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A SPECTRUM HOLE DETECTION METHOD FOR COGNITIVE RADIO NETWORKS IN DYNAMIC TIME DIVISION MULTIPLEXING BASED SYSTEMS

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ABSTRACT
The usage of radio spectrum based communication for the current society is in exponential raise and it is being exhausted day to day. The cognitive radio optimizes the usage of licensed radio spectrum pre-allocated by the government and public agencies. The cognitive radio network has two major processes: the spectrum hole detection and the spectrum allocation. This article presents a dynamic approach for spectrum detection in time division multiplexing based wireless cognitive communication systems. The method can be used for the systems with fixed as well as the varying number of primary users. The proposed method is simulated and analyzed the performance.

INTRODUCTION
The world is being transformed rapidly from the traditional wired communication to wireless communication at the user level. In addition, the mobile devices bring many physical characteristic challenges to suit the current living style, for example communicating from building interior infrastructures, and high speed vehicular communication. Many of the challenges are fulfilled with the wireless communication using the radio spectrum. The radio spectrum frequency ranges from 3 KHz to 300GHz in the electromagnetic radiation and the optical spectrum frequency ranges from 300GHz to 3000 Thz [20], see the Figure 1. The whole radio spectrum is allocated into different spectrum bands.

These spectrum bands are assigned for specific tasks and function differently from other frequency ranges. In other words, the frequencies from 3 KHz to 300GHz are divided into regions. The rational process happened on the radio frequency is the division of frequencies into spectrum bands and it continues to be standard. These spectrum bands are defined and governed by International Telecommunications Union (ITU) authority for the civil, military, navy, government agencies, and public sector users of all nations. As the radio communication users are increased day to day, the predefined allocation not sufficient to the current society. Hence, researchers focused on new technology called Cognitive Radio (CR), which optimizes the radio spectrum usage [1,3,4,8]. In cognitive radio system, the pre-allocated unused radio channels are detected and allocated to the requested users. The Cognitive Radio Network (CRN) has two major tasks, the first one is spectrum hole detection process for finding the unused licensed spectrum of the primary user (PU)s and the second process is the allocation of these unused spectrum to the cognitive user (CU)s or secondary user (SU)s. In this paper, we focused on spectrum hole detection methods. In the literature, many spectrum whole detection methods exists [5, 6, 7]. One of the well-known method is energy detection method [2, 9, 10, 11, 12], which detects the signal presence in channels. This method is simple if the communication system uses the frequency division multiplexing (FDM) communication systems or its predecessors, and it is not well suited for time division multiplexing (TDM) based communications. We provided a strategy to detect a spectrum hole on TDM based systems [21]. However, the method assumes that the counts of primary users are fixed. In practice, number of users may vary any time. This article proposes a new spectrum detection method, which suits for TDM based system with varying number of primary users.

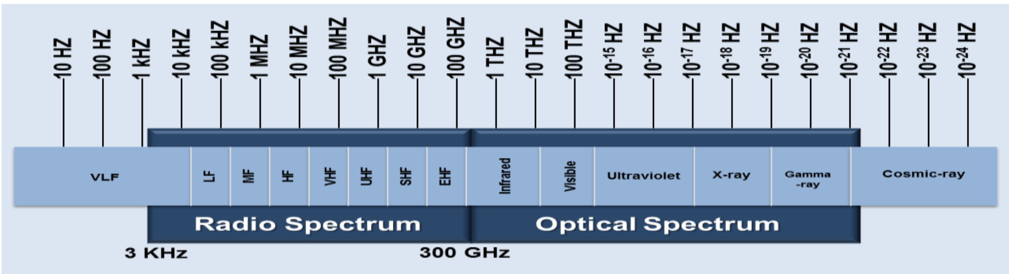

Figure 1 Electromagnetic Spectrum Divisions

The remaining of the paper is as follows: the section 2 provides related work and literature review. The section 3 presents a new method with the algorithm. The section 4 provides the information related to the simulation work and results. The paper is concluded in 4section 5.

RELATED WORK

The demand for the radio spectrum has increased exponentially as massive usage of mobile devices. The government regulatory authorities such as ITU made a static spectrum allotment, which brings underutilization of spectrum in some sectors and a significant amount of registered spectrum is not effectively utilized, Figure 2. From this drawback, an emerging technology is required to effectively utilize the pre-allocated electromagnetic radio spectrum. Hence, the cognitive radio is invented for such purpose.

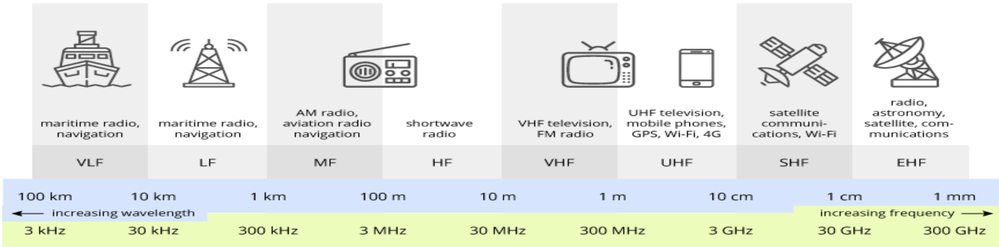

Figure 2 Radio frequency bands and applications

The cognitive radio is an intelligent system, which has a sequence of activities such as sensing the environment, learns from the environment, and records various parameters to manage the radio spectrum available in the real environment [1,3,4,8]. The primary responsibility of the CR is to provide the efficient communication system by effectively utilizing the radio spectrum. In other words, the CR's main objective is to optimize the utilization of precious radio spectrum by detecting the unused licensed channels to the needy secondary users or cognitive users from the available spectrum. Even, the CR technology can be applied to intra spectrum bands. In radio wireless systems, modulation techniques are important to improve the communication system performance at various conditions. A modulation method aiming to avoid the interference for LTE based system is proposed [22]. There are few well known simulators for simulating the modulation methods [23].

The spectrum hole detection process is still an active area and various mechanisms are being developed to adapt to the current physical properties of the environment. Various methods are proposed in the literature for spectrum sensing. These methods consider different parameters such as signal characteristics, and signal types [5,6,7].

One of the well know spectrum sensing method is matched filter method, which mainly depends on the signal information [15,16]. The method is standard and it increases the signal to noise ratio. The matched filter method compares output signal with the time shifting one. One of the drawbacks of the method is that it does not perform well if the signal information is unknown.

A method for the spectrum sensing states that the test statistics maximizes the possibility of finding the spectrum holes [17]. The method is based on statistical probability and it uses a parameter called false alarm probability. This parameter can be used to increase the chances of detecting the spectrum holes. The performance of the system is inversely proportional to the high detection probability. Hence, a balance is required between complexity of signal processing and the system performance.

The signal of the primary users can be considered as periodic signal or cyclo stationary signal, and their mean value and auto correlated function exhibit periodically. Based on this idea, the cyclo stationary detection method is used for spectrum sensing [13,14]. The approach has the advantage of differentiating signal of primary user from the noise. However, the drawback of this method is the complexity of the process.

The Fast Fourier Transform (FFT) output at the receiver is used to detect a DTV pilot tone signal in the noise environment. A certain series of Fourier transformation processes are used to adjust the received signal power. This type of approach is used to detect the existence or absence of DTV pilot tone [18,19].

A fundamental approach for spectrum sensing in radio communication systems is the energy detection method [2,9,10,11,12]. This method has a radiometer device, which is useful to find the existence or absence of the wave in the channel. Based on the noise in a channel, a threshold value is computed. This threshold is used to confirm the signal in the channel. The advantage of this method is the simplicity and does not require any prior knowledge of primary users, unlike in cyclo stationary and matched filter methods.

A spectrum sensing method was proposed for TDM based system [21]. However, this method does not work well if the numbers of primary users vary frequently. In this article, a dynamic approach is described to detect the spectrum holes for the varying number of primary users.

CONTRIBUTIONS

The radio spectrum is very useful for wireless communication because of its useful characteristics. The radio spectrum had been allocated and governed by ITU based on the sectors. In order to save the precious radio spectrum, the CR is used to effectively utilize the spectrum holes [1,3,4,8]. The cognitive radio has two major tasks: the spectrum sensing and spectrum allocation. We presented an approach new method for spectrum sensing in the TDM based communication system [21]. However, the approach works well for the fixed number of users. In the real environments, the users are dynamic and may vary in number at any time. In order solve this problem, in this section; we present a new method as Spectrum-hole Detection for Dynamic TDM based systems (SD-DTDM), which works well for both the static and dynamic number of primary users.

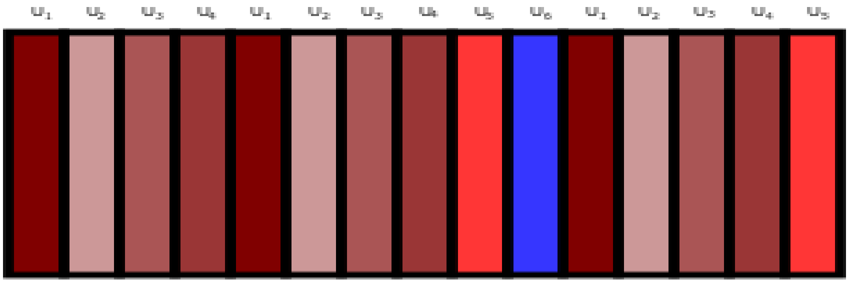

Figure 3 Primary users in TDM based systems

In this method, we consider that the primary users can join or exit at any given time during the detection process. For example, see the Figure 3, initially the numbers of primary users are four, it adds two new users after the first iteration, and it becomes five primary users in the second iteration. The full bandwidth is allocated for a quantum period of time Δ_x for every user.

The proposed method SD-DTDM uses the energy detection procedure to check the existence and absence of signal in the channel. The following is the algorithm for the proposed dynamic approach:

Algorithm: SD-DTDM

Step 1: Collect the primary user information in the vector *P_User*. Let '*n_counter*' be the number of users.
Step 2: ∀*i* € *n_counter*, initialize P_User[i] = *free*. Assign *current_clock_time* to *start_time*. Define the parameters Δ_x, T_{thresh}, SNR_{thresh}.
Step 3: ∀*i* € *n_counter*, check for each user the *SNR*

```
if (SNR ≥ SNRthresh)
 {
    P_User[i].occc = busy;
 }
else
{
    no-op
}
```

Step 4: If (*current_time* – *start_time* ≥ T_{thresh}) then stop the iterations and go to step 6. Otherwise go to step5.
Step 5: Collect the currently available primary users in the vector *Q_User[]* with index *m_counter*. Compare the two vectors *P_User* and *Q_User* and do the operations below

```
If ( P_User[n_counter] ≠ Q_User[m_counter] )
{
    Start_time = current_clock_time,
    n_counter = m_counter,
    P_User[n_counter] = Q_User[m_counter]
```

}
go to step 3
Step 6: $\forall i \in n\_counter$, check for each user the attribute *P_User[i].occ = free*. Declare the channels are free if their attribute *occupancy* value is *free* and can be allocated to SUs.

In the algorithm, initially it defines the parameters Δx, T_{thresh}, SNR_{thresh}, and n_counter. The Δx, is the quantum time for which the entire spectrum is allocated for the primary users in the given slot. The T_{thresh} value is the time duration which is the maximum time to decide whether the primary user is free or not. In other words, the number of iterations to check whether the primary user is busy or free is defined using the T_{thresh},. However, the number of iterations may vary if the primary users vary in number. The SNR_{thresh} is used to check the signal presence in the channel. The n_counter is the total number of primary users available. In the step 1 of the algorithm, the SD-DTDM collects all the primary user information and let n_counter be the number of PUs. In step 3 of the algorithm, each PU is allocated the full spectrum for a time period Δ_x. During the Δ_x, the algorithm needs to check the signal to noise ratio in the channel. If it is more than the SNR_{thresh} then we consider that the channel is being used and assign the user P_User[i].occ=busy. This process is repeated for all the PUs. After doing this process for all the PUs and before go to the next iteration, we check the duration of the process is exceeded T_{thresh}, value. If it is less than the T_{thresh} before going to the next iteration in step 3, the algorithm updates the primary user information in the step 5 for any changes in the number of primary users. If the process exceeds the T_{thresh} value then stop the process and declare the primary users are free whose occupancy value is free, P_User[i].occ = free.

There is a tradeoff between the accuracy of method and the number of iterations. In other words, the accuracy of the method is inversely proportional to the number of iterations. Hence, the balance is required to get the better performance of the approach. To improve the accuracy of the approach, the parameter *start_time* is assigned the *current_clock_time* if there is any change in the number of PUs.

SIMULATION

The simulation is carried out to present the performance the method SD-DTDM. The counts of primary users are varied for the simulations: 10, 15, 20, 25, and 30. The quantum time for algorithm is 5 seconds. The users in the system are non-homogeneous and they are provided different spectrum bands for the TDM based system. The SNR_{thresh} value is 20 dB The T_{thresh} value is 200 seconds. The random process is used in the simulator on generating data.

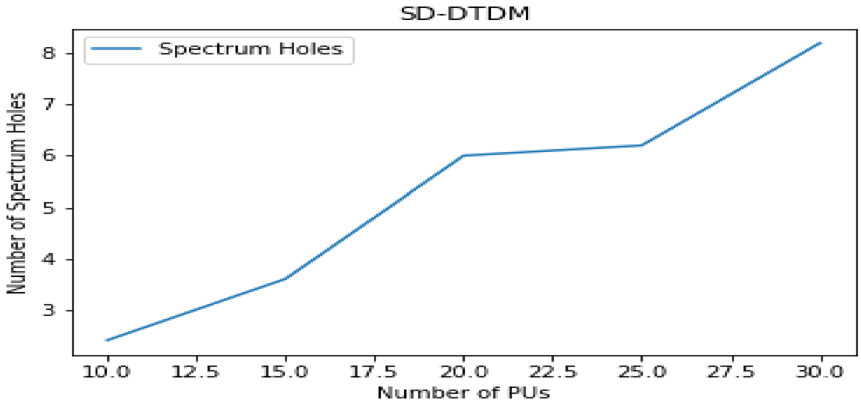

Figure 4: The average number of spectrum holes

In the first experiment, the numbers of spectrum holes are calculated varying numbers of primary users. The plot in Figure 4 shows the average number of spectrum holes from primary users 10, 15, 20, 25, and 30. For each set of primary users, we have run 5 simulations. From the plot, we observe that the number of holes increase with primary users.

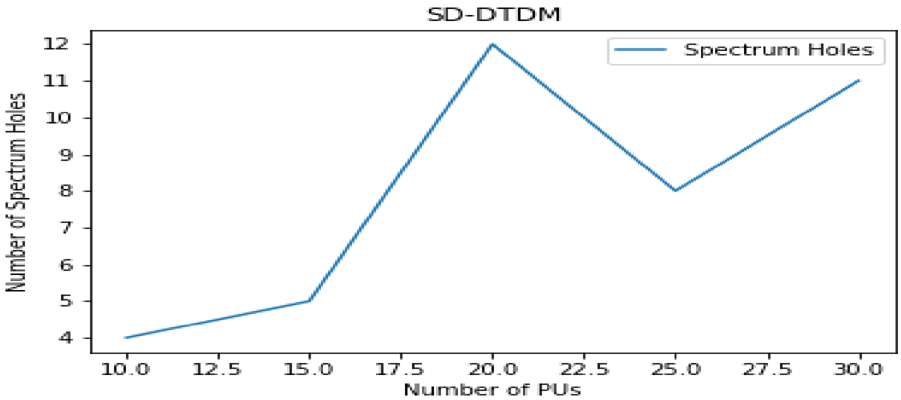

Figure 5: The maximum number of spectrum holes

In the second experiment, the maximum numbers of holes are calculated among the five simulations, the Figure 5. We got a spike in the fifth simulation for the 20 primary users. This could happen because we use a random process in the simulation code.

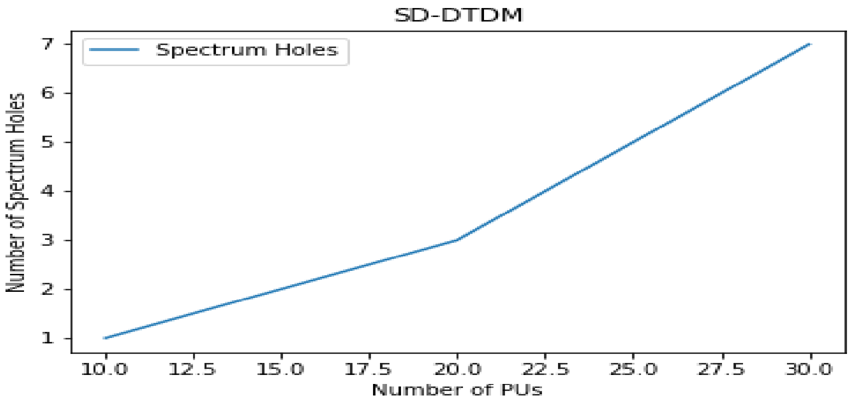

Figure 6: The minimum number of spectrum holes

In the last trial, the minimum of holes are calculated for varying number of primary users, see the Figure 6.

CONCLUSION

The telecom regulatory authority ITU classified the radio spectrum into different frequency bands based on the sectors. The CRN optimizes the usage of the radio spectrum and provides a way of efficiently using radio spectrum, which in turn leads to increase the utilization of radio spectrum. The paper presented a new spectrum sensing approach for TDM based radio communication systems, which works well even in varying number of primary users. The performance of the algorithm is evaluated with the simulation work and presented the results.

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