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A Mobility Management Scheme for Handling Handoffs in Cognitive Radio Networks

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Abstract*— Mobility is most important feature in wireless cellular communication system. Continuous service of communication can be achieved by supporting handoff. To solve the problem of spectrum scarcity and inefficient usage of the spectrum to handle handoffs efficiently a solution is proposed in Cognitive Radio networks. In CR networks unused spectrum spaces is given to secondary users and provide efficient usage of spectrum, but problems arises with unstable nature of spectrum. A novel approach is introduced to use unstable spectrum, where a scheme to support for mobility management and inter cell channel allocation is developed for various handoff events in Cognitive Radio networks. Here, for reducing switching latency a proper handoff mechanism is selected and Inter-cell channel allocation improves the mobility management performance by efficiently allocating the channel and multiple cells will able share the spectrum resources. The results show that the scheme improves the performance of handling handoffs compare to conventional schemes.

Index terms – Wireless Cellular Networks, Bandwidth, Handoff, Cognitive Radio, Spectrum.

I. INTRODUCTION

We ask that authors follow some simple guidelines. In essence, we ask you to make your paper look exactly like this document. The easiest way to do this is simply to download the template, and replace the content with your own material. In the wireless cellular communications, managing the mobility, one of the important functionality is the handoff scheme [1]. Several proposed researches has discovered various handoff issues [2][3] in cellular networks, largely concentrating on selecting the cell while moving from one cell to another cell and managing the available resources. Although various methods for cell selection has been proposed for handoff schemes that improves the network usage, but all these methods are based on the conventional multiple cell cellular networks and has not considered the varying traffic in the spectrum resource in Cognitive Radio networks[4]. That is in particular, no special interest is given for time varying spectrum availability for the users or time taken to switch from one spectrum to another, which makes these traditional handoff schemes not feasible in the Cognitive Radio cellular networks.

Research in the CR networks has showed interest in many areas, including channel sensing [5], [6], [7], spectrum pooling [8], [9], and the coexistence of Secondary Users [10], [11]. The spectrum traffic and the user mobility both should be considered for designing the scheme for Cognitive Radio cellular networks, which is an important but untried topic in Cognitive Radio networks. The Spectrum availability in Cognitive Radio networks is not same all the time, it will vary over the space and time, and reliable communication is more difficult to provide for the mobile users moving across the different cells. In Cognitive Radio networks for efficient management scheme, we don't find contiguous spectrum bands of desired range. Thus, when Cognitive Radio users want to switch their spectrum bands, first the operating frequency has to be reconfigured for tuning to a new spectrum band, which increases the delay for switching the bands and it is more compare with the classical wireless networks.

A paradigm for the problem is to allocate channels based on current channel availability is given to SSP [12], [13], [14]. But, due to fast dynamic changes in Primary User activity this solution may not be efficient. To deal with the factors mentioned above, a mobility managing scheme is proposed for Cognitive Radio cellular networks with spectrum awareness. This Mobility managing scheme will support various mobility events in Cognitive Radio networks, which consists the resource allocation within the cell, managing the dynamic spectrum mobility, and managing the user mobility. For improving the total usage of spectrum we determine the spectrum configuration for resource allocation within each cell. The Mobility managing scheme function determines suitable handoff type and the target cell for Cognitive Radio users observing the Primary User activities by taking into consideration both the spectrum utilization and connectivity. The user mobility managing scheme focuses on the varied spectrum available and to improve Quality of service a switching cost mechanism is specified for mobile users.

II. THE NETWORK ARCHITECTURE

In Wireless technology the cellular network is most important and successful technology which has been affected with the increase in the data traffic. The Cognitive Radio has become a most important solution for the problem of increase in data traffic in current cellular network. The Cognitive Radio network can be applied to unused TV spectrum bands, as FCC recently has allowed the unlicensed devices to use them [15]. The Cognitive Radio technology will enable availability of bandwidth by sharing the spectrum owned by the other cellular operators or any spectrum bands licensed to other services. To implement this, the base station will need to have an RF unit and a digital unit implemented in a separate server which is used for all communication functionalities. By considering this the cost is cheap enough for the base station to be installed wherever required. So in its own base station's local area a new mobile virtual operator will operate without any spectrum licenses which is based on Cognitive Radio. The model of the system is described in the following sections which will focus on mobility issues.

The basic system model we consider is the infrastructure based Cognitive Radio network which consists of the multiple cells, in which each cell has a Base station and its Cognitive Radio users. The architecture shown, the cognitive Radio users will observe their radio environment and the observation will be reported to the base station. The base station then will determine the actions in support of the mobility management entity in 3GPP LTE [16]. The Cognitive Radio users can sense multiple contiguous spectrum bands with single wide band RF transceiver without RF reconfiguration. As each cognitive Radio user k requires n channels for continuous transmission of calls without dropping any ongoing call. All the spectrum bands are assumed as licensed to the various primary user networks. In primary user activity region, multiple primary user networks are operated independently in various regions in each spectrum.

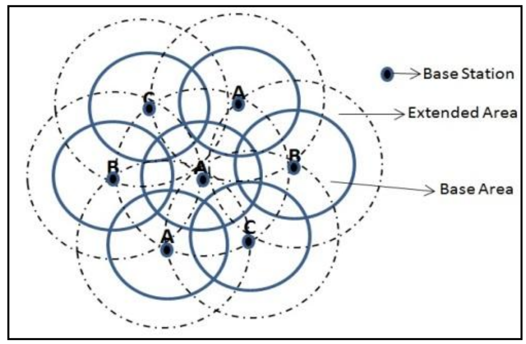
Most of the primary user networks are generally fixed [17]. Each of the primary user activity region in the licensed band has presence and non-presence states those can be indicated as ON and OFF simultaneously. We consider the lengths of ON and OFF periods at the primary user region p in the spectrum band k is distributed exponentially by the means $1/\alpha(k,p)$ and $1/\beta(k,p)$ respectively [18][19].

A. Spectrum Pool Architecture

In most of the cellular networks to avoid the intercell interferences, an interface coordination scheme is adopted where different spectrum bands are used by each cell along with the neighbor cells. The same can be applied to the cognitive radio networks. Whenever the primary user presence is felt operating frequency range must be varied by the secondary users which will result in the switching latency, but however the mobile users without changing their radio frequency can switch the spectrum to another if the bands are positioned in narrow frequency range and contiguous.

In Spectrum mobility to solve the above problem a conventional pooling concept is introduced which is most suitable structure for adapting to this dynamic radio environment [20] [21] in the cognitive radio networks for handling the both user mobility and spectrum management in a multicellular environment. This is defined as spectrum pool which is a set of contiguous licensed spectrum bands with multiple channels in each band. The architecture of spectrum pool is shown in figure 1 where each cell is assigned to one spectrum pools. As this architecture provides support for a seamless transition for all the spectrum bands within the pool, we still have some difficulties for providing the seamless communication to all the cognitive users moving across the different cells. The figure 1 illustrates, the Base coverage area and neighbor cells are not overlapped. The extended area which is a large coverage area overlapped along with the neighbor cells in the base areas. In this design, each of the cells has several spectrum bands that are available only with in the basic area and extended spectrum band. The cells which are adjacent to each other having the same spectrum pool in the extended area are called as the extended neighbors. The Mobility Management performance can be improved with usage of the extended area to the mobile users by maintaining the operating frequency of those users.

Figure 1. Spectrum pool Based Cognitive Radio



The spectrum offers Kc max (p) channels in the basic area of a base station. High transmission power is used for the extended spectrum than the basic spectrum in a larger coverage area to support similar number of channels. Assume that at extended area the spectrum pool p with extended spectrum c supports the Kc max(p) channels for the Cognitive Radio users. Then it supports more channels, δ Kc max(p) to the users in the basic area due to the shortest distant from the base station where δ is the greater than the unity and it is determined dependent on maximum signal strength and transmission power for the decoding. The cell capacity is the sums of the channels currently are not occupied by the primary users in all the spectrum bands in the cell. Thus the total cell capacity can be improved with the usage of extended spectrum. But to avoid the intercell interference the extended spectrum cannot be used along with extended neighbors.

III. SYSTEM DESCRIPTION

Managing the Mobility in the Cognitive Radio networks is more complicated when it is compared with the traditional cellular networks with dynamic spectrum traffic and different types of the handoffs. The Cognitive Radio transfers ongoing call from a mobile user's from one base station to another without breaking the call as it reaches to the cell boundary this event is called as user mobility. When the secondary user in cognitive radio networks try to change the spectrum due to the primary user activity, each base station will monitors these type of events for current spectrum availability. The variations are properly managed and in case of spectrum availability with the user mobility, the Cognitive radio will decide to select a proper handoff to use for the switching mobile user by using the mobility management scheme. Based on the decision, the Cognitive Radio users will be selecting either a cell with in the spectrum or to select available spectrum.

If any mobile user wants the resources of current cell and if it cannot provide the resources due to unavailability of the spectrum resources with increase in the primary user activity in that cell, the BS will coordinate with the neighbor cells and performs the resource allocation. The cell will able to obtain spectrum pool additionally with this operation. As there is sharing of spectrum which increases the availability, but due to dynamic nature in the availability of the resources in Cognitive Radio networks we cannot extend the spectrum to the cell permanently. The spectrum allotted will not be permanent for the CR users as the resource availability in CR networks is time varying and dynamic in nature. The spectrum change for a mobile user will optimizes the allocation but it also has several overhead activities to be performed for achieving this like it takes much of the computations and some communication overhead because of the spectrum switching. But, we will consider the important characteristic of the spectrum which is available temporarily for use when it is free. Which will improves the total capacity of the network for the mobile users which will decreases the dropping of the handoff calls, which increases the efficiency of handling the handoff calls.

Handoff schemes can be categorized in two ways as soft handoff and hard handoff.

Soft handoff: When the Cognitive Radio user finds the handoff events, the handoff procedure is performed while maintaining the communications. When the Cognitive Radio user decides to make a handoff, communication channels is disconnected and then switch to a new base station or to a new spectrum band. Most preferred handoff approach is soft handoff approach.

Hard handoff: In this scheme the Cognitive Radio user will stop the transmission first then they will make decisions regarding handoff and then they will perform the handoff operation. This type of handoff has some delay in handling calls compare to soft handoff. In this the Cognitive radio network will select the hard handoff by moving the secondary user out of the spectrum when it finds the PU activity in the spectrum and avoids the interference to primary user. This scheme has additional delay for handling handoff unlike the soft handoff. So when the primary user presence is felt in the spectrum, the Cognitive Radio network has to initiate the hard handoff and vacating the spectrum so that there will be no interference to the PU and then it selects the available new band for the secondary user.

These schemes can be modeled in different ways like, Intracellular handoff scheme occurs when the PU appear in spectrum and hard handoff is implemented. To implement this approach first we determine the handoff type then we check different spectrum bands for the availability in the pool and then identify proper spectrum. Then after identifying the CR user will move in to the spectrum band identified and then transmission will resume. Then another handoff scheme can be considered when CR users in the extended area switches successfully to the extended neighbors and further the new target cell of the CR user is an extended neighbor so the reconfiguration is not needed as they use the current cell in the same spectrum pool. This will not increase the latency for handoff scheme. So latency is reduced in this handoff scheme compared with the other schemes.

IV. MOBILITY MANAGEMENT IN CR NETWORKS

Selecting the cell is the main challenge in the cognitive radio mobility management. To determine the proper target cell is an important aspect. To monitor the signals the Cognitive Radio users will reconfigure their radio frequency front ends from the neighbor cells as the spectrum is spread to a large range of frequency bands which leads to temporary long disconnection of the transmission. The connectivity estimation is done based on distance that is from the transmitter that is for the mobile user to the base station.

Further the important factors such as the multipath fading and shadowing will affect the connectivity. As multiple spectrum bands present in the spectrum pool, the connectivity of the spectrum pool i , and connection probability p_i^c can be defined as the probability of at least one spectrum band that provides the valid connection, which is expressed as $1-\prod_{j\in S_i}(1-p_i^C(j))$ where $p_i^C(j)$ is the connection probability of the spectrum j in pool i. Further the connectivity and spectrum utilization is also very important factor in determining the target cell. Thus the cognitive radio users will select the target cell i which is having highest weighted connectivity, P_i^w , which is obtained by considering both the spectrum utilization and the connectivity as

$$P_i^w = \left(1-\prod_{j\in S_i}(1-p_i^c(j))\right).\left(1-\frac{N_i^b+\rho N_i^e}{\sum_{j\in S_i} N_i^{\max}(j)}\right)$$

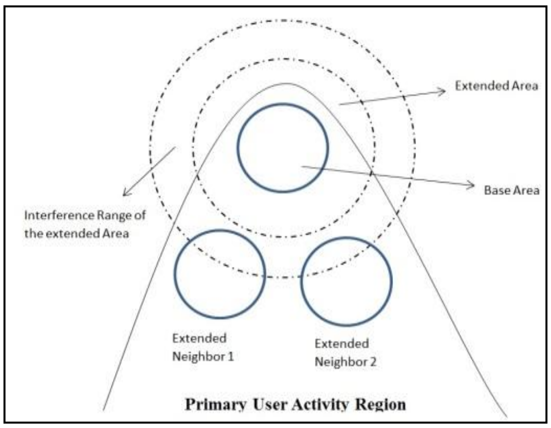
An important note that, one of the candidate cell is selected as the target cell that has cell connectivity Pc which supports the minimum QoS for the mobile user.

A. Mobility management for Mobile Users

One of the main reasons to initiate the handoff is the user mobility in the cognitive radio networks which will be happening at the boundary of either the BA or the EA. So when the mobile user approaches the boundary of the extended area, they will check a proper handoff scheme. The Cognitive radio users are able to measure the signal strength directly from other base station which is similar to traditional handoff schemes. They will find a cell if the user cannot find a target cell that is present in different spectrum pool. As a Cognitive Radio user in the Base Area has highest priority, it influences the use of channel accessing and cell overload in the extended spectrum band. So for the mobile users at the boundary require a sophisticated algorithm for selecting the better handoff scheme for the Cognitive Radio users in the base area. Here importance is given to the mobility management at the boundary of the base area. When the cognitive radio user become closer to the boundary of the base area, the base station will initiate the handoff procedure and then gather the neighbor cell information from the network entity. Based on this information the base station will estimate the connectivity of the candidate cells and then determines the handoff timing t and the target cell i as

$$[t,i] = \arg_{i \in C, t>0}[\, p_{i_c}^{C}[d_{i_c}^{0} + v_{i_c}^{r} t] \le \max_{i \in C}[\, p_{i_c}^{C}[d_{i_c}^{0} + v_{i_c}^{r} t]]]$$

Here p_i^c is a connectivity function for cell i and is the function of the distance d_i^0 and the relative velocity v_i^r to its base station. C is a set of the candidate cells, ic represents current cell and t is moving time. Then once the target cell is determined, the base station determines the handoff scheme by



considering he expected costs of switching of the both the handoff schemes at the boundary of the base area.

Figure 2. The effect of PU activities in the EA

The expected costs of the switching can be determined by the estimations of probability of the mobile events after the decision. After decision, the cognitive radio users may experience an unexpected intercell handoff due to the Primary user activity in the extended area. First we will analyze the event after the decision and then accordingly select a handoff decision scheme for this event.

B. PU Activity in EA

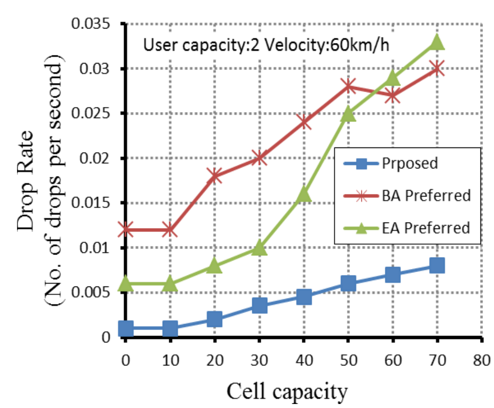
The Cognitive radio users can be in the current cell if they want to perform intercell handoff scheme as it not require a long switching latency. But however, due to different mobility events in the extended area may cause intercell handoff scheme for cognitive radio users. Such events are the primary user activities. As shown in the figure 2, more of the primary user activity regions can be involved for determining the spectrum availability in the extended area, which will lead to higher primary user activity. Further, the interference range of extended spectrum is more than its coverage area, and hence is overlapped with base area of the extended neighbors. Thus, for accurate detection, all the extended neighbors to be involved in the process of detecting the primary user activity by using their own detection methods and the false alarm probabilities. Assume that OR rule is used for the cooperative detection to the data fusion. Then as the total number of the cells increases the cooperative detection probability will converges to 1. So, while spectrum availability is estimated the detection probability is ignored. But on other side the false alarm probability will be increased as the number of the cells increases, which will considerably influence the spectrum availability in the extended area. Though when a spectrum band is idle, it will be determined to be unavailable if false alarm is detected. So, in order to avoid intercell handoff, any primary user activities or the false alarms are to be avoided and should not be detected in extended area. The probability is derived based on these observations, that no primary user activity is able to be detected during the r sensing periods as:

$$p_i^{av}(1) = \prod_{i' \in N_i^E} (1 - p_{i'}^{f}) . \prod_{k \in A_i^E(j)} e^{-\beta(j,k)\Delta t}$$

$$p_{E,i}^{h_{pu}} = \sum_{r=2}^{R} p_i^{av}(r-1).(1 - p_i^{av}(1)).$$

$$r = 2,3....,R$$

Where $R = \lceil T_m / \Delta t \rceil$ and T_m is expected time for user m expected to stay in extended area. The first term indicates the probability for not generating any false alarm during the r sensing periods by the extended neighbors. This rule is based on OR rule in decision fusion, but if other cooperative criteria's are been used then this will change. Then here, the assumption for sensing operation that is to be done for every Δt sensing period. The next term denotes probability of that no primary user activity appears in the extended area during the r sensing slots. The $p_{E,i}^{under}(r)$ is the probability that each cell does not experience the capacity overload during the r sensing slots. The probability of the intercell handoff due to the primary user activity in the extended area can be derived



as follow:

$$p_{E,i}^{h_{pu}} = \sum_{r=2}^{R} p_i^{av}(r-1).(1 - p_i^{av}(1)).$$

The first term in the summation will represent the probability that extended spectrum is available without the cell overload during the $(r-1)$ sensing slots, which is then multiplied by the probability of that primary user activity that is detected at the slot r.

V. Performance Evaluation

A. Simulation Model and Parameters

The performance of proposed scheme is studied with network simulator, which supports the network which consists of the multiple cells with a range of 10km X 10km area is implemented. Here, we consider 60 cells having various channel consumption. The range of transmission is set to 750 meters for each cell. The range of interference for each cell is set to twice more than the transmission range of the cells. The range of transmission for the extended spectrum is twice more than the basic spectrum of each cell. Further, three spectrum pools, each of the pool consists of 10 spectrum bands. Both spectrum bands basic and extended can support 10 to 30 channels for the users in the base area. Furthermore, each of the bands has three to five different primary user activity regions, α (j,k) and β(j,k) that are uniformly distributed in 0.01,0.05 respectively. The sensing interval is set to 0.1 sec. Then assume that the false alarm is generated by the base station for every 2 hours on the average when they sense the availability of the spectrum. User mobility is described based on the Gauss-Markov mobility model. Where 0.5 is set to the memory level parameter, and the asymptotic standard deviations are been 1.2,6,12, and 20 m/s for the average velocities 6, 30, 60, and 100 km/h, respectively. The performance of the proposed method will change significantly with other mobility model, but according to its accuracy.

B. Performance Metrics

Here with the transmission statistics we investigate the performance of the proposed schemes for the mobile users under various network environments.

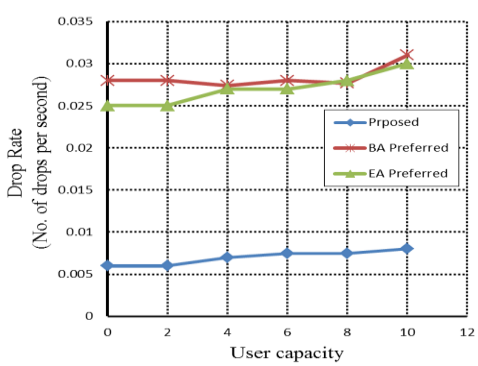


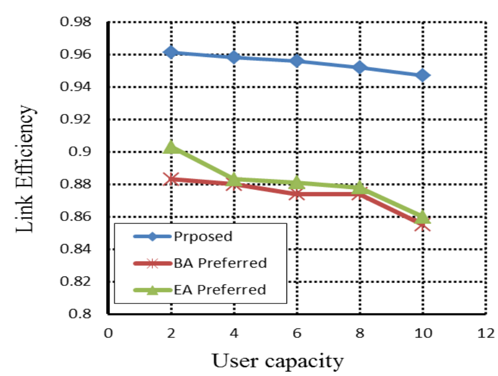
Figure. 3(a): Drop Rate based on User Capacity

Fig. 3(b): Drop Rate based on Cell Capacity

Here the experiments are carried out by a twenty 1 hour simulations for each case and obtained the values. Mobility management scheme performance is analyzed by considering three factors these are the current load in network, the QoS for user, and the velocity of each mobile user. In simulation the proposed method is compared with the classical handoff methods. The BA preferred scheme increases the number of channels in the base area as it has extended spectrum. At the boundary of a cell the mobile user will switch to neighbor cell if there is a valid cell available. Otherwise, it moves to extended area. As the other scheme EA preferred will focuses mainly on the enhancement of mobility of user, the mobile user can try to stay in the extended area if there is an available cell in the extended spectrum when he reaches the boundary of a cell. An important statistics in the mobile communication is a call dropping probability. While a mobile user with an ongoing call cannot find any other free channels spectrum moving from one cell to another then the call drop will occur. Fig. 3 shows the experimental results under various situations for the drop rate. For reliability the proposed method is indicated on graph with 95 percent of the confidence interval.

Figure. 4(a): Link Efficiency based on User Capacity

In figure 3 the better performance is shown by the proposed method when compared with other classical handoff methods for the total drop rate of ongoing calls. As shown in the figure.3 (a), The degree of drop rate increases slightly in the proposed method compare to other classical handoff methods and the drop rate will increase more as the network load increases for the proposed scheme, as at that time the spectrum resource availability decreases. But compare to other classical methods it is still lower than the others.



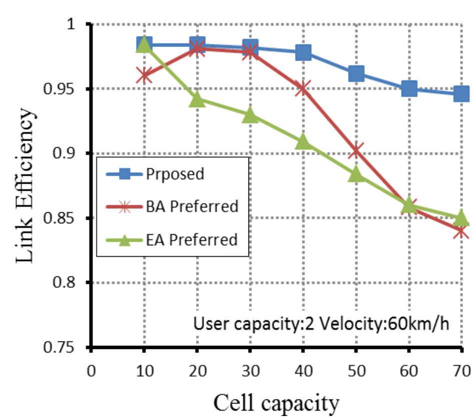


Figure. 4(b): Link Efficiency based on Cell Capacity

Figure 4 shows the lower link efficiency has shown by the classical method compared with all other schemes because of quality degradation due to frequent intercell handoffs. Further the link efficiency will reduce as the mobile users cannot find the spectrum until any changes in the current spectrum with users moving to new target cell. As both methods do not consider switching latency will show lower link efficiency. But, the proposed approach shows higher link efficiency by determining the handoff type to reduce the total latency and the drop rate. These experiments show that the proposed method achieves less quality degradation and more transmission opportunity for mobile users.

VI. CONCLUSION

Mobility Management is an important factor for handling handoffs. Here, Mobility management and Spectrum management schemes for Cognitive Radio cellular networks for handling handoffs. As the spectrum bands in the cognitive radio discontinuously distributed over a wide range of frequency and change dynamically over the space and time. The mobility management framework has been defined with a network architecture used to support different mobility events in the CR networks for mobile users with mobility management function for mobile users, intercell resource allocation and spectrum management function. Total cell capacity and user mobility management can be improved as each cell determines the spectrum configuration with intercell resource allocation which reduces the call dropping probability for handoffs. In mobility management scheme the handoff decision is made based on switching cost which minimizes the degradation in quality caused with user mobility. The results of simulation have shown that the proposed schemes provides better performance compare to previous handoff schemes by using maximum cell capacity and provides better QoS to the mobile users.

REFERENCES

[1]. Won-Yeol Lee, Lan F.Akyildiz, “Spectrum-Aware Mobility Management in Cognitive Radio Cellular Networks,” IEEE Transactions on Mobile Computing, Vol. 11, No. 4, pp. 529-542, April 2012.
[2]. N. Zhang, Jack M. Holtzman, “Analysis of Handoff Algorithms Using Both Absolute and Relative Measurements,” IEEE Trans. Vehicular Tech., vol. 45, no. 1, pp. 174-179, February 1996.
[3]. Shian-Tsong Sheu, and Chin-Chiang Wu, “Using Grey prediction theory to reduce handoff overhead in cellular communication systems”, The 11th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, (PIMRC 2000), vol. 2, pp. 782-786, 2000.
[4]. S. Haykin, “Cognitive Radio: Brain-Empowered Wireless Communications,” IEEE J. Selected Areas in Comm., vol. 23, no. 2, pp. 201-220, Feb. 2005.
[5]. S. Shankar, C. Cordeiro, and K. Challapali, “Spectrum Agile Radios: Utilization and Sensing Architectures,” Proc. IEEE Int’l Symp. First New Frontier in Dynamic Spectrum Access Network (DySPAN), 2005.
[6]. N. Chang and M. Liu, “Optimal Channel Probing and Transmission Scheduling for Opportunistic Spectrum Access,” Proc. ACM MobiCom, 2007.
[7]. H. Kim and K.G. Shin, “In-Band Spectrum Sensing in Cognitive Radio Networks: Energy Detection or Feature Detection,” Proc. ACM MobiCom, 2008.
[8]. T. Weiss and F. Jondral, “Spectrum Pooling: An Innovative Strategy for the Enhancement of Spectrum Efficiency,” IEEE Comm. Magazine, vol. 42, no. 4, pp. S8-14, Mar. 2004.
[9]. W. Lehr and N. Jesuale, “Spectrum Pooling for Next Generation Public Safety Radio Systems,” Proc. IEEE Third Symp. New Frontiers in Dynamic Spectrum Access Networks (DySPAN), 2008.
[10]. J. Huang, R.A. Berry, and M.L. Honig, “Spectrum Sharing with Distributed Interference Compensation,” Proc. IEEE First Int’l Symp. New Frontiers in Dynamic Spectrum Access Networks (DySPAN), 2005.
[11]. R. Etkin, A. Parekh, and D. Tse, “Spectrum Sharing for Unlicensed Bands,” Proc. IEEE First Int’l Symp. New Frontiers in Dynamic Spectrum Access Networks (DySPAN), 2005.
[12]. Y.T. Hou, Y. Shi, and H.D. Sherali, “Optimal Spectrum Sharing for Multi-Hop Software Defined Radio Networks,” Proc. IEEE INFOCOM, 2007.
[13]. L. Cao and H. Zheng, “Distributed Spectrum Allocation via Local Bargaining,” Proc. IEEE Second Ann. Comm. Soc. Conf. Sensor and Ad Hoc Comm. and Networks (SECON), 2005.
[14]. Y. Yuan, P. Bahl, R. Chandra, T. Moscibroda, and Y. Wu, “Allocating Dynamic Time-Spectrum Blocks for Cognitive Radio Networks,” Proc. Eighth ACM Int’l Symp. Mobile Ad Hoc Networking and Computing (MobiHoc), 2007.
[15]. J. Sachs, I. Maric, and A. Goldsmith, “Cognitive Cellular Systems within the TV Spectrum,” Proc. IEEE Symp. New Frontiers in Dynamic Spectrum (DySPAN ’10), Apr. 2010.
[16]. 3GPP TSG-RAN, “Requirements for Further Advancements for Evolved Universal Terrestrial Radio Access (E-UTRA),” 3GPP TR 36.913 V9.0.0, Dec. 2008.
[17]. Guodong Zhao, Jun Ma, Geoffrey Ye Li, Tao Wu, Young Kwon, Anthony Soong, Chenyang Yang, “Spatial Spectrum Holes for Cognitive Radio with Relay-Assisted Directional Transmission” Proc. IEEE Transactions on Wireless Communications, vol. 8, no. 10, Oct 2009.
[18]. Jeong, C. K.; Un, C.K., "Performance analysis of a voice/data multiplexer based on Markov renewal process modelling," Proceedings of the IEEE , vol.76, no.10, pp.1390,1393, Oct. 1988
[19]. C. H. Huang, Y. C. Lai, and K. C. Chen, “Network capacity of cognitive radio relay network,” Physical Commun., vol. 1, no. 2, June 2008.
[20]. T.A. Weiss and F.K. Jondral, “Spectrum Pooling: An Innovative Strategy for the Enhancement of Spectrum Efficiency,” IEEE Comm. Magazine, vol. 42, no. 3, pp. 8-14, Mar. 2004.
[21]. D. Cabric, S. Mishra, D. Willkomm, R. Brodersen, and A. Wolisz, “A Cognitive Radio Approach for Usage of Virtual

Unlicensed Spectrum," Proc. 14th IST Mobile and Wireless Comm. Summit, June 2005.

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