CLUSTER-BASED COORDINATED BIPARTITE MATCHING APPROACH FOR EFFICIENT SPECTRUM SENSING BASED DATA TRANSMISSION

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Abstract

A cluster-based coordinated multi-wavelength spectrum sensing approach for mobile and geographically distributed cognitive radio networks (CRNs). The scope of the process is to sense and detect channel availability with maximum probability and dispersed to SU and PU with optimized energy. In geographically, the channel with the empty condition is varied over the space due to this sensing results and sensing assignments depending upon the user location. However, SUs are not located with a known location, so joining the detecting outcomes in order to find the efficient spectrum allocation for the next sensing duration becomes difficult for the base station (BS). To solve the above-mentioned problem here introduces the low complexity clustering approach, which enables BS to form a network into the cluster and provide a unique count of channels for each cluster. Then SU senses the availability of channels which is empty with maximum probability. At last, the bipartite matching approaches initiated to perform a relay mechanism where SU acted as a relay to PU for exchange their data transmission via the same channel which returns the maximum capacity and decreases power consumption. Finally, cluster-CMSS appreciably achieves the spectrum discovery ratio for SUs with the reduction of energy consumption by relay based transmission. Finally, simulation results demonstrate the benefits of the proposed cluster-based matching approach comparing with other existing techniques.

Index Terms: *Bipartite matching, Cognitive radio network, Cluster-CMSS, Spectrum sensing, clustering*

Introduction

Cognitive radio (CR) is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones. This optimizes the use of available radio-frequency (RF) spectrum while minimizing interference to other users. Cognitive radio is considered as a goal towards which a software-defined radio platform should evolve: a fully reconfigurable wireless transceiver which automatically adapts its communication parameters to network and user demands. Licensed-Band Cognitive Radio, capable of using bands assigned to licensed users. The IEEE 802.22 working group is developing a standard for wireless regional area network (WRAN). Unlicensed-Band Cognitive Radio, which can only utilize unlicensed parts of the radio frequency (RF) spectrum. One such system is described in the IEEE 802.15 Task Group 2 specifications.

Spectrum mobility is the process by which a cognitive-radio user changes its frequency of operation. Cognitive-radio networks aim to use the spectrum in a dynamic manner by allowing radio terminals to operate in the best available frequency band, maintaining seamless communication requirements during transitions to better spectrum. Spectrum sharing cognitive radio networks allows cognitive radio users to share the spectrum bands of the licensed-band users. However, the cognitive radio users have to restrict their transmit power so that the interference caused to the licensed-band users is kept below a certain threshold. In sensing-based spectrum sharing cognitive radio networks, cognitive radio users first listen to the spectrum allocated to the licensed users to detect the state of the licensed users. Based on the detection results, cognitive radio users decide their transmission strategies. If the licensed users are not using the bands, cognitive radio users will transmit over those bands. If the licensed users are using the bands, cognitive radio users share the spectrum bands with the licensed users by restricting their transmit power.

In Database-enabled Spectrum Sharing, cognitive radio users are required to access a white space database prior to be allowed, or denied, access to the shared spectrum. The white space database contain algorithms, mathematical models and local regulations to predict the spectrum utilization in a geographical area and to infer on the risk of interference posed to incumbent services by a cognitive radio user accessing the shared spectrum. If the white space database judges that destructive interference to incumbents will happen, the cognitive radio user is denied access to the shared spectrum. The number of wireless sensors deployed for different applications has increased. In WSN, data traffic is usually correlated both temporally and spatially. When any event occurs, WSNs generate packet bursts and they remain silent when there is no event. These temporal and spatial correlations introduce to the design challenge of the communication protocols for WSN. With the intelligent communication protocols in CR-WSN, it is possible that the wireless sensors deployed for the same purpose use the spectrum of different incumbents in spatially overlapping regions. This is possible with cooperative communication among SUs, which obviously mitigates interference issues.

The Cognitive Radio prototype permits a new form of users called unlicensed users or secondary users (SUs) to cooperate with the licensed users or primary users (PUs). The SUs are allowed to access the spectrum provided without interfere with the PUs. CR is able to efficiently detect and allocate all spectrum based on the dynamic behaviour of PUs, SUs always conscious of the occupancy status of multiple narrow bands or channels of spectrum. Clustering of PUs and SUs in geographically dispersed networks, and mobility in CRNs are discussed. Power control approach proposed to effective communication along with channel sensing. Cognitive users conduct spectrum sensing to determine whether a certain spectrum band is occupied by incumbent users. The corresponding methods include energy detection, feature detection, matched filtering, coherent detection, and so on. To measure the accuracy of the spectrum sensing, two metrics are widely adopted. The first one is detection probability, which means the probability that occupied spectrum is correctly detected. The second one is false alarm probability, which means the probability that idle spectrum is detected to be occupied.

Existing System

Spectrum Sensing Provider

The existing system proposes a CR network (CRN) with disjoint subsets for each cluster of sensor nodes as a solution to the problem – effective sensing achieved with high energy efficiency. The CRN is composed of ad hoc CRs, assigning mobility to CRs to be more general, and infrastructure sensor nodes. An ad hoc CR, which is a cluster head, is surrounded by a cluster of infrastructure sensor nodes within one-hop communication range of the CR, and each cluster is further partitioned into subsets. To achieve energy efficiency, sleep-wake scheduling for the subsets based on the statistical behavior of the PU is also proposed. The system uses an energy-efficient cluster updating and subset formation (CUSF) process for the operation of ad hoc CRs assisted by an infrastructure sensor network.

The CRs randomly move in time and the subsets of the clusters in the sensor network are updated accordingly in which only one subset in a cluster is active at a time while others switch to sleep mode. Even the one active subset can be switched to sleep mode for a certain number of time slots by the proposed scheduling algorithm, based on the PU activity. Due to free and frequent moves of the CRs and the subsequent CUSF process for each move, energy consumed in the setup stage is also considered. Energy savings during spectrum sensing is a critical matter with a CRN including many sensor nodes. Though energy for each sensing is considerably less than communication energy, the short interval in the periodic sensing process of the CRNs makes it significantly important. Thus, minimization of sensing energy helps to prolong the lifetime of the sensor network

System Architecture

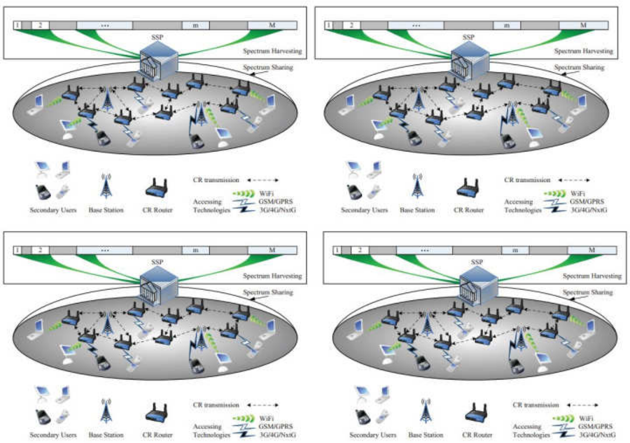

Fig.1: System Architecture of SSP

The architecture of CCH is consists of four types of network entities: an SSP, a few numbers of BSs, and a large number of CR routers and SUs. We assume that SSP has its own spectrum (called basic band) and its deployed network facilities (BSs and CR routers) can use the basic band to provide basic reliable services. The BSs and CR routers are equipped with multiple cognitive radios, which can tune to any basic band or harvested band for communication. With cooperation of BSs and CR routers, the SSP harvests spectrum resource and allocates it on demand. The SSP, BSs, and CR routers form a spectrum cloud and could provide service for SUs with or without cognitive capability.

In this spectrum cloud, the SSP is the manager, the BSs act as gateways of the cloud and further connect to Internet or other data networks, and the CR routers and BSs are the access points which facilitate SUs to access the CCH. The SUs can be any wireless device using any accessing technique (e.g., Laptops, tablets, or desktop computers using Wi-Fi, cell phones using GSM/GPRS, smart phones using 3G/4G/Next, etc.). If a SU has cognitive capability, it could communicate with CR routers and BSs over both harvested bands and basic band. Otherwise, it could only communicate over the basic band. As a spectrum cloud, the performance of CCH heavily depends on the routing protocol, which needs to provide optimal and reliable routing between any two nodes (two CR routers, two BSs, or one CR router and one BS) for internal communication in the CCH domain, or a node (CR router) and multiple gateways (BSs) for external communication. SAAR is a centralized protocol.

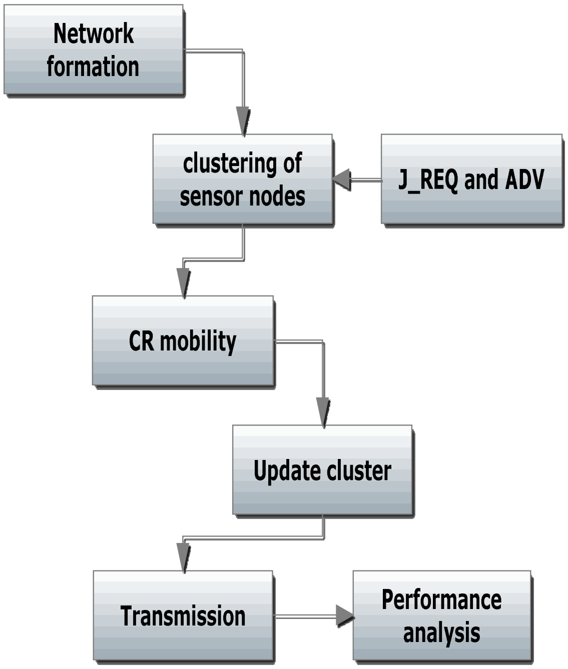

Fig.2: Block Diagram of SSP

CR routers sense the channel and link statistics periodically and send this information to SSP with CCC. SSP calculates the any path routing for each node with the statistical information of the networks. Given the channel quality q_i^m, the SSP could determine the priorities for every channel at each node by sorting q_i^m in a descending order, so that a channel with higher availability probability will be used with higher probability. As for the priorities of the nodes within a forwarding set, the SSP determines their priorities by sorting their any path cost D_j in an ascending order, so that a node with lower any path cost to the destination will become the actual forwarding node with higher probability.

Disadvantages

In existing system, it provided spectrum to limited number of PUs because only the BS is in moving condition. Here SUs are not considered for occupying the spectrum. Each user spent their own power for both data transmission and spectrum sensing, it increased power consumption of the networks.

Proposed System

Cluster-CMSS Approach

In proposed system, Cluster based coordinates multiband spectrum sensing approach is implemented to allocate spectrum for CR users. Connectivity and robustness of cognitive radio network are the challenges faced by cognitive radio network due to moving nature of the channels, which are available for the communication to take place, among cognitive radio nodes. This challenge can be addressed by the concept of Clustering, which groups the neighbouring nodes of a cognitive radio network. It helps the node to switch to other channel i.e. coordinated channel switching. It also helps in better spectrum sensing and simplification of routing. But the connectivity between or within cluster could be lost due to sudden movement of the primary nodes.

System Architecture

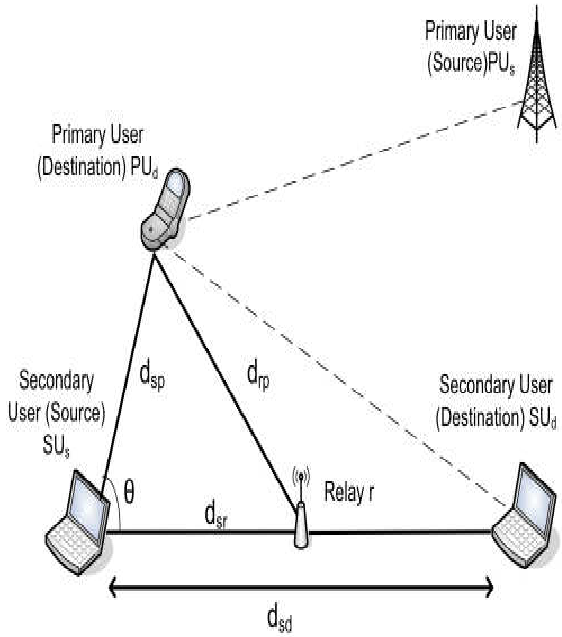

Fig.3: System Architecture of Cluster-CMSS

Initially, the BS updates the belief vectors for all SUs and PUs, based on which SUs and PUs are divided into different clusters. For each cluster, the BS determines the unique channels to be sensed in the next time frame by performing a one-to-one matching algorithm between the members of that cluster and the channels that allow us to group the SUs based on the similarity of spectrum holes that they can find. Second, proposed a learning algorithm for estimating the PU’s dynamic based on the mobility of SUs. Designed CRNs is the energy cost of the spectrum sensing where energy consumption for sensing getting reduced because of formed clusters.which includes the energy consumed by spectrum sensing, channel switching, and data transmission, is minimized, whereas multiple constraints on the reliability of sensing, the throughput, and the delay of the secondary transmission are satisfied. Optimality is achieved by jointly considering two fundamental tradeoffs involved in energy minimization. the coarse sensing stage and fine sensing stage. In the coarse sensing stage, all the channels in the band are sensed shortly and the channel that have maximum (or minimum) energy is identified to make a dense fine sensing for confirming the presence of the PU signal (or hole).

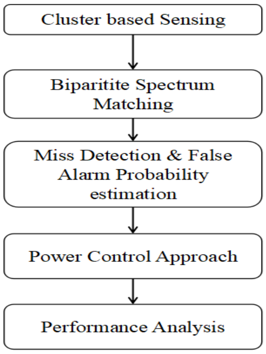

Fig.4: Block Diagram of Cluster-CMSS

Coordinated spectrum sensing within clusters using bipartite matching where SU to sense the channel it believes to have the highest probability of being empty and also it acted as relay for grouped PUs within the cluster. A matching in a Bipartite Graph is a set of the edges chosen in such a way that no two edges share an endpoint. A maximum matching is a matching of maximum size (maximum number of edges). In a maximum matching, if any edge is added to it, it is no longer a matching.

To reduce the energy consumption by this relay based approach, where SU use the same channel for their own data transmission and PUs data transmission which increased channel capacity of each cluster. Proposed an efficient relay-based spectrum sharing protocol in the cognitive radio network, where the secondary user (SU) can implicitly harvest the radio frequency (RF) energy from the primary user (PU) transmissions. Using the harvested energy, the SU can assist the PU transmission to exchange for the opportunity of spectrum access. This above mentioned strategy compensate the power consumption between sensing and data transmission.The more power allocated for the primary data relaying, the higher throughput can be achieved for the PU, while the less throughput is available for the SU with less energy remained. The optimal power allocation is numerically determined by maximizing the SU throughput while guaranteeing the PU throughput.

Sensing-based Clustering

In the geographically dispersed networks, clustering permits frequency reuse and more prompt spectrum sensing. By classifying the nodes which share a identical set of spectrum holes, the BS can cooperate sensing distribution among users of every cluster. In the lack of SU's location information, here proposed to use the sensing results of SUs as a clustering metric. Defined the distance between two SUs based on the distance between their belief vectors. More specifically, we define the spacing Dx between any two SUs as the Kullback-Leibler (KL) deviation between beliefs of those SUs. is a measure of how one probability distribution is different from a second, reference probability distribution.

Relay Based Approach

The CMSS problem onto a bipartite matching problem. After the BS clusters the SUs, it assigns each SU within each cluster a unique channel to sense. The goal is to assign every SU to sense the channel it believes to have the highest probability of being empty. For each cluster, the BS solves this problem by finding a minimum-weight matching on a bipartite graph. A matching is a set of edges with no common vertices. Matching with maximum number of edges is a maximum matching. Maximum bipartite matching for a graph isn't unique.

Proposed the familiar known Hungarian Algorithm, to solve the minimum-weight matching problem. Hungarian involves steps as follows, Subtract row minima, here each row, find the lowest element and subtract it from each element in that row. Then Subtract column minima, where for each column, find the lowest element and subtract it from each element in that column. Next Cover all zeros with a minimum number of lines, Cover all zeros in the resulting matrix using a minimum number of horizontal and vertical lines. If n lines are required, an optimal assignment exists among the zeros. Finally Create additional zeros Find the smallest element (call it k) that is not covered by a line in Step 3. Subtract k from all uncovered elements, and add k to all elements that are covered twice. The double-lined edges represent the minimum weight matching and the dashed edges represent the unmatched edges.

E. Miss-detection and false-alarm probabilities over AWGN channels

Consider the case, in which the SNR of the sensed signal at SUs follows Rayleigh, Rician and Nakagami-m distributions. Rician model represents the scenarios in which SUs receive the PU signal from several different paths, with one direct path that is stronger than the others. Rician factor K is the ratio between the power received from the direct path and the power received from other scattered paths. The parameter K is an indicator of the severity of the fading. A smaller K indicates a sever fading. Rayleigh model is suitable for scenarios where the direct path does not exist (severe fading). In addition Nakagami-m distribution has gained substantial application in modelling fading channels because of the good fit to the empirical data. The parameter m determines the severity of the fading channel. The smaller values of parameter represent more severe fading condition.

The probability of false alarm over non-fading AWGN channel, the probability density function defined under H0. Define signal-to-noise ratio (SNR),

$$P_{fa} = \int_{\gamma}^{\infty} \frac{1}{\sigma_n^N 2^{N/2} \Gamma(N/2)} y^{(N/2)-1} \exp(\frac{-y}{2\sigma_n^2}) dy$$

Substituting t = y/s2 and further integrating the P_{fa} results in,

$$P_{fa} = \int_{\gamma/\sigma_n^2}^{\infty} \frac{t^{(N/2)-1}}{2^{N/2}\Gamma(N/2)} \exp(\frac{-t}{2}) dt$$

The right-hand side is the chi-squared density.

Which can be written as, $P_{fa} = Q_{x_N^2}(\gamma/\sigma_n^2)$. In the energy detector, the threshold γ can be computed using $\gamma = \sigma_n^2 \left\lfloor \sqrt{2/N} Q^{-1}(P_{fa}) + 1 \right\rfloor$,

Where $Q(x) = (1/\sqrt{2\pi}) \int_x^{\infty} e^{-u^2/2} du$ is the standard Gaussian tail probability function.

The probability of detection over non-fading AWGN channel, the probability density function defined under H1,

$$P_d = \int_{\gamma/\sigma_n^2}^{\infty} \frac{1}{2} (\frac{t}{\rho})^{(N-2)/4} \exp(\frac{-(t+\rho)}{2}) I_{(N/2)-1}(\sqrt{t\rho}) dt$$

Substituting $t = x^2$, $\rho = a^2$ and with the further simplification, P_d can be written as,

$$P_d = \frac{1}{a^{(N/2)-1}} \int_{\sqrt{\gamma/\sigma_n^2}}^{\infty} x^{N/2} \exp(\frac{-(x^2+a^2)}{2}) I_{(N/2)-1}(ax) dx$$

Can rewrite the equation using the definition of generalized Marcum function as,

$$P_d = Q_{N/2}(\sqrt{\rho}, \sqrt{\frac{\gamma}{\sigma_n^2}})$$

Literature Review

Multi-hop cooperative caching in social IoT using matching theory; Author: Li Wang, Senior Member, IEEE, Huaqing Wu, Student Member, IEEE, Zhu Han, Fellow, IEEE, Ping Zhang, Senior Member, IEEE, and H. Vincent Poor, Fellow, IEEE; Year: 2018

Social networking and device-to-device (D2D) communications in the IoT, the resulting social IoT can potentially provide services more effectively and efficiently. Content sharing among smart objects (devices) in the social IoT with D2D based cooperative coded caching. Generally, complete content items or coded fragments are allowed to be delivered via multi-hop cooperative D2D communications. Firstly, aiming at maximizing the overall success rate of multi-hop based content sharing, the interplay between coding parameter optimization and wireless resource allocation is investigated by considering both physical and social characteristics. Moreover, a Roth and Vande Vate (RVV) based distributed scheme is proposed to solve the dynamic matching problem between the content helpers and content requesters.

Practically, some smart objects in the IoT are wearable or handheld, and thus these objects or devices may move around because of user mobility. Therefore, the cooperative caching and communication performance of these objects can be significantly affected by mobile users' behaviour. For simplicity, in this manuscript, mobile users or mobile devices can be used to represent this kind of IoT objects or devices owned or held by mobile users. In content sharing scenario, the contact duration between mobile users is limited and may not be able to support content delivery. Furthermore, considering that mobile devices generally have batteries with limited energy, some content helpers (CHs) that have stored several content items may become invalid and lose the ability to provide cached content items for content requesters (CRs).

To facilitate efficient and effective content sharing in D2D caching based social IoT, the interplay between coding parameter optimization and wireless resource allocation is investigated in this work. Particularly, the overall success rate of content sharing (including both content download success rate and content repair success rate) is maximized by considering: 1) the determination of repair interval, 2) the optimization of coding parameters, 3) the selection of new caching nodes to repair the lost data, 4) the selection of proper CHs for CRs in the content download process, and 5) the allocation of CHs to new caching nodes in the content repair process.

The concept of multi-hop cooperative caching and communication is proposed in this work. By enabling multihop data delivery among smart devices, the success probability of content sharing is largely improved. Furthermore, the interplay between social networking and resource allocation is investigated in the social IoT setting, leading to higher resource utilization efficiency. This work can provide a theoretical basis for future studies related to smart devices in the social IoT setting, especially for the coordination among caching, communication, and computation.

Wireless distributed storage systems are used to encode content items by applying an erasure code. Typically, content items in this work are allowed to be transmitted via multiple hops to increase the probability that mobile users can successfully receive desired content items via D2D communications. The analytical expression for the overall transmission success rate has been derived as a function of the repair interval, the matching between CRs and CHs in the content download process, and the matching between new selected caching nodes and CHs in the content repair process.

Advantage

Achieved higher success rate when enabled D2D communication. Multiple hops to increase the probability that mobile users can successfully receive desired content items.

Disadvantage

When transmission established by introducing the interference among D2D scheme. Delay has not discussed during transmission which affect the throughput of the system.

Title: Decentralized Computation Offloading and Resource Allocation for Mobile-Edge Computing: A Matching Game Approach; Author: Quoc-Viet Pham, Tuan LeAnh, Nguyen H. Tran, Bang Ju Park, and Choong Seon Hon; Year: 2018

An optimization framework of computation offloading and resource allocation for mobile-edge computing (MEC) with multiple servers. Concretely, we aim to minimize the system-wide computation overhead by jointly optimizing the individual computation decisions, transmit power of the users, and computation resource at the servers. The crux of the problem lies in the combinatorial nature of multi-user offloading decisions, the complexity of the optimization objective, and the existence of inter-cell interference. To overcome these difficulties, we adopt a sub optimal approach by splitting the original problem into two parts: (i) computation offloading decision and (ii) joint resource allocation. To enable distributed computation offloading, two matching algorithms are investigated.

An efficient framework of distributed computation offloading and resource (computation and communication) allocation to minimize the system-wide computation overhead in multi-server MEC HetNets. Here, computation offloading pertains to finding the solution for the user association and sub channel assignment and resource allocation relates to the transmit power allocation of offloading users and computation resource allocation at the MEC servers. The considered problem faces difficulties caused by the combinatorial nature of multi-user offloading decisions, the complexity of the optimization objective, and the existence of inter-cell interference among offloading users, i.e., an NP-hard combinatorial problem.

Then, an optimization problem is formulated subject to constraints on the MEC server and sub channel selections, maximum transmit power of mobile devices, and maximum computation resources at the MEC servers. To solve the problem, we adopt a sub optimal approach by splitting the original problem into two parts: (i) computation offloading decision, which includes user association and sub channel assignment, and (ii) joint resource allocation, which is further decomposed into the transmit power of offloading users and computation resource allocation at the MEC servers. A joint framework of resource allocation and server selection in collocation edge computing systems is currently under investigation of our ongoing work. Moreover, we will take into account the effects of computation offloading to the quality of service of macro cell users.

Advantage

Jointly determined the computation offloading decision Efficiently allocated the transmit power of users and computation resources at the MEC server.

Disadvantage

Not suitable for users with latency-sensitive applications.

Simulation and Results

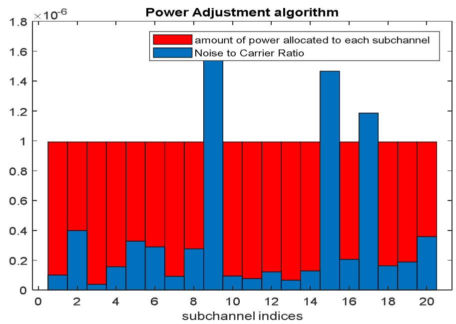

Fig. 5: Power Adjustment Algorithm for sub channels

Above graph describes the power allotted for each sub channel by power adjustment algorithm. Here taken the 20 sub channels, red colour lines denoted the amount of power dissipated by each sub channel. Blue colour line denoted the noise variance at each sub channels.

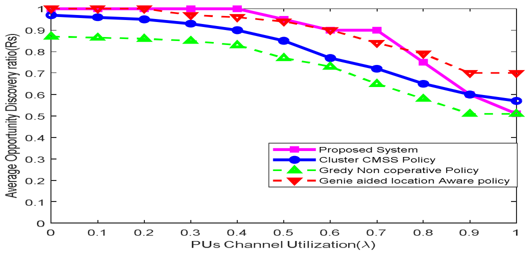

Fig.6: Probability of Spectrum Discovery Ratio

From the above graph, based on the probability of utilization of channel for PUs, estimated the opportunity of spectrum discovery ratio for SU. It is observed that the probability of opportunity of spectrum discovery ratio is high when the utilization of PU is smaller. It is decreasing when PU utilization is increased.

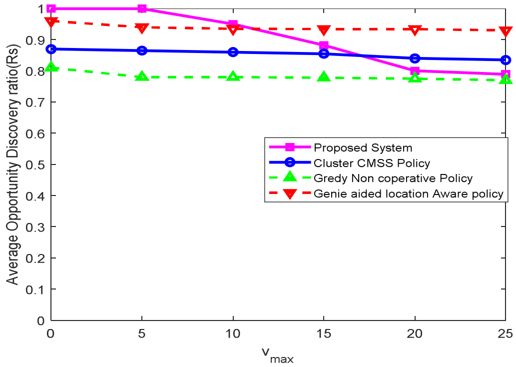

Fig.7: Maximum Velocity of SUs Movement Vs Opportunity of Spectrum Discovery Ratio

The above graph, plotted between maximum velocity of SUs movement vs opportunity of spectrum discovery ratio. Analyzed that the increasing the velocity of SUs movement, can maintain the average opportunity of spectrum prediction for that SUs. Compared with existing system, proposed method provides higher probability when movement of SUs is low.

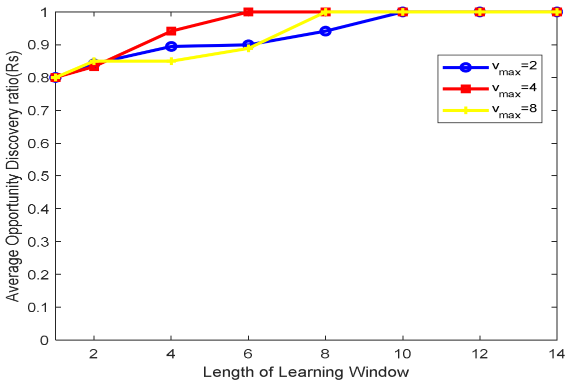

Fig.8: Prediction Ratio Gets Increased When Learning Rate Is High

The same average opportunity discovery ratio plotted by varying the length of learning window when the maximum velocity of SUs movement is fixed to 2, 4 and 8. From above figure, it is observed that the prediction ratio gets increased when learning rate is high.

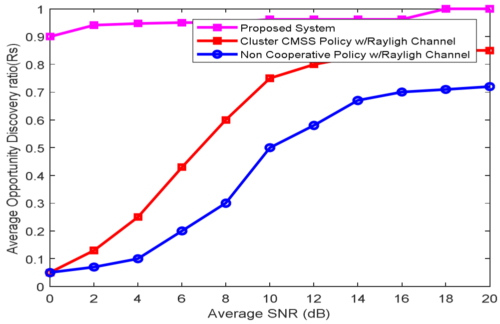

Fig. 9 Average Opportunity Discovery Ratio Increases When Increasing The Average SNR

Above graph stated that, gradually increased the average opportunity discovery ratio when increasing the Average SNR(dB). Which basically allows each SU to access the channel it finds empty and used to transmit on that channel.

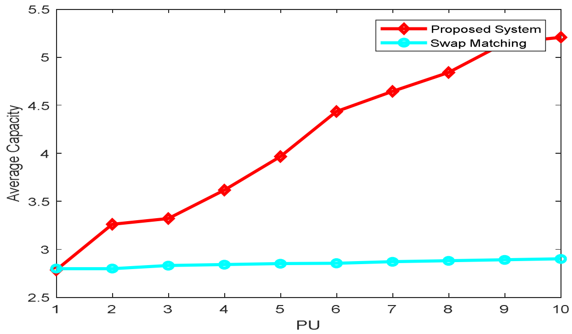

Fig.10: Average Capacity of the System Increases with Number of PUs

Above graph observed that, when number of PU gets increased, then the average capacity of the system increased. Capacity of the system depends upon the power utilization, band width uses and SNR in the available channel.

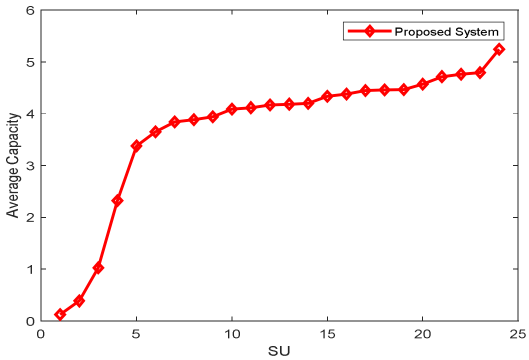

Fig.11: Average Capacity of the System Increases with Number of SUs

Above graph observed that, when number of SU gets increased, then the average capacity of the system increased. Here SU used their power to sense the spectrum and used for transmitting PUs data along with their data to achieved high capacity.

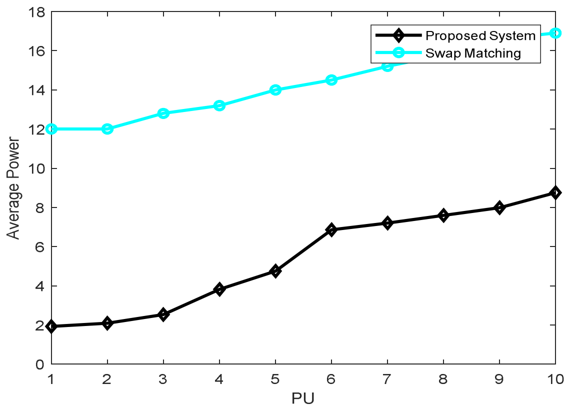

Fig.12: Power Dissipation of the System Increased with Number of PUs

Above graph observed that, when number of PU gets increased, then the average power dissipation of the system increased and the same decreased when compared with existing system. In this process, spectrum sensed and transmitted data is mostly depends upon the SUs total power.

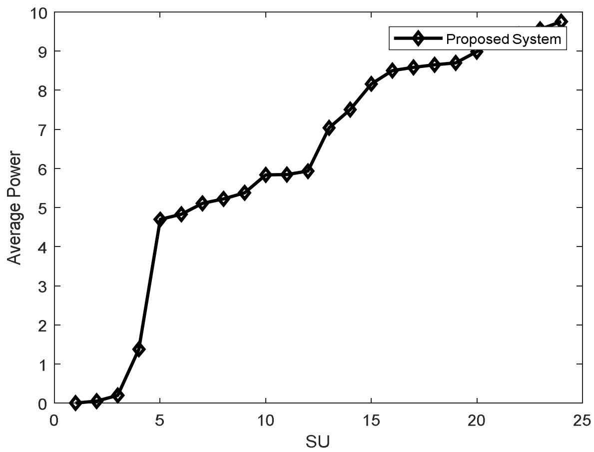

Fig.13: Power Dissipation of the System Increased with Number of SUs

Above graph observed that, when number of SU gets increased, then the average power dissipation of the system increased. SU used their power for sensed spectrum and transmission data for both SU and PU

Conclusion

Proposed policy which detects the spectrum holes without depending on the location information of the primary users. Based on this policy, the secondary users and primary users are clustered based on their spectrum sensing results. CMSS approach for clustering SU nodes and PU nodes, which is based on the consensus among the SUs' & PUs channel sensing results. Here, the BS uses this metric to form the clusters without knowledge of the location of the SUs. Then, the BS performs a graph-theory-based coordinated spectrum sensing among members of each cluster, then the relay mechanism for data transmission to increase capacity of the system. Probability of detection and miss detection are analyzed.

Future Enhancement

In future, wireless communication system will deal with IOT based application. Wireless communication system is the essential part for IoT infrastructure, which acts as the bridge for dual directional communication for data collection and control message delivery. It can be applied to various IoT applications, including mission critical industries, such as power grid, oil field, and cases in our routine life like the smart city.

In order to solve those issues, we build up an end-to-end SDR wireless platform for IoT to support the optimized communication from the senor network to the wide area radio network. We used the IT-based software-defined radio (SDR) technology to complete the entire base band processing on General IT platform with multi-cores processors, such as POWER, x86 and Cell BE. The acceleration technologies, such as SIMD, vector processing, parallel processing, etc., have been used to speed up the signal processing with extremely low latency.

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