Spectrum Sharing for Large Scale Network in Cognitive Radio Network

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Abstract— **Cognitive Radio technology is an example Software Radio. With the diversification of wireless communication services and the proliferation of different wireless network technologies, the demand for radio spectrum is increasing dramatically. The spectrum measurement indicates that the allocated spectrum is not fully utilized, that is, there exist a unused spectrum. In order to overcome this cognitive radio technology is used. Here the unused spectrum is allocated to secondary users by considering the social welfare of particular bid valuation. and the spectrum is divided in Time-Frequency manner so that the secondary user can buy the spectrum he desired. Here the social welfare can be determined by different method and it is compared by tracing the graph between social welfare and number of secondary user's. and spectrum utilization ratio also can determine by combined algorithm. The SU's with highest social welfare and spectrum utilization ratio can share the PU's spectrum.**

Index Terms— **Cognitive Radio Network, social welfare, spectrum utilization ratio.**

I. INTRODUCTION

Software Defined radio technique was proposed to improve adaptability and flexibility of wireless transmission so that wireless system performance can be enhanced. Developed based on software-defined radio, "cognitive radio" has been identified as a new paradigm for designing next generation wireless networks. A cognitive radio transceiver has an ability to observe, learn, optimize, and change the transmission parameters according to the ambient radio environment. With this agility of the radio transceiver, frequency spectrum can be shared among licensed (i.e., primary) and unlicensed (i.e., secondary) services to improve spectrum utilization and also to generate higher revenue to the spectrum owner. For efficient dynamic spectrum sharing, an economic model would be required for the spectrum owners and the spectrum users so that the revenue (hence profit) and the user satisfaction can be maximized.

In CR networks, the original licensed operators are called Primary users (PUs) and the users who want to access spectrum opportunity are called as Secondary users (SUs).

When the allocated spectrum is not fully utilized, the spectrum owner (or primary service provider) has an opportunity to sell the spectrum opportunities to secondary service providers1, and thereby, generate revenue. This is referred to as the spectrum trading mechanism which involves

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spectrum selling and buying processes. For spectrum trading, one of the challenging issues is pricing, for example, how to set the spectrum price in a competitive environment where multiple sellers (e.g., primary services) offer spectrum to the buyer (e.g., secondary service), so that the sellers are satisfied.

In this paper, we model the spectrum opportunity in time-frequency manner so that the buyer can buy the spectrum he desires. And spectrum sharing for large scale networks is done by finding social welfare and spectrum utilization ratio.

The Secondary user bid with highest social welfare and spectrum utilization ratio can allowed sharing the spectrum of primary user in large scale network.

In this model PO presents as an auctioneer. Periodically, the PO contacts with the spectrum opportunity data centre to obtain the free spectrums of PU's. The PO then divides the acquired spectrum opportunity by frequency and time as shown in Fig.1. We can see that spectrum opportunity at time from t_0 to $t_0+\Delta t$ at frequency f_0 to $f_0+\Delta f$, we denote this piece of spectrum opportunity as a *slot*. Thus, the spectrum sharing can satisfy the SU's flexible requirement and improve the spectrum efficiency.
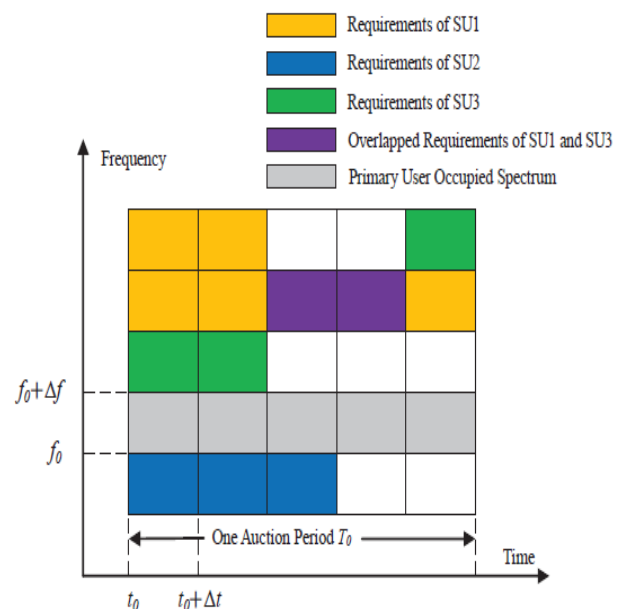

Fig.1. PO's spectrum opportunity in Time-Frequency manner

II. II.NETWORK MODEL AND PROBLEM FORMATION
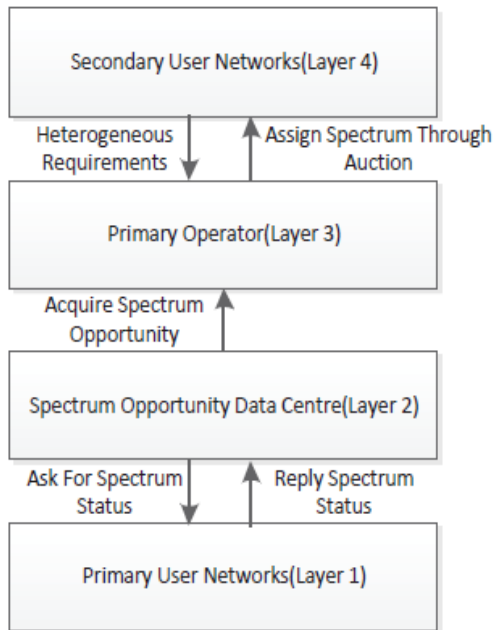
A. Network Model

Fig.2. Cognitive Radio Network Model

The Fig.2 shows the novel four- layer model, which includes the data centre layer .the network model consist of primary network, secondary network, and secondary network base station. We divide the base station network into data centre and PO.

In the CR network model, the first layer is the PU network and it is the source of spectrum opportunity. The second layer contains the spectrum data center, and it collects the information of spectrum opportunity from the PUs via various ways and divides the acquired spectrum into groups based on the spectral characteristics. The spectrum data center periodically asks the primary users for the spectrum opportunities and the PU network replies to this enquiry. The third layer lies the primary operators which contact the data center for the spectrum opportunity and sell them to SUs, which lie in the fourth layer of the model. That is, the PO can acquire the spectrum from the spectrum data center and then PO realizes the dynamic spectrum sharing among the SUs cooperated.

B. Problem Formation

In this mechanism, the buyer i can submit up to one bid and $b^i(T)$ is the valuation of the bundle T. However, there may be several buyers submitting on the same bundle of goods. It can simply keep the bid with the highest valuation on the same bundle, and the others can be discarded since it can never increase the social welfare for the auctioneer to accept one of these discarded bids. The buyer with the highest valuation of the bundle goods is buyer i = $argmax_{j \in bidders} b^j(T)$. Other bids on the same bundle are discarded and we assume that the Corresponding buyer j's valuation bj(T) = 0. Thus, it can reduce the computational complexity in winner determination.

Under these preprocess of all the bids, there are two crucial parts of the auction mechanism in this work: cognitive radio winning SUs determination problem (CRWDP) and truthful

mechanism design problem (TMDP), which refers to winner determination and payment mechanism. The task of the CRWDP is to determinate the winners and allocate the goods and the goal of the TMDP is to propose a payment mechanism that can guarantee the auction truthfulness.

C. Combined Algorithm for CRWDP

> Initial State
> 1: All buyers submit their bids $b_i = \{C_i, v_i\}$ to the auctioneer, an integer k and $W = \emptyset, W_{app} = 0$.
> Calculate approximated solution of Part 1
> 2: $A_k = \{W \subseteq S : T, T' \in W \Rightarrow T \bigcap T' = \emptyset, |W| \leqslant k\}$,
> $W_k^* = argmax_{W \in A_k} \sum_{T \in W} b(T)$
> Calculate approximated solution of Part 2
> 3: $A' = \{T \in S, |T| \leqslant \sqrt{m/k}\}$
> 4: $t = 0, A'_0 = A'$
> 5: WHILE $|A'_t| > 0$
> $\quad t = t + 1$
> $\quad X_t = argmax_{T \in A'_{t-1}} b(T)/\sqrt{|T|}$
> $\quad Z_t = \{T \in A'_{t-1} : X_t \bigcap T \neq \emptyset\}$
> $\quad A'_t = A'_{t-1} - Z_t$
> END WHILE
> 6: IF $\sum_{T \in \{X_1, X_2, ..., X_t\}} b(T) > \sum_{T \in W_k^*} b(T)$
> $W = \{X_1, X_2, ..., X_t\}, V_{app} = \sum_{T \in \{X_1, X_2, ..., X_t\}} b(T)$
> ELSE $W = W_k^*, W_{app} = \sum_{T \in W_k^*} b(T)$
> ENE IF
> 7: Output W, W_{app}

The above Algorithm is a combined algorithm. Construct the combined algorithm of greedy algorithm and partial exhaustive search algorithm to improve the allocation algorithm. Now briefly describe the combined Algorithm and then derive about the computational efficiency and approximation ratio.

The algorithm is composed of two parts:
- Part 1: It is an partial exhaustive search of all bids and obtain at most k bids that does maximize the social welfare as large as possible, namely Exst-k algorithm. Therefore, the k different disjoint bids are the winners and the social welfare is the sum of these bids' valuation at this part.
- Part 2: It is a greedy set packing algorithm to find a social welfare on the specific bids that the number of goods is less than $\sqrt{m/k}$, where $k \in N$ and $1 \leq k \leq m$. Then it greedily selects sets of maximal that is not selected previously, ordering by the norm $v\sqrt{ci}$.

By comparing the social welfare of these two parts, then select the better one as the ultimate result and the corresponding winners are obtained. Algorithm 2 establishes a better upper bound $2\sqrt{m/k}$ under some specific cases, where $k > 4$. The auctioneer can choose the value of k. As k increases, the upper bound improves but the computation time increases. Though the computation complexity increases, the algorithm is still a polynomial time algorithm for a fixed k.

III. SIMULATION RESULT

Approximated Simulated Result in Large Scale Networks:

Let us assume there survive only one primary operator in the network. Since solving the optimal solution under the general model is NP hard, the simulation results of the optimal solution with the small number of SUs so as to compare the difference of the optimal solution and these two approximate algorithms. and also provided the simulation results with large scale networks of SUs to compare the performance of combined algorithm and other methods. The primary operator divides the time period into 10-min long 6 sectors and divides the whole frequency band to 24 slices. Therefore, the number of frequency-time slots for SUs to choose is $m = 144$. And assume the number of SUs n varies from 100 to 1000. The maximal requirement number for any SU is 36 slots and each SU randomly chooses an integer as the slot number from 1 to 36.

For better comparison, use different ordering method and the combined algorithm to generate allocation results. It can be seen that the social welfare generated under the proposed combined Algorithm 2, denoted as Algorithm 2 and for the Algorithm 1, it is denoted as Norm. Value means reordering the bids only in descending order of valuation. Number means reordering the bids only in ascending order of the number of the required slots. AVG means reordering the bids in descending order of average value per slot.

Fig. 3 shows the relation between social welfare and the number of SUs. And all the curves are ascending with the increasing number of SUs. By comparing the simulation results, Algorithm 2 is better than the Norm on the social welfare. But Algorithm 2 and other algorithms are approximated when the number is 100. Value is the worst one and the gap is about 10 with respect to Algorithm 2 when the number of SUs is 1000. Therefore, the proposed combined Algorithm 2 is better than other algorithms**.**

Fig. 4 uses Algorithm 2 as a benchmark to evaluate percentage of social welfare reached by other algorithms compared to that reached by Algorithm 2. Only the Value is decreasing verses the number of the SUs and others' changes are small. And *Norm* is the best one and AVG is the second better following by the Number.

Fig. 5, show the spectrum utilization ratio, which indicates the ratio of allocated slots to the total slots of PO. Fig. 6 shows that Value has the best spectrum utilization ratio and Norm is the second best followed by AVG and Number. Spectrum utilization ratio of Algorithm 2 is nearly the same as that of the Norm when the number of SUs is large and it becomes to be worse than the Norm when the number is relatively small. However, when the number of SUs is sufficiently large the utilization ratio is nearly equal and acceptable.
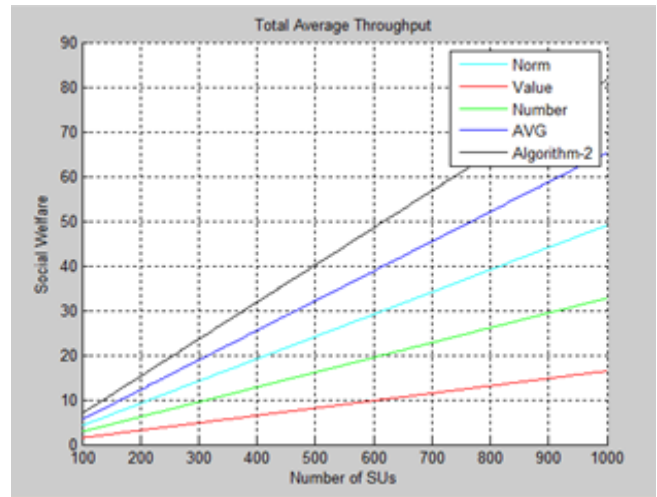

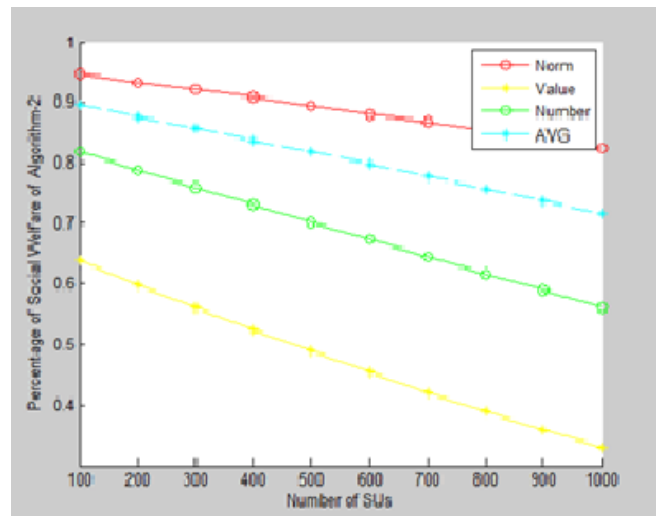Fig.3 Comparison of Social Welfare under General Model in Small-scale Networks

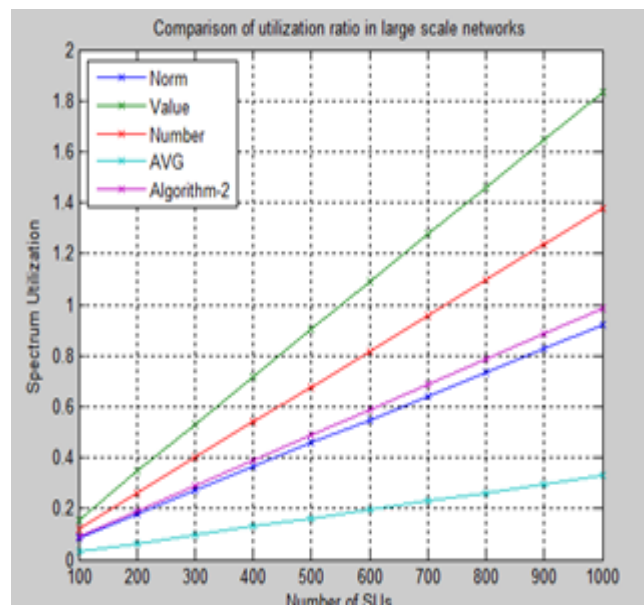Fig 5 Percentage of Social Welfare of the Norm Solution under General Model in Large-scale Networks

Fig. 6. Comparison of utilization ratio under General model in large-scale networks.

IV. CONCLUSION AND FUTURE WORK

A. CONCLUSION

Here initially the unutilized primary user's spectrum is divided in Time-Frequency manner so the secondary uses can buy the desired spectrum. By using Greedy Algorithm the social welfare of secondary user's determined by different methods like Norm, Value, Number and AVG. After comparing these values in large scale networks the Algorithm 2 has the better social welfare. By considering the algorithm 2 as benchmark the percentage of social welfare for different method is determined and here Norm is best one when compare to benchmark the percentage of social welfare for different method is determined and here Norm is best one when compare to other's. Later the spectrum utilization ratio is determined and the graph between spectrum utilization ratio and number of SU's shows that Value has the best spectrum utilization ratio and Norm is the second best followed by AVG and Number. The spectrum utilization ratio of Algorithm 2 is nearly same as that of the Norm when the number of SU's is large and it becomes to be worse than the Norm when the number is relatively small. However, when the number of Su's is sufficiently large the spectrum utilization ratio is nearly equal and acceptable for large scale networks.

B. FUTURE WORK

In future the social welfare and spectrum utilization can be determined for small scale networks and we can also determined winner of secondary user and how much he has to pay for a particular spectrum he won by truthful payment mechanism. Here the secondary are allowed to submit only one bid but in future the secondary user can allowed submitting the multiple bids.

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