

ANALYSIS OF DYNAMIC COOPERATIVE SPECTRUM SENSING MECHANISM IN IEEE 802.22 WRAN

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Abstract

IEEE 802.22 Wireless Regional Area Networks (WRAN) utilizes the Cognitive Radio dynamic spectrum access technique in TV bands. When allocating available spectrum to Secondary Users (SUs), in the absence of Primary Users (PUs), it is essential to ensure the Quality of Service (QoS) of SUs. The motivation behind this research is to devise a mechanism to ensure the QoS of SUs. The End to End delay (EED) experienced by SU through the devised mechanism need to be kept within the threshold suggested by WRAN standard. To achieve the above requirement, Dynamic Cooperative Spectrum Sensing (DCSS) is developed in this research. Two entities namely Spectrum Manager (SM) in Base Station (BS) and Spectrum Automation (SA) in SUs are engaged to realize them. They do the sensing of channel occupancy by the PUs. Further, a concept of Urgent Coexistence Situation (UCS) notification is issued by BS to indicate the re-arrival of PUs to SUs. The impact of modulation schemes, occurrence of PUs traffic on average EED is analysed. From the simulation results, the modulation scheme that provides average EED within the threshold as per IEEE 802.22 is identified, thereby ensuring the QoS of the SUs.

Key words: IEEE 802.22, wireless regional area network, cognitive radio, DCSS, EED and Netsim simulator

1. Introduction. The demand for spectrum usage is increasing tremendously due to the continuous proliferation of wireless devices. The available spectrum is found to be underutilized. Hence an efficient resource management approach is required to address this problem. Cognitive Radio (CR) technology is identified to provide promising solution to the above problem [1]. The CR users can be classified into two types. They are Primary (PU) and Secondary (SU) [2].

IEEE 802.22 [3] is the first wireless standard devised for CR network. The working group of this standard was established in November 2004, to develop operational standard for fixed wireless broadband connectivity in both rural and remote locations. Wireless Regional Area Networks (WRAN) is the new wireless air interface standardized by IEEE 802.22 for Television (TV) bands incorporated with CR technology [4]. The major services supported by WRAN are TV broadcast, wireless microphone, terrestrial mobile radio service, and medical telemetry. IEEE 802.22 provides lower frequency TV channels for SUs [5].

The SUs of IEEE 802.22 WRAN can be of various service types. Some of them are Constant Bit Rate (CBR), Voice and Video. In general, as mentioned earlier the SUs utilize the resource of PU in its absence [6]. However, they are bound to return the same upon their arrival aborting their ongoing traffic. Hence, the motivation behind this research is to devise a certain mechanism to alleviate this issue and ensure the QoS of SUs.

The organization of the report is as follows: Section 2 discusses the state of art related to improvement of QoS for various services through the concept of CRN. Section 3 details the concept of developed work with system model and configuration used in analysing the performance. Section 4 elaborates the results along with inference. The future work and the conclusion are highlighted in Section 5.

2. Literature survey. This section details the state of art that are similar to the carried out investigation. A reliable channel estimation scheme for IEEE 802.22 to enhance communication quality is developed in [7]. In [8], to encourage the partial SUs in participation of cooperative spectrum sensing, a contract theory based approach is developed. This strategy promotes cooperation of SUs that has a partial understanding about their wireless environment. The simulation findings demonstrate that the contract successfully incentivizes collaboration and outperforms other benchmark systems in terms of PUs detection probability.

A distributed non-cooperative technique based on a game theory framework is given in [9] to ensure self-coexistence over several IEEE 802.22 networks. In [10], a two-tier CR Network that uses game theory to improve the QoS of SUs is developed. In [11], an analytical framework is provided to investigate the effect of traffic characteristics of Opportunistic Spectrum – Orthogonal Frequency Division Multiple Access (OS-OFDMA) in an IEEE 802.22 standardized network.

The performance of IEEE 802.22 on energy detection sensing method and spectrum sensing interval are investigated in [12]. The proposed algorithm performs sensing in k consecutive sensing time slots starting from the current slot and

continues with $k + 1$ and $k - 1$ adjacent slots. Depending on the traffic model, the probability of false alarm and detection probability is computed for any value of k . The sensing performance increases with increase in number of time slots. However the developed methodology is restricted only to non-cooperative sensing [13].

As mentioned earlier the re-arrival of the PUs leads to termination of ongoing traffic of SUs [14]. This can tremendously affect their QoS. In this research, a new mechanism namely Dynamic Cooperative Spectrum Sensing (DCSS) is developed to address the above issue. Hence the objective of this research is to investigate the End to End delay experienced by the SUs under the above circumstances.

3. Dynamic cooperative spectrum sensing. 3.1. System model. The system model of the developed DCSS is illustrated in Fig. 1. The various notations used are given in Table 1.

T a b l e 1
Notations used

Notations used	Description
α_i	No of Base Station (BS)
β_j	No of Primary User (PU)
γ_k	No of Secondary User (SU)
T_{tm}	Types of Traffics
τ_{si}	Departure time at source node
τ_{di}	Arrival time at destination node
d_i	Coverage distance offered by BS
Δ_σ	Delay when operation channel is allocated
Δ_K	Delay when backup channel is allocated
Δ_C	Delay when candidate channel is allocated
σ_N	Set of operational channels
K_N	Set of backup channels
C_N	Set of candidate channels

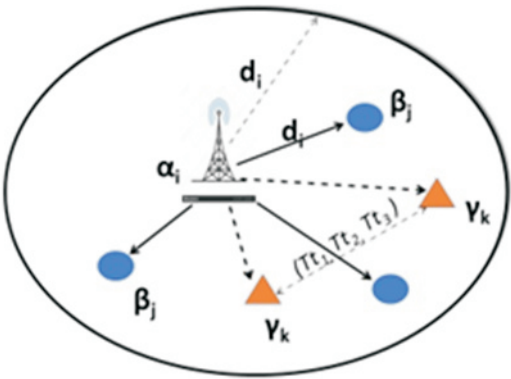


Fig. 1. System model of the proposed dynamic cooperative spectrum sensing

The SM has the responsibility to provide connectivity and resource allocation to γ_k that are within the coverage of corresponding α_i . Every γ_k , present within the coverage of α_i , executes the process of initialization to get associated with α_i . The SA module present in the γ_k does continuous spectrum sensing mechanism to obtain the availability status of the channel and report this information periodically to the SM module of α_i .

This functionality is executed by the SA module mainly to avoid the γ_k experiencing interference with the other channel.

3.2. Channel classification and channel allocation to SU (γ_k). In this research, DCSS mechanism is executed to realize efficient spectrum management. It is accomplished by exploring the association between SM of α_i and SA of γ_k . The available channels maintained by the database are categorized as operating, backup, candidate channels and protected, respectively [15]. Whenever the γ_k requests α_i for resource allocation, the operating channels are initially allocated to the authorized γ_k . However, when the β_j resumes its transmission with this operating channel, immediately α_i issues UCS notification to the γ_k . This notification indicates that α_i changes the resource assigned to γ_k from operating channel to backup channel, as the available operating channels are re-assigned to the licensed β_j . Thus, the γ_k will experience a certain level of latency due to this switching operation. However, the packet delivery is ensured by the above operation. Based on the resource availability and circumstances, this switching mechanism is repeated with respect to backup and candidate channels. Thus the spectral efficiency and throughput is enhanced by the developed DCSS mechanism as mentioned in Fig. 2.

From the perspective of DCSS, the capability of γ_k in spectrum sensing is limited within its coverage distance (d_1). The developed DCSS mechanism utilizes the inputs obtained from both SA and SM. Energy detection technique [16] is adopted in spectrum sensing.

3.3. Two way handshaking. Let σ_N represent a set of operating channels as expressed in equation (1). Let K_N denote the set of backup channels represented in equation (2), and C_N be the set of candidate channels represented in equation (3).

- (1) $\sigma_N = [\sigma_1, \sigma_2, \sigma_3, \dots, \sigma_N]$
- (2) $K_N = [K_1, K_2, \dots, K_N]$
- (3) $C_N = [C_1, C_2, C_3, \dots, C_N]$

On the other hand, in the developed DCSS, when UCS notification is witnessed, the ongoing transmission of γ_k is buffered, and the energy level of the next operational channel σ_2 is measured and the process is repeated for all other channels in σ_N . If all the channels are being utilized, then the abovementioned process is extended with back-up channels (K_N) and resource reallocation is ensured. All the above activities are executed by γ_k in coordination with SM mechanism of α_i .

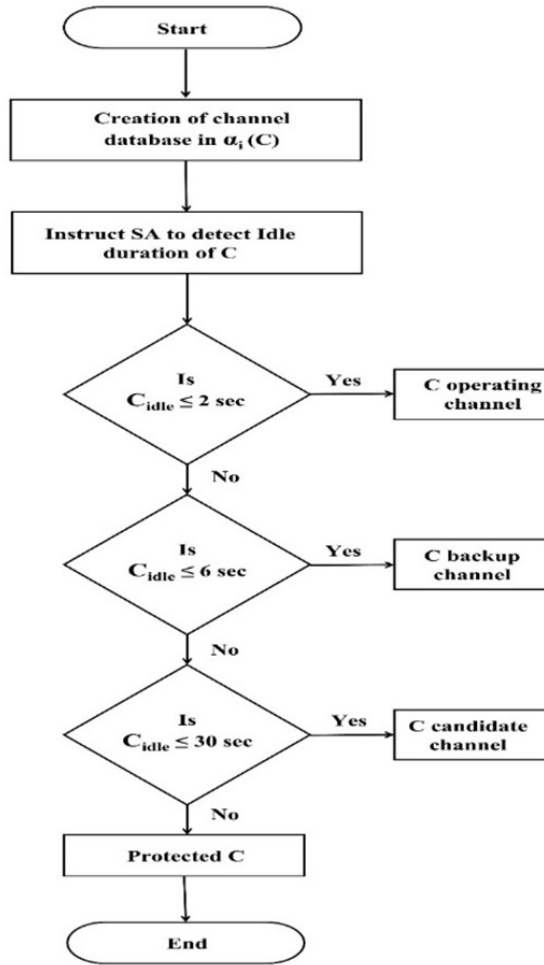


Fig. 2. Mechanism involved in developed DCSS

In order to acquire the channel availability at any given instant of time, the γ_k has to register itself with the α_i and then depending on the presence/absence of the β_j activity, the channel is allocated to the γ_k by the α_i .

After successful registration, γ_k contends for the channel by sending CHA_REQ packet to the α_i which cross-checks with the β_j for its activity. If β_j is idle, then α_i acknowledges the request with CHA_RSP packet, after which the data transmission is carried out. In case of appearance of β_j , the UCS packet is realised making the γ_k to switch to next available channel. But if β_j is active, α_i sends a busy signal to γ_k . SM in association with SA searches the availability of channels among the back-up channels. Upon release of UCS packet indicating the return of β_j , the γ_k is switched to the next available channel. This process is repeated until resource reallocation is accomplished.

4. Results and discussion. 4.1. Average End to End delay. The End to End Delay (EED) experienced by a packet is computed as the time taken by the packet to travel from source node to destination node [17]. Let τ_{si} represent the time at which the packet is transmitted from the source node, and τ_{di} represent the time of packet arrival at the destination node. Δ_σ represents the delay experienced by the above transmitted packets when allocated with channels σ_N . Similarly Δ_K represents delay when K_N is allocated while Δ_C when C_N is allocated. Thus the EED can be mathematically expressed as:

$$(4) \quad \text{EED} = \frac{1}{N} \sum_{i=1}^N (\tau_{si} - \tau_{di}),$$

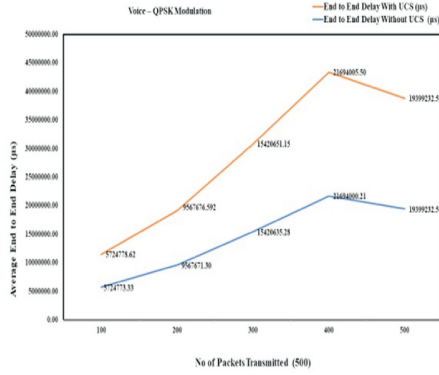
where N denotes the number of packets on flow. EED is also the sum of queueing delay, transmission delay and propagation delay [18].

4.2. Average End to End delay for voice traffic. NetSim version 12 is the simulator used in this research. The developed scenario comprises of 3 PUs with the frequency ranges: 54–60 MHz, 60–66 MHz and 66–72 MHz [19]. The average EED for voice traffic with respect to number of packets transmitted when QPSK, 16 QAM, 64 QAM modulation are used, is shown in Fig. 3a, b, c. The size of a voice packet is 1480 bytes [20].

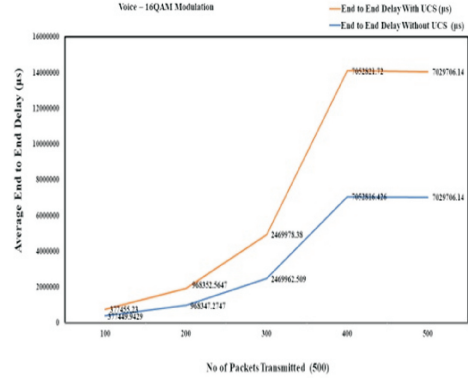
It is observed that γ_1 experiences 1 UCS notification during the transmission of (i) first 100, (ii) 101–200, (iii) 201–300 and 3 UCS notifications during the transmission of packets 301–400. There is no UCS notification during the 401–500 packet transmission. The time delay created by 1 UCS notification is 5.29 μs as per IEEE 802.22. Thus, overall UCS notification received during the transmission of these 500 packets is 6. Further, it is also observed that whenever β_1 enters into the channel used by γ_1 , an UCS notification is released by the α_1 and additional 5.29 μs delay is added with the existing delay.

4.3. Average End to End delay for video traffic. The average EED for video traffic with respect to the number of packets transmitted when QPSK, 16 QAM and 64 QAM are used are shown in Fig. 3d, e, f. Unlike voice traffic, video traffic has variable packet sizes since it has audio and image files. Each packet is divided into 8 to 13 segments based on the size. The packet size varies from 56 to 1240 bytes. From the results, it is found that reduction of 100 μs is observed when 16 QAM is used while comparing to QPSK. It is observed that γ_1 experiences 1 UCS notification during the transmission of the first 100 packets. Similarly it experiences 3 UCS during the transmission of packets 101–200, no UCS notification from 201–300 and 301–400 and 1 UCS notification during the 401–500 packet transmission. Overall UCS notification received during the transmission of 500 packets is 5. The UCS notification creates an additional 5.29 μs delay with the existing one.

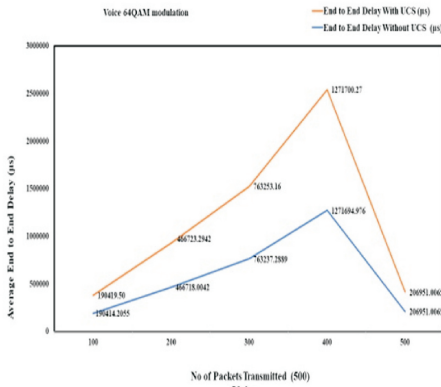
5. Conclusion and future work. In this research, DCSS mechanism is developed to guarantee the throughput of SUs in an IEEE 802.22 WRAN. Coop-



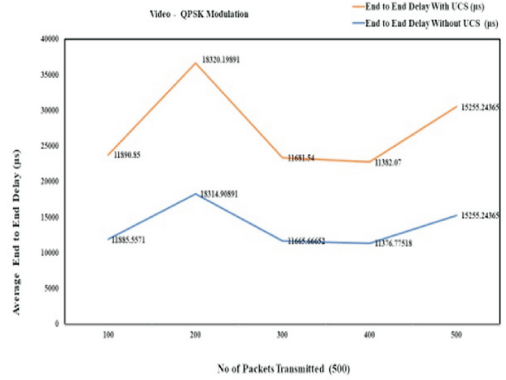
(a)



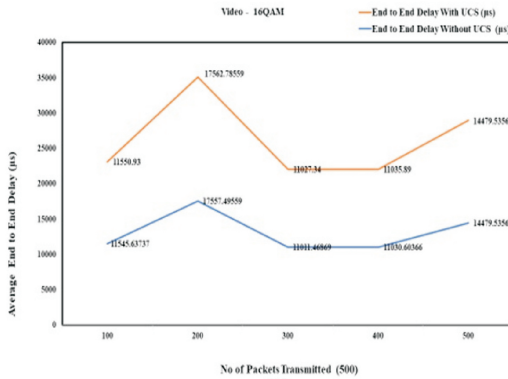
(b)



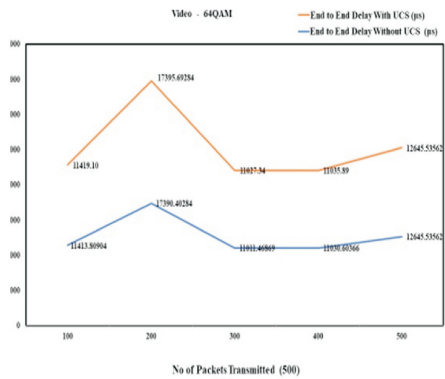
(c)



(d)



(e)



(f)

Fig. 3. Average End to End delay for voice traffic, with and Without UCS: (a) QPSK (voice); (b) 16 QAM (voice); (c) 64 QAM (voice); (d) QPSK (video); (e) 16 QAM (video); (f) 16 QAM (video)

erative spectrum sensing is realized by the association of two modules namely SM and SA. The concept of UCS notification is introduced to indicate the re-entry of PUs to the SUs. Buffering mechanism is also introduced to provide lossless communication. The average EED experienced by packets of Video and Voice under QPSK, 16 QAM and 64 QAM modulation schemes are analysed in a NetSim based simulated environment. From the results obtained the modulation schemes suitable for each of the above traffic is determined by comparing the average EED with the EED suggested by the IEEE 802.22 standard. As mentioned earlier, propagation delay also influences EED. Hence, the above investigation can be extended to various channel conditions which is planned to be future work.

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