# QoS Variance Aware Spectrum Sensing and Allocation Strategy for Cognitive Radio Wireless Mesh Networks

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## Abstract

QoS (Quality of Service) aware spectrum sensing and channel allocation in cognitive radio wireless mesh networks is a continuous practice due to the divergent scope of communication in wireless mesh networks. Henceforth the current research is moving in a direction to find effective solutions towards QoS aware spectrum sensing and channel allocation. But all of these solutions are specific to one or two QoS factors. According to the real-time practices the QoS assessment by one or two factors is impractical.

***Index terms***— cognitive radio networks, channel assign-ment, dynamic spectrum access, wireless mesh networks, dynamic frequency selection, selective cooperative sen

# 1 I. Introduction

ognitive Mesh Network (COMNET) based on Cognitive radio technology [9], [12], [15], ??26], ??27] is the recent network type implemented in wireless networking that is influencing the communication scenario in many ways. COMNET is a spectrum aware and self-managed meshed network and based on Dynamic Spectrum Access (DSA) improves spectrum detection enhancing the communication approach. The Dynamic Spectrum Access (DSA) is implemented with cognitive radio technology is an efficient way of handling the spectrum utilization as well as the communication for the business organization with spectrum rights of a geographical area and for the user accessing the network.

The existing Wireless Mesh Networks (WMNs) is an accepted technology for connectivity and broadband networking [3] between clients and networks of mobile, Wi-Fi etc. However scarcity of bandwidth is a drawback for its wide implementation and user acceptance. DSA overcomes the problems of the previous technique of spectral allocation which is Fixed Spectrum Allocation. FSA due to gross mismanagement of spectrum usage causes spectrum shortage as well as user saturation. This can be overcome with the COMNET approach implemented in DSA for detecting the allotted and underutilized spectrum in the licensed spectrum space. It automatically makes suitable spectrum in this region available in the unlicensed spectrum space. COMNET utilizes the technology of cognitive radios included in the algorithmic framework [4] and with the cognitive capability and reconfiguration [2] the network dynamically modifies its settings in real time [1] for improving the spectrum availability to the users.

Exploring the best spectrum selection and channel assignment for minimizing interference and improving connectivity is a known difficult problem ??24]. The channels accessibility varies in terms of intensity of primary user activity and data error rates as unexpected altercations in these parameters will change available spectrum and disturb prevalent path flows and the connectivity. The best channels for allocation are selected based on high idle time and less error rates. Intelligent channel assignment decisions by the way of improving the algorithms as well as other factors of CRN avoid channel switching delay as well as retransmissions and give an enhanced throughput.

Several approaches for channel selection have been studied in the past for WMNs and CRNs. The channel selection approaches in [7], [19] for wireles s communication aim at the dynamic selection of channels for cognitive radios with distinct primary user bands. The channel selection approaches in [11], [14], [15], [17], [18], ??21] have been developed for cognitive radio nodes and in these a few selection strategies are intended for Multi-Radio nodes. Interference-aware channel assignment in multi-radio wireless WMNs are given in [13], [16], ??23], ??24]. The literature work [11], [15], ??26] discusses the modeling of the interferer's activity as a continuous-time alternating ON/OFF Markov Renewal Process (MRP) and this process of primary user ON/OFF activity model for occurrence of the primary user signal in IEEE 802.11b is proved in the study ??28].

# 2 II. Related Work

In this section, brief information of some of the important techniques of research done in channel assignment for Networks of Wireless Mobile and Cognitive Radios are, The heuristics for spectrum allocation, Clique Based and Localized Heuristic by V. S. Rao, R. V. Prasad, C. Yadati, I. G. M. M. Niemegeers [6] are proposed for spectrum allocation in Cognitive Radio Adhoc Networks.

The channel access techniques by L. Yang, L. Cao, H. Zheng [10] for DSA networks, are two strategies for channel selection and switching propose to ease the primary users based disruptions. They are practical in accessing the spectrum and cleverly forecasts the future spectrum availability based on integrating previous histories of channels.

The strategy for modeling the problem of maximum channel selection (MCS) as a binary integer nonlinear optimization problem is developed by Fen Hou, Jianwei Huang [19]. The approach for secondary networks proposes to maximize the usage of the complete channel. The greedy channel selection problem for cognitive radio networks with channel diversity is also further studied and measureable efficiency close to the optimal value is offered by the approach.

A distance based MAC protocol (DDMAC) by H. Bany Salameh, M. Krunz, and O. Younis [20] in Channel Assignment for Cognitive Radio Networks is both Distance and Traffic-aware. An algorithm is developed for channel assignment based on DDMAC and includes the traffic profile that's based on association between signal's attenuation model and distance.

# 3 III. Qos Variance Aware Spectrum Sensing and Allocation

Let us consider a cognitive radio wireless mesh network with set of network regions and each region is having set of nodes as secondary and primary users.

The spectrums in set1 2 3 { , , ,.... } i x st s s s s =

are x number of spectrums that available for sensing and allocation to secondary users of the mesh network. Hence the spectrum allocation to a secondary user should be considered from set of x spectrums.

The selected spectrum to allocate to secondary user can influence the QoS. Hence, it is essential to pick optimal spectrum. The QoS variance aware strategy proposed in this paper is based on the characteristics of spectrum and their earlier allocation impacts, which are described as follows:

? A spectrum can be rated best in a particular factor, but might fail to deliver the same performance under the consideration of multiple QoS factors. ? A spectrum can be rated divergently with respect to its various QoS factors. As an example, a spectrum s can be best with respect to Primary User conflict scope, but the same spectrum might be moderate in terms of retransmissions and inference scope, worst in the context of channel occupancy time elapse scope. ? The importance of the QoS factors might vary from context of mesh network to other.

According to the characteristics of the spectrums described, it is evident that the best ranked spectrum under single QoS factor is not always the optimal towards spectrum sensing allocation. The spectrum that performed well under some prioritized QoS factors are always need not be the best fit under other prioritized QoS factors. In regard to this the devised QoS variance aware strategy finds the fitness of the spectrum, which is based on QoS variance and primary QoS factor opted. This process is labeled as QoS variance evaluation of the spectrum. Further spectrums are ranked according to their QoS variance and will be used in the same order to finalize a spectrum towards sensing and allocation.

The QoS metrics of each spectrum considered to assess the best fit spectrum for sensing and allocation are describe below, and these metrics are categorized as positive and negative, which is based on their value. The metrics with desired value as high referred as positive metrics and the metrics with desired value low are referred as negative metrics.

? PU (Primary User) conflict scope (-ve metric): Since low conflict scope is desired, this metric is categorized as negative metric. This metric indicates the ratio of conflict between primary user of a spectrum with the secondary user to whom that spectrum allocated. The conflict scope can be measured as follows.

( ) i

# 4 a) Evaluation strategy of QoS variance of Spectrums

Let PU conflict scope, retransmissions scope, inference scope, channel occupancy time lapse scope, spectrum fading scope and spectrum usage scope as a set of QoS factors j k k s f f F ? ? Begin // here j s F is the set factors of service j s If k f is positive factor then 1 ( ) 1 ( ) k k norm f val f = ? Else if k f is negative factor then 1 ( ) ( ) k k norm f val f = End End

Then the available spectrums are ranked by their normalized values from maximum to minimum, such that each service gets different rank for different factors.

Further these ranks will be used as input to measure the QoS fitness.

Let rank set of a spectrum [ ] ( qvv ) of each spectrum can be measured as follows.j j s s S ? ? is1 2 ( ) 1 ( ) 1 ( ) n r f f F i i s j n i r f f F k k s j n k qvv s j n ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? = ? ? ? ? ? ? ? ? ? ? ? ? = ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? = ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ? ?

The above equation is derived from the statistical approach of calculating variance between given number of attribute values. Here in this equation,( ) 1 n r f f F i i s j i n ? ? ? ? ? ? ? ? ? ? = ? ? ? ? ? ? ? ?

represents the mean of the all feature ranks of the feature set F s j .

Then the QoS fitness of the spectrum will be sorted based on the rank of theopt f ( [ ] opt opt i i f f f f F ? ? ? ? ), which is the anchor factor. Then the set of spectrums [ ] ij ij pst st ?

will be considered, which is based on the max rank threshold mrt given. Then the processed spectrums set j pst will be sorted from minimum to maximum of their QoS variance value and the same order will be preferred to select services for composition.

# 5 IV. Empirical Study by Simulation

The aim of the simulations is to analyze the relevance of quality of service towards handling the Spectrum Sensing and allocation to secondary users in cognitive radio wireless mesh networks. A simulated model of a cognitive radio wireless mesh network is devised with the nodes of range between 80 and 500 of 8 to 35 network groups. The characteristics and attributes are illustrated in table1. The devised QoS variance value ( qvv ) metric for cooperative spectrum sensing and allocation model for cognitive radio wireless mesh networks is assessed by comparing with detect and relay model [20], since this proposed QoS variance aware spectrum sensing and allocation strategy for cognitive radio wireless mesh networks and Cooperative Spectrum Sensing by Detect and relay [20] are both comes under similar category called cooperative spectrum sensing by QoS assessment. The metrics used in this assessment are (i) ratio of inference observed and (ii) ratio of spectrum fair utilization.

Figure 2 shows the ratio of inference between secondary and primary nodes spectrum utilization activity. The average inference ratio observed under the 'detect and relay' strategy [20] is more than that observed under QoS variance aware spectrum sensing and allocation strategy that devised here in this paper. The average ratio of inference observed in 'detect and relay' strategy is around 3.2% more than that observed in QoS variance aware strategy. The performance of the devised model is observed better, which is due to the QoS factors considered and the approach of identifying the variance of these factors. The QoS variance aware spectrum sensing and allocation strategy is scalable and robust against divergent percentage of nodes and network groups. 3 indicates the ratio of idle spectrum utilization by secondary users in cognitive radio wireless mesh networks, which indicates the advantage of the QoS variance aware spectrum sensing and allocation strategy over detect and relay strategy. The simulation in regard to assess the metric called ratio of fair spectrum utilization, the spectrum utilization ratio is observed in dense and sparse network groups. The observations are indicating that the spectrum sensing and allocation is fair, optimal and robust in devised QoS variance aware Strategy that compared to detect and relay strategy. The average of 8% percent of fair spectrum utilization by secondary users is observed in proposed QoS variance aware Cooperative Spectrum sensing that compared to detect and relay strategy, which is due to the QoS factors considered in proposed model.

# 6 V. Conclusion

Here in this paper we proposed a novel QoS variance aware Cooperative Spectrum Sensing and allocation strategy for cognitive radio wireless mesh networks that depends on sensitive QoS factors of spectrum and these factors are (i) Primary User conflict scope, (ii) retransmissions scope, (iii) inference scope, (iv) channel occupancy time elapse scope, (v) spectrum fading scope and (vi) spectrum usage scope. The model proposed here is capable to avoid the falsified spectrum sensing and allocation. The impact of the QoS variance assessment is observed as robust and scalable towards effective spectrum sensing and allocation. Majority of the existing models are only using the specific QoS factors and also not considering the deviation of the opted QoS factor state from other QoS factors, which in turn reflecting negative performance of spectrum sensing and allocation. Henceforth, here in this paper we consider the other dimension of QoS assessment for spectrum sensing and allocation. The model devised here is having two stages and those are (i) assessing ranks of spectrum under different QOS factors and (ii) Finding the variance between divergent spectrum ranks under different QoS factors. These two stages followed by the process of ordering the spectrums by the anchor (primary) QoS factor and then the spectrum with less QoS variance value, which is in the order of max ranked threshold will be allocated to the secondary users. The quantitative analysis done through simulations indicating that the devised model is scalable and robust towards handling the QoS ware spectrum sensing and allocation in cognitive radio wireless mesh networks. The model devised here in this paper is not considering falsified cooperation or non cooperation attitude of the malicious and selfish nodes.. Hence in our further work these factors will be considered in QoS aware spectrum sensing and allocation. [1] [2]

Figure 1:

2

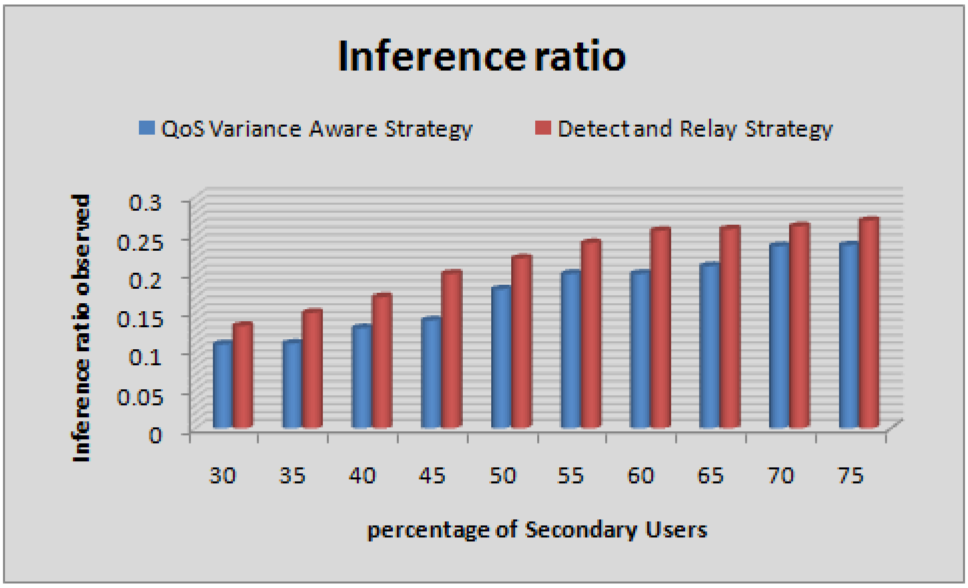



Figure 2: Figure 2 :

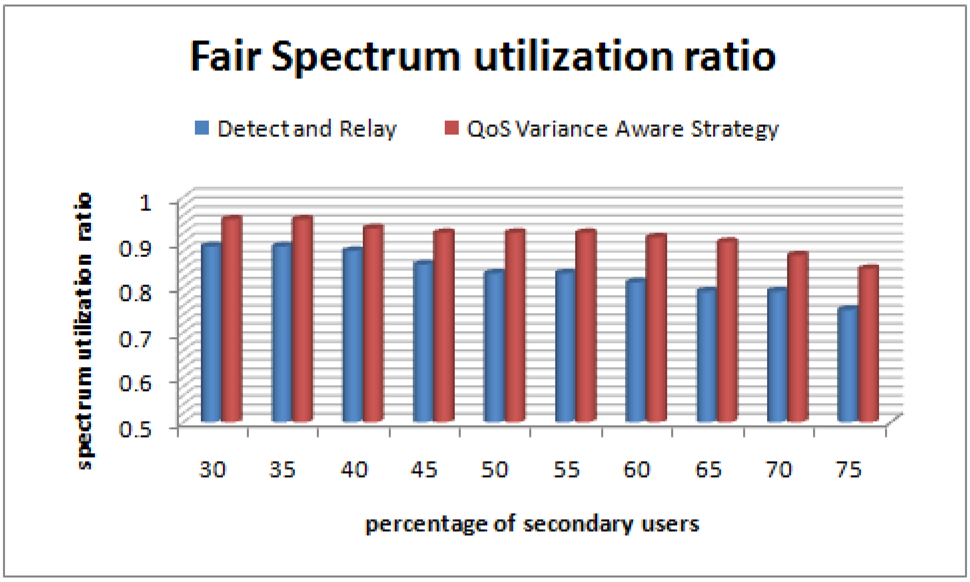
3 


Figure 3: Figure 3 :

( ) i rs s = ( ) ( ) i i notr s trr s

o Here in the above equation ( ) i rs s indicates the retransmission scope metric value of a spectrum i s , of transmissions occurred in previous allocations and ( ) i trr s is indicating the transmissions required in earlier allocations.

? Inference scope (-): This metric is also desired with lower values, henceforth it is categorized as

Year negative metric. This metric indicates the possible inference observed at spectrum, which is due to unpredictable spectrum utilization intervals of the PU . This metric can be measured as follows

( ) i is s = noii noi

o Here in the above equation ( )

(
)

( ) i os s = nol noa

o Here in the above equation ( ) i os s is indicating the occupancy time elapse scope, nol is indicating the number of occupancy time elapses observed and noa is indicating the number of allocations done.

? Fading scope (-): Is also another negative metric, which indicates the possibility of channel fading during spectrum utilization. this metric can be measured as follows:

( ) i fs s = nof nos

o Here in the above equation ( ) i fs s indicating the

fading scope of the spectrum i s , nof is indicating the number of times fading observed and nos is indicating the number of attempts to sense the spectrum.

i us s = nsu noa

*[Note: ? Retransmissions scope (-): This is also a negative metric, since the lower values are desirable. This metric indicates the average of retransmissions required on specific spectrum. This can be measured as follows:i is s? Occupancy time elapse scope (-): This is also a negative metric, since it desires low values. This metric indicates that how frequently this spectrum effected by time elapse in usage by secondary users. This metric can be measured as follows:? Usage Scope (+): is only positive metric, which is indicating the successful spectrum usage ratio. This can be measured as follows:( )]*



Figure 4:

**1**

| | |
|---|---|
| Number of nodes | 80 to 500 |
| Percentage range of secondary users | 45% to 75% |
| Range of network groups formed as a mesh network | 8 to 35 |
| Mesh network coverage area | 2750 m × 1550 m |
| Radio spectrum minimal range | 124 sqm |
| No of channes | 92 |
| Radio frequency per second | 9 rps* |
| Average transmission load | 0.9 KB |
| Transmission speed | 256 to 512 kb per second |
| Core transmission size at physical link | 3.0 Mb per second |
| Figure | |

Figure 5: Table 1 :

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