through the network.

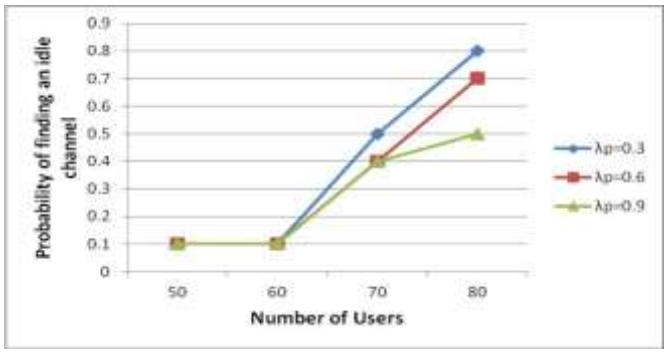


Figure6: Probability of finding an idle channel with different arrival rates of primary users

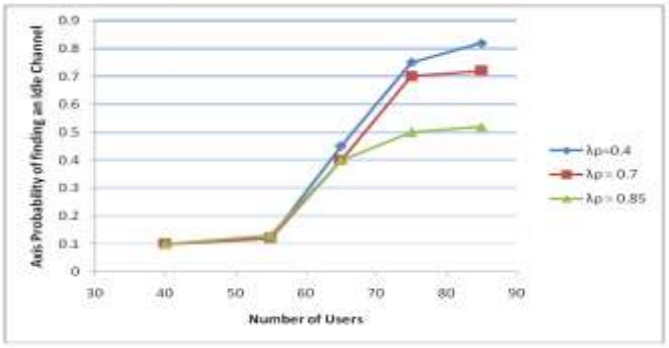


Figure7: Probability of finding an idle channel with different arrival rates of primary users

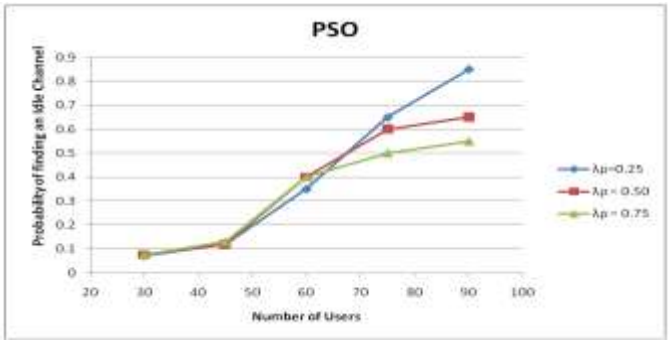


Figure8: Probability of finding an idle channel with different arrival rates of primary users

Fig. 6, 7 and 8 represents probability for finding idle channel having different rates of arrival related to primary users. It is also evident from fig. that probability for finding idle spectrum increases with increment in secondary users. It may be evident from fig. if $_p$ means, primary user arrival becomes high, handoff method is not recommended.

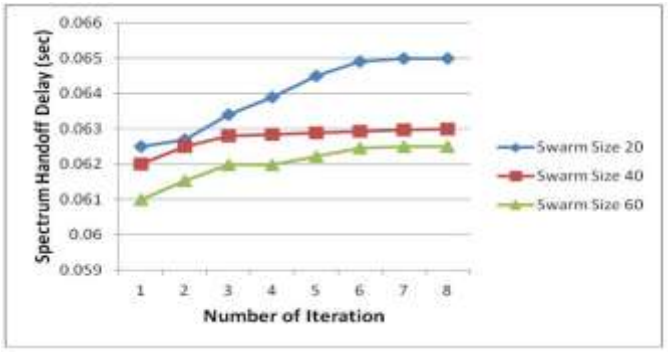
The probability of finding channel for primary user is more in the case if secondary user become high and therefore the delay for primary user will be less. With the help of the graph, it is detected that once the arrival of primary user sensed then secondary user have to leave channel without any delay and secondary user have to find different spectrum for smooth communications for unfinished task.

Policies for Spectrum sensing in searching of idle channels in primary band being underutilized may significantly affect secondary user performance regarding 'throughput, reliability, and energy efficiency'. The goal for cognitive user is for sensing accurately maximum idle channels in underutilized primary band considering energy consumption at the time of sensing and sharing.

Scheme which is parallel sensing in nature may be more efficient because it can save time, power and identify different idle channels to CRN from PU band, but, delicated trade-off among contradicting requirements may be required.

Result-II

Figure 9 represents delay of spectrum handoff 'with respect to the different number of swarm sizes. Since, swarm sizes are considered equivalent to the number of secondary users. It can be seen that when the number of secondary users are high then delay is less



.**Figure 9:** Spectrum Handoff Delay (sec) with different number of Swarm Sizes (Number of Secondary Users)

Figure10: Spectrum Handoff Delay (sec) with different number of Swarm Sizes (Number of Secondary Users)

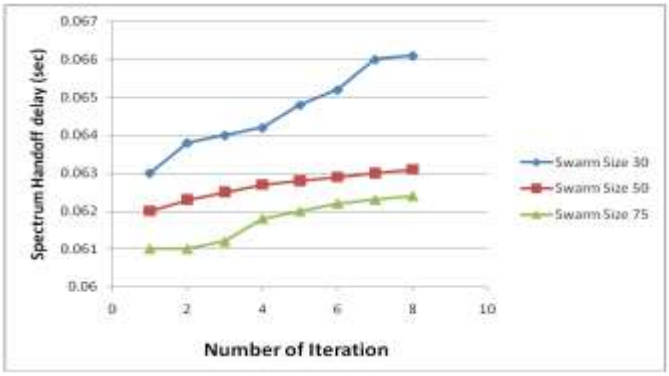


Figure11: Spectrum Handoff Delay (sec) with different number of Swarm Sizes (Number of Secondary Users)

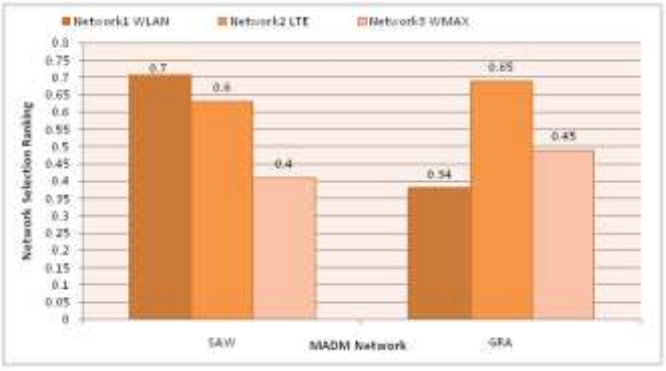


Figure12: Network Selection Ranking of MADM methods when Node preference is not considered

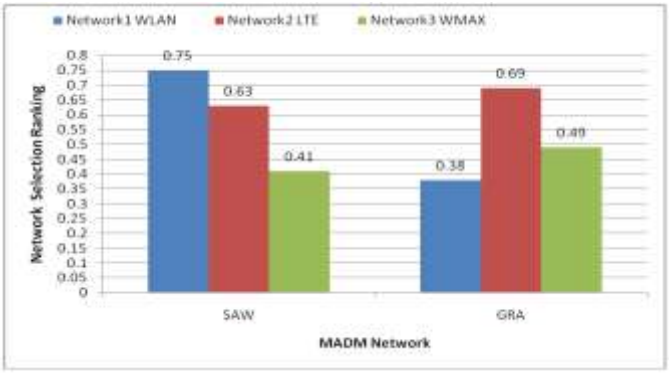


Figure13: Network Selection Ranking of MADM methods when Node preference is not considered

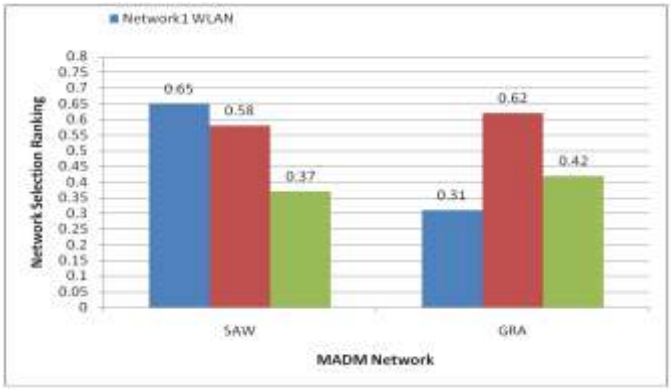


Figure14: Network Selection Ranking of MADM methods when Node preference is not considered

Fig. (9, 10 and 11) compares the different SH parameters 'in terms of delay (latency) of handoff and based on the arrival of the main users on the channel. It is seen in this figure that the handoff delay for the pure proactive technique of SH is very small (less than 10%), which proves that the proactive technique of handoff gives a better performance than the other handoff techniques.

The non-handoff technique has a very high latency because this technique allows the secondary user to remain on the target channel until the channel is available again before continuing to retransmit the information packets'. Therefore the graph indicates that if the swarm size is less than the spectrum handoff delay can be more and if the swarm size is high then the delay will less. It also indicates that the availability of free channel more for the PU when swarm size is high.

This paper includes an innovative technique dependent upon PS (particle swarm) intelligence been proposed regarding cognitive radio (CR) networks. Cognitive radio networks consist of 'primary users, secondary users and base station' which exists in same area related to communication. Due to, licensed spectrums been limited so proper use related to licensed bands is assured by secondary users to neglect interference. In the case secondary user uses licensed spectrum, if primary users be present for occupying own band, as a result of it secondary user will stop its trans-mission and switches for different idle spectrum for resuming of transmission.

It is a process known as handoff. Hence using the licensed bands, operated using particle swarms. Present technique of optimization is applied for minimizing of delay regarding handoff and maximizing probability for finding idle spectrum band.

Fig (12, 13 and 14) resulted that in various type of network like WLAN, LTE and WiMAX, the network can be selected using MADM technique where the best available network can be identified using GRA methods.

5. CONCLUSION

GRA method is used to select the network that is optimal when users preferences are not considered in CR vehicular networks. The method of entropy applied to calculate subjective weight. The technique is tested for a scenario

where multiple attributes are considered. The results obtained prove that the any MADM method may be used in selection of optimal network. GRA method helps CR vehicular node for the selection of the optimal network for spectral handoff.

All proved to be effective in selection of optimal network in spectrum handoff. Results obtained prove that entirely the MADM methods are operational in the selection of network that is optimal for spectrum handoff.

REFERENCES

[1] Wang, C. X., Haider, F., Gao, X., You, X. H., Yang, Y., Yuan, D., Aggoune, H. M., Haas, H., Fletcher, S.and Hepsaydir, E., (2014). Cellular Architecture and Key Technologies for 5G Wireless Communications Networks, IEEE Communications Magazine, Vol. 52, no. 2: 122–130.

[2] Ma, Z., Zhang, Z., Ding, Z., Fan, P. and Li, H. (2015). Key Techniques for 5G Wireless Communications Network Architecture, Physical layer and MAC layer perspectives, Science China Information Sciences, Vol. 58, no. 4: 1–20.

[3] Bezabih, H., Ellingsaeter, B., Noll, J. and Maseng, T. T. (2012). Digital Broadcasting: Increasing the available White Space Spectrum using TV Receiver Information, IEEE Vehicular Technology Magazine, vol. 7, no. 1: 24–30.

[4] Das, D. and Das, S. (2015). A Survey on Spectrum Occupancy Measurement for Cognitive Radio, Wireless Personal Communications, vol. 85, no. 4: 2581–2598.

[5] Wang, B. and Liu, K. R. (2010). Advances in Cognitive Radio Networks: A Survey, IEEE Journal of Selected Topics in Signal Processing, vol. 5, no. 1: 5–23.

[6] Talay, A. C. and Altilar, D. T. (2013). Self-adaptive Routing for Dynamic Spectrum Access in Cognitive Radio Networks, Journal of Network and Computer Applications, vol. 36, no. 4: 1140–1151.

[7] Jouini, W., Moy, C. and Palicot, J. (2012). Decision Making for Cognitive Radio Equipment: Analysis of the First 10 Years of Exploration, EURASIP Journal on Wireless Communications and Networking, vol. 2012, no. 1: 26-41.

[8] Stevenson, C. R., Chouinard, G., Z. Lei, W. Hu, S., Shellhammer J. and Caldwell, W. (2009). IEEE 802.22: The first Cognitive Radio Wireless Regional Area Network Standard, IEEE Communications Magazine, vol. 47, no. 1: 130–138.

[9] Singh, K. D., Rawat, P. and Bonnin, J. M. (2014). Cognitive Radio for Vehicular Adhoc Networks (CRVANETS): Approaches and Challenges," EURASIP Journal on Wireless Communications and Networking, vol. 2014, no. 1: 49

[10] Akyildiz, I. F., Lee, W. Y., Vuran, M. C. and Mohanty, S. (2008). A Survey on Spectrum Management in Cognitive Radio Networks, IEEE Communications Magazine, vol 46, no. 4: 40-48

[11] Akyildiz, I. F., Lee, W.Y. and Chowdhury, K. R. (2009). Spectrum Management in Cognitive Radio Adhoc Networks, IEEE Network, vol. 23, no. 4: 6–12.

[12] Kumar, K., Prakash, A. and Tripathi, R. (2016). Spectrum Handoff in Cognitive Radio Networks: A Classification and Comprehensive Survey, Journal of Network and Computer Applications, vol. 61: 161–188.

[13] Chandavarkar, B. and Guddeti, R. M. R. (2016). Simplified and Improved Multiple Attributes Alternate Ranking Method for Vertical Handover Decision in Heterogeneous Wireless Networks, Computer Communications, vol. 83: 81–97.

[14] Kassar, M., Kervella, B. and Pujolle, G. (2008). An Overview of Vertical Handover Decision Strategies in Heterogeneous Wireless Networks, Computer Communications, vol. 31, no. 10: 2607–2620.

[15] Barja, J. M., Calafate, C. T., Cano, J. C. and Manzoni, P. (2011). An Overview of Vertical Handover Techniques: Algorithms, Protocols and Tools," Computer Communications, vol. 34, no. 8: 985–997.

[16] Zekri, M., Jouaber, B. and Zeghlache, D. (2012). A Review on Mobility Management and Vertical Handover Solutions over Heterogeneous Wireless Networks, Computer Communications, vol. 35, no. 17: 2055–2068.

[17] Takagi, H. and Walke, B. H. (2008). Spectrum Requirement Planning in Wireless Communications: Model and Methodology for IMT Advanced. John Wiley and Sons, vol. 2.

[18] Nardis, L. D, and Guirao, M. D. P. (2010). Mobility-aware Design of Cognitive Radio Networks: Challenges and Opportunities, Proceedings of the Fifth International Conference on Cognitive Radio Oriented Wireless Networks and Communications, IEEE: 1–5.

[19] Wang, C. W., Wang, L. C. and Adachi, F. (2010). Modelling and Analysis for Reactive Decision Spectrum Handoff in Cognitive Radio Networks, 2010 IEEE Global Telecommunications Conference GLOBECOM 2010, IEEE: 1–6.

[20] Christian, I., Moh, S., Chung, I. and Lee, J. (2012). Spectrum Mobility in Cognitive Radio Networks, IEEE Communications Magazine, vol. 50, no. 6: 114–121.

[21] Ahmed, E., Yao, L. J., Shiraz, M., Gani, A. and Ali, S. (2013). Fuzzy-based Spectrum Handoff and Channel

Selection for Cognitive Radio Networks, 2013 International Conference on Computer, Control, Informatics and its Applications (IC3INA). IEEE: 23–28.

[22] Afshari, A., Mojahed, M. and Yusuff, R. M. (2010). Simple Additive Weighting Approach to Personnel Selection Problem, International Journal of Innovation, Management and Technology, vol. 1, no. 5: 511.

[23] Hwang, C.L. and Yoon, K. (1981). Methods for Multiple Attribute Decision Making, Multiple Attribute Decision Making, Springer: 58–191.

[24] Deng, H., Yeh, C. H. and Willis, R. J. (2000). Inter-company Comparison using Modified TOPSIS with Objective Weights, Computers and Operations Research, vol. 27, no. 10: 963–973.

[25] Wei, G. (2011). Grey Relational Analysis Model for Dynamic Hybrid Multiple Attribute Decision Making," Knowledge-Based Systems, vol. 24, no. 5, pp. 672–679, 2011.

[26] Mareschal, B., Brans, J. P., Vincke, P. et al. (1984) Promethee: A new family of outranking methods in multicriteria analysis, ULB–Universite Libre de Bruxelles, Tech. Rep.

[27] Yu, P.L. (1973) A class of solutions for group decision problems, Management Science, vol. 19, no. 8: 936–946.

[28] de Carvalho, F. B., Lopes, W. T., Alencar, M. S. and Jos Filho, V. (2015). Cognitive Vehicular Networks: An overview, Procedia Computer Science, vol. 65: 107–114.

[29] Harada, H. (2014). White Space Communication Systems: An overview of regulation, standardization and trial, IEICE Transactions on Communications, vol. 97, no. 2: 261–274.

[30] Di Felice, M., Doost Mohammady, R., Chowdhury, K. R. and Bononi, L. (2012). Smart Radios for Smart Vehicles: Cognitive Vehicular Networks, IEEE Vehicular Technology Magazine, vol. 7, no. 2: 26–33.

[31] Wang, J., Ghosh, M. and Challapali, K. (2011). Emerging Cognitive Radio Applications: A survey, IEEE Communications Magazine, vol. 49, no. 3: 74–81.

[32] Rehmani, M. H., Lohier, S. and Rachedi, A. (2012). Channel bonding in cognitive radio wireless sensor networks, 2012 International Conference on Selected Topics in Mobile and Wireless Networking. IEEE: 72–76.

[33] Gao, B., Yang, Y. and Park, J. M. (2011). Channel aggregation in cognitive radio networks with practical considerations, 2011 IEEE International Conference on Communications (ICC). IEEE: 1–5.

[34] Joshi, G. P. and Kim, S. W. (2011). An enhanced synchronized MAC protocol for cognitive radio networks, 7th International Conference on Wireless Communications, Networking and Mobile Computing. IEEE: 1–4.

[35] Mitola, J., Maguire G. Q. et al. (1999). Cognitive Radio: Making software radios more personal, IEEE Personal Communications, vol. 6, no. 4: 13–18.

[36] Mitola, J. (2001). Cognitive radio for flexible mobile multimedia communications, Mobile Networks and Applications, vol. 6, no. 5: 435–441.

[37] Mitola, J. (2009). Cognitive radio architecture evolution, Proceedings of the IEEE, vol. 97, no. 4: 626–641.

[38] Marinho, J. and Monteiro, E. (2012). Cognitive radio: survey on communication protocols, spectrum decision issues and future research directions, Wireless Networks, vol. 18, no. 2: 147–164.

[39] Dudley, S. M., Headley, W. C., Lichtman, M., Imana, E. Y., Ma, X., Abdelbar, M., Padaki, A., Ullah, A., Sohul, M. M. and Yang, T. (2014). Practical issues for spectrum management with cognitive radios, Proceedings of the IEEE, vol. 102, no. 3: 242–264.

[40] Filin, S., Baykas, T., M. Rahman, A. and Harada, H. (2011). Performance evaluation of IEEE 802.19.1 coexistence system, 2011 IEEE International Conference on Communications (ICC). IEEE: 1–6.