An Improved Scheduling Algorithm for Cognitive Radio Networks under Different Traffic Patterns

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Abstract. In this paper we propose a spectrum sharing scheduling algorithm for an infrastructure based cognitive radio network. The problem is formulated to allocate channel to the secondary user (SU) based on the idle frequency band, distance, power, bit error rate and SINR. Two scheduling algorithms namely tournament scheduling (TMS) and optimized back–tracking scheduling (OBS) has been developed for the scenario where few primary and many secondary exist in a typical cognitive radio environment. The OBS and TMS algorithm has been implemented and simulated under different traffic patterns namely, Poisson and Pareto over constant bit rate (CBR), variable bit rate (VBR) and best effort services. The simulation result shows a considerable reduction in execution time for the OBS method under varying traffic load.

Keywords: Cognitive Radio, traffic load, bit error rate, sensor network, optimized back–tracking scheduling

1. Introduction
A Cognitive radio is planned to be responsive of the adjustments in its current circumstance. Spectrum sensing empowers CR clients to change in accordance with the radio background by persuasively adjust unused Spectrum the alleged Spectrum holes. The vital objective of Spectrum detecting is to manage the cost of more Spectrum access holes that are known as Dynamic Spectrum access (DSA) is a procedure that permits the Cognitive clients (auxiliary) to share the Spectrum in a opportunistic way [1]. The idea of cognitive radios was first authored by Joseph Mitola [2] said, An cognitive radio network (CRN) is based on the rule that an unlicensed clients persistently sense the use of Spectrum band by authorized clients and astutely devour the Spectrum while primary user (PU) isn't being used. Any secondary user (SU) should perform the sensing to find out the presence or absence of PU and then communicating at appropriate power when the PU is absent.

Cognitive radio network can be a cheerful way to deal information communication with exacting QoS necessities. The communication has end up being a critical component in ongoing society, today the absolute number of buying in clients in cell remote services have outperformed the quantity of clients buying in to the wired mobile utilities. The diverse remote communication frameworks existing today are distinctive regarding information pace of transmission, inclusion zone, and correspondence force and versatility support [3].

The communication systems can be categorized as high power broad area network, low power and speed in local area systems.

These issues include the distribution of radio capacity and medium-access regulation, rate tracking, handoff, mobility management, service efficiency and protection. [4] Presently, significant studies of...
complex spectrum access networks concentrate on developing resource utilisation and management processes, according to a comment that different traffic performances will actually be demonstrated by primary users (PU) and secondary users (SU) traffic.

In this paper, we look at a radio network that uses the Spectrum Holes of several PU channels by many secondary users (CR). User data traffic is modelled by the On-Off method for Poisson and Pareto, in which the channel is controlled and OFF remains in ON state [5]. Each CR has an input queue, and a random number of calls arrive at any slot. The effect on the cognitive radio network of the heavy tailed traffic is also analysed.

The rest of this paper is organized as follows. Section II introduces the system model and preliminaries. Section III formally presents the network stability and scheduling algorithm, results and discussion. Final section concluded the paper.

2. Related Works

Heavy tailed traffic has been tested in an assortment of PC organizations, for example, Ethernet, WLAN, adhoc networks, and cell networks [6]. The age of VoIP, FTP, HTTP, and video traffic depends on five kinds of traffic conveyance. Here the Poisson cycle has two states wherein [7] information created during the on and off state. Opportunistic scheduling was studied for cognitive radio network under the common model [8]. The joint problem of stabilising the secondary nodes that meet the long term limitation on the primary channels becomes a problem of queue consistency using the virtual queues technique. The sensing of continuing propagation delays that can result in interfering with the primary network should be observed [9]. In this case, two types of CBR and random[9] maximal effort(BE) traffic are considered based on the IEEE 802.15.4 MAC standard, all containment based and containment free packets are defined. CBR traffic shall be equipped with protected time slots and BE traffic with a containment access span in order to achieve limited transmission delays [10].

Improved TWO Acknowledgment strategies [11] clearly send a two-hop affirmation to affirm hub cooperation. A cross layer outline work is acquainted with better information appropriation and versatile traffic in multi hop remote network [12],[13]. A progression [14] of mathematical programming, and a solitary buildup technique based iterative calculation is proposed to tackle the non-raised max min problem. The clustering time and energy prerequisites have been limited by presenting the idea of CH board.[15] At the underlying phase of the convention, the BS chooses a bunch of likely CH hubs and structures the CH board.

System model

The CR user has to choose an suitable sensing schedule so that the PU can be protected, and if not in use the spectrum is utilized to the best extent by the CR user. The radio frequency is created by a virtually We have consider a single sequential test with respect to time and sensing process and the sensing decision is under the Hypotheses H₀ and H₁ as in equation1.

\[ x(t) = \begin{cases} 
  n(t) & H_0 \\
  hs(t) + n(t) & H_1 
\end{cases} \quad (1) \]

Where x(t) is the received as signal, s(t) is the sent signal of PU, where n(t) is a zero mean added substance while gaussian commotion (AWGN), H is the sufficiency gain of the channel, H₁ and H₀ are utilized to address the presence or nonattendance of the essential signal separately.

CRN embrace the way path channel model which incorporates log typical shadowing while the transmission and got power of a hub is acquired by equation(2)

\[ P_R = P_T - l_P - 10α \log \Phi(\mu, σ) \quad (2) \]

Where, q is a Gaussian irregular variable, pl is the way path adjustment, α is the way path type, PT and PR are the transmission and recipient controls separately. The getting power is furnished by a Gaussian arbitrary variable with mean μ(noise floor) and σ(noise deviation). We consider a structure based cognitive radio organization network the sight of both the Secondary and Primary cell and
The inclusion zone of the both are the equivalent. The transmission of both Primary and Secondary cell use time division duplex mode as the time synchronization is thought to be ideal for the both networks. Each cell is sectorized into sectors equally as to avoid inter cell interference and each CR depend on their parameter value and try to fetch connection as shown in Figure 1.

![Figure 1](image)

**Figure 1**: PU and SU scenario in cognitive radio network.

At the cell there are number of PU and CRs, where the secondary users can be allocated opportunistically to the idle frequency. If the serving CR node of the SU and the serving PU node are located at the same position then due to false alarm or missed detection they cannot receive data for the respective serving node that results severe interference to each other. And in this paper we assume that the CRBS and PUBS need exactly one channel to serve each of the SU, PU and we consider the optimized and non-optimized scheduling. We formulate the BER based sensing and transmission for N number of CR users that can be a parallel queuing network as in Figure 2.

![Figure 2](image)

**Figure 2**: Parameters assigned to each CR nodes.
For each frame in a cell, \( T_{\text{min}} < T_{\text{type}} < T_{\text{max}} \) supposing that an optimal user can be identified at time \( t \) and assuming SNR(\( \Gamma \)), Power (\( P_{\text{threshold}} \)) and BER for all \( N \{0,1,...,N\} \) will carry out the sensing on the cell and allowing one of the NCR users to occupy the idle frequency \( \text{fidle} \).

Our aim is to schedule the optimal user allocations in conditions of Best effort (BE) services are designed to support transmission in which no minimum service guarantees required. Poisson Constant Bit Rate Poisson-(CBR,VBR)/Variable Bit Rate Pareto(CBR,VBR) system, We observe the values of each parameter such as SNR, distance, Channel Quality Index taken as random. By computing each by the expression given in equation 3

\[
y_i = w_1 \times \text{ber} + w_2 \times p + w_3 \times d + w_4 \times t_{\text{type}} \quad (3)
\]

\[
Y = \max \sum_{i=1}^{N} (4) \ 'value' \ _i
\]

Where, \( W_i \leq 1 \)

\( P_{\text{value}} \in \{ \text{BER, Distance SINR, Power} \} \)

\( w \) is a weight of each node that specify the delay value of CR nodes with some selected constant. Further by stabilizing the queues for random BER experienced for N number of users. With the parameter value obtained select the optimal user \( Y \) by way of scheduling algorithm select the optimal user \( Y \) by way of scheduling algorithm.

3. Proposed Algorithm

Tournament scheduling method is used to select a user from N users in this method the iteration process will be more to select a user from N users, the selected users are involve for crossover to the another users. This method is a type of min (max) heap and also mention as complete binary tree. Each and every exterior user represents as SU and crossover users are represent as selected users for crossover to another users. In this method the first selected user will use the idle frequency, for another idle frequency or same idle frequency the tournament iteration has to implement to find the user. So the total iteration will be \( n(1/2+1/4+...) = n \) to overcome the n iteration and also reduce the time one more algorithm has been implemented.

Optimal back – tracking scheduling algorithm is same as tree concept, the tree will contain parent and child from that maximum users will selected. In proposed algorithm the concept is inverse triangle it means root at bottom is use to find the second maximum user, it will use to utilize the time to allocate the idle frequency and for another idle frequency or same idle frequency. To find highest user start from root element and compare with another user, this root element method will reduce the time and also contain next high Pvalue user to allocate for other idle frequency or same idle frequency if the SU left it after his usage. The process of this algorithm will reduce the duration time to allocate the SU from N SU i.e \( \{0[ n+\log(n)] \} \) is reduce the iteration time to find the SU than \( n(1/2+1/4+...) = n) \)

3.1. Tournament Scheduling (TMS) Algorithm

With the value for each user is \( y_i \), stored as a vector, to find out the maximum value from the array, choose the first value and compare it with the next and choose the maximum of the two. Again comparison is done with the third value. These processes are done for all vectors present and finalize the maximum (Y) value. The CR user who has the max is chosen as a best user to allocate to the idle frequency. For all N users we need to do (n-1) comparison to obtain this max value then that user is relieved from the list (NCR-1), To find the second maximum with 2n-3 comparisons (i.e) first two elements is compared + 2 comparisons for left out elements of array in the form of dynamic programming.
### (a) TMS Algorithm
1. Read the input parameters for all CR users;
2. for each CR users
   Observe the input parameters.
3. Calculate $y_i$ for $i$th CR using (3)
4. Pair the $Y_i$ with another $CRY_j$
5. Repeat step 3 and 4 for $N$ CR
6. Find $CR$ with highest $Y_i$
7. Get first two $y_i$ values.
8. Compare these two values and find max value.
9. for rest of $y_i$ values.
   Compare next $y_i$ values with max value from step 8.
   If next value is greater than max value return max value
   else it returns next value as max value.
end for.
10. return max value ($y_i$)
11. if max($y_i$) ≥ $y$ threshold, then
    set fidle = $Cr_i$;
else wait for random amount of time and go to Step 1.

### 3.2. Optimized Back-Tracking Scheduling (Obs) Algorithm
The execution time and n comparisons for single user is much higher, so computation complexity is high. To overcome this we go far other scheduling based on BER. Here the user is consider as a players, the values obtained are said to form another array with half of the size, comparing the adjacent values of the array and remaining two values are selected to form half size array. The logic is at finding the maximum value should knock out the second value.

#### (b) OBS Algorithm
1. Read the input parameters for all CR users;
2. for each CR users
   Observe the input parameters.
3. Calculate $y_i$ for $i$th CR using (3)
4. Pair the $Y_i$ with another $CRY_j$
5. Repeat step 3 and 4 for $N$ CR
6. Find $CR$ with highest $Y_i$
7. Construct a tree with $yi$ values (inverse triangle it Means root at bottom )
8. Starting from root element and find the highest of two adjacent $y_i$ values
9. one row above find highest $y_i$ value with adjacent values.
10. compare the adjacent $y_i$ value with highest $y_i$ value and select the highest of two values and return max value of $y_i$.
11. if max($y_i$) ≥ $y$ threshold, then
    set fidle = $Cr_i$;
else wait for random amount of time and go to Step 1.
end.
So by the way of backtracking from the element at the root and all the way to the top and read-through all the adjacent values and choose the second obtained max value, it can be obtained by the index of the value, therefore there is no necessary to check complete sub array. Comparisons for finding maximum: $n$ For finding the 2nd maximum we need $\log(n)$, Thus, $O(n+\log(n))$.

4. Results and Discussions

We have simulated the TMS and OBS algorithm on Java platform. The traffic patterns of different types namely BE, RT-CBR, RT-VBR, NRT-CBR, NRT-VBR are considered during simulation. The following are the main simulation parameters in Table 1. Consider the Case 1. Collecting the parameter values for CR users varying from 10, 20 ...100 users, In Figure 3 shows the execution time over the Poisson constant bit rate of CR users. We obtain the best user $Y$ from the set of user’s list in minimum execution time (i.e) for example computing 10 users using OBS scheduling takes 71.85sec whereas TMS based scheduling takes 164.7sec.

| S.No | Parameter used for simulation     | Value         |
|------|-----------------------------------|---------------|
| 1    | Number of Primary Nodes           | 30            |
| 2    | Number of CR Nodes               | 40            |
| 3    | Simulation Dur. (min)             | 90            |
| 4    | Transmit Power (db)               | -10           |
| 5    | Noise Floor (db)                  | -85           |
| 6    | Noise Floor Std Dev (db)          | 20            |
| 8    | Seed Model                        | Random Seed / Constant Seed |
| 9    | Animation                         | On            |
| 10   | Traffic                           | Poisson Traffic / Pareto On-Off Traffic |
| 11   | Off Duration (hour)               | 0.5           |
| 12   | On Duration (min)                 | 2             |
| 13   | Sector Number                     | 3             |
| 14   | Radius of cell                    | 100 m         |
| 15   | Number of Sensing Slots           | 30            |
| 16   | Sensing Slot Duration (msec)      | 10            |
| 17   | Dur.of Sensing results ack. (msec) | 10          |
| 18   | Sensing Scheduling Advert. Dur. (msec) | 10 |
| 19   | Comm. Duration (msec)             | 630           |
| 20   | Comm. Schedule Advert. Dur. (msec) | 10          |
| 21   | Number of Frequencies             | 60            |
| 22   | Channel BandWith (KHZ)            | 8000          |
The figure 3 shows the performance of two different scheduling under Poisson – Constant bit rate. In Fig 4 we assume that the number of channels stay as previous, consider the case Poisson traffic in Variable Bit Rate (VBR) takes 74.1ms to execute 10 users and find the optimal user in OBS though there execution time also reduces with the increase in number of users and in TMS based BER it takes about 167ms for 10 users.

Figure 3: Execution time with Poisson Variable

Figure 4: Performance of two different scheduling under Pareto – Variable bit rate

Figure 5: Performance of two different scheduling under Pareto constant bit rate.
It can also be noted that while simulating 100 users the time taken for identifying the Y value is 67.0ms executing for 10 users which is considerably less than TMS, though for executing for more number of users the time get increased. Performance of two different scheduling under Pareto – Variable bit rate is shown in Figure 4 and Pareto constant bit rate in Figure 5.

![Figure 4: Performance of two different scheduling under Pareto-Variable BR](image)

Figure 4: Performance of two different scheduling under Pareto-Variable BR

Whereas in Figure 6 the performance shows for pareto variable bit error rate where there the time increases for executing 20users and then gradually reduces for the increase in the number of users. Figure 7 shows the performance in terms of execution time for the best effort services. Here too the OBS algorithm takes less time to perform the job.

![Figure 6: Performance of two different scheduling under best effort services](image)

Figure 6: Performance of two different scheduling under best effort services

![Figure 7: Performance of two different scheduling under best effort services](image)

Figure 7: Performance of two different scheduling under best effort services.

5. Conclusion
This paper shows the noteworthy effects in scheduling aspect. The proposed algorithm were simulated and analyzed under two traffic models: Poisson and Pareto. Further five type’s services namely BE, RT-CBR, RT-VBR, NRT-CBR, NRT-VBR were considered. From simulated result it is observed that the OBS algorithm performs better than TMS under different traffic pattern and services. Introducing a suitable learning method in scheduling algorithm for cognitive radio is our future work.
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