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Spectrum Handoff Decision Schemes in Cognitive Radio Network Modelling and Analysis

Mir Nusrat[1] and Er. Tanika Thakur[2]
M.Tech Scholar, Department of Electronics & Communication Engineering[1]
Swami Vivekanand Institute of Engineering & Technology, Ramnagar, Banure, Punjab, India
Assistant Professor[2], Swami Vivekanand Institute of Engineering & Technology, Ramnagar, Banure, Punjab, India

Abstract - Cognitive radio is an intelligent technique which is used to improve spectrum utilization. Radio frequency becomes very valuable due to the increase in the number of mobile devices and different types of wireless services. Each wireless service has its own spectrum in which the user operates. However, some of the wireless services have a wide spectrum with not many users as could be accommodated. The bandwidth becomes very expensive due to the shortage of frequency. Spectrum efficiency through cognitive radio (CR) is achieved via four main functions; spectrum sensing, spectrum decision, spectrum sharing, and spectrum mobility. In this thesis we focus on spectrum mobility which is called as SPECTRUM HANDOFF which is a procedure that's initiated when the primary users (PUs) appear to occupy its licensed band that was being utilized by the secondary users (SUs) during its idle time and enables the SUs to have an efficient and less delayed mode of communication.

Keywords- CR, OSA, DSA, (PRP) M/G/1 Queuing Model.

I. Introduction

With most of our activities involving some kind of access to network in one way or other, wireless communication has now become extremely important in modern society. This has caused the applications and services, standards, and the total of wireless users, to increase with every passing day, considering that the larger part of the limited available radio spectrum resources have been allocated well and can restrict this growth [1]. Also, finally, the amount of expansion is determined by the existing radio spectrum; the regulatory authorities and government bodies have taken up a stringent procedure/approach toward the distribution and licensing of radio frequency spectrum to disparate organizations (e.g., service providers, military applications, cellular telephony, service providers, and TV), all of these individual entities own absolute transmissions to their assigned frequency channels. By using this strict approach, the main method of accessing a radio spectrum resource is based on a fixed spectrum allocation method, known as Fixed Spectrum Access (FSA). An expansive report compiled by the (SPTF) Spectrum Policy Task Force [2] and issued by (FCC) The Federal Communication Commission, which conclusively proved the fact that a lot of the assigned (licensed) spectrum underwent quite low utilization efficiency, such as those dedicated to a military applications, analogue cellular telephony or TV, which are not completely utilized. The survey has uncovered temporal(time-related) as well as spatial(geographic) variations in the exploitation of radio spectrum, extending from 16-86% in the bands as low as 3GHz and below, while extending lower tan this at high frequencies[3]. These temporally unused spectrums, called white spaces or spectrum holes, are demonstrated in Figure 1.1. Often the spectrum holes are referred to as the "virtual channels"; these virtual channels are analytical channels constructed over the spectrum holes of the licensed PU channels [4]. Because of this, it's mandatory that new regulations and rules are implemented to efficiently utilize the existing spectrum bands. Two solutions are being provided for the regulating authorities to conquer this problem. The first approach toward solving the aforementioned problem is to expand or augment the spectrum for the unlicensed bands. However, this solution would take a very long time and prove cumbersome for the regulators to implement on the ground on practical basis. The second solution is to grant permission to the unlicensed wireless networks to utilize the unutilized licensed spectrum bands i.e. white spaces opportunistically; the net result would be that the overall utilization would increase.

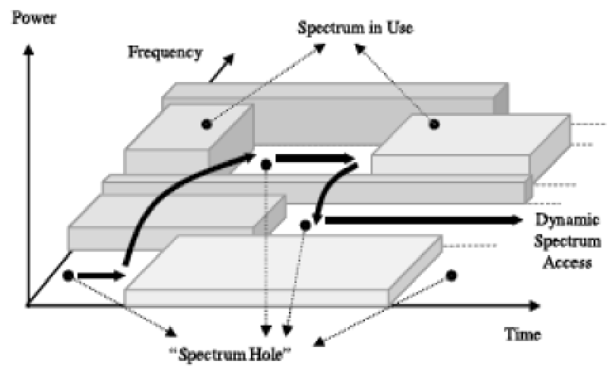

Figure – Virtual Network

II. Problem Definition

There's no denying that there are many advantages of cognitive radio networks, some instances being an improvement in the utilization of the radio spectrum for wireless networks. Even though the boons of cognitive radio technology are many, there does exist some hurdles one necessarily has to overcome, and which need to be explained in briefly:

- The cognitive radio technology was devised to work over a diverse (heterogeneous) radio spectrum, consisting of unlicensed spectrum bands and licensed spectrum bands; while a major study has been carried out in licensed spectrum bands, only a small percentage of study has been done in a spectrum environment in the merging licensed and unlicensed spectrum bands for conveyance of data/information which aims at overcoming underuse of the wireless cognitive radio networks.

- Secondly, considering CRNs the utilization of spectrum will be improved but the impact of several simultaneous and sudden appearances of the PUs in the licensed spectrum band haven't been explored vastly. Higher preference should be given to the handoff SUs (secondary users) over the newly arriving, uninterrupted secondary users to alleviate and hence make up the untoward, unfavorable effects of spectrum handoff.

Hence the aforementioned challenges motivated us to: contrive new spectrum handoff schemes that can enhance the accomplishment of the secondary users towards the successful transmission of data in terms of their handoff delay, which is one of the actual themes of our research as well.

Objectives:

The below mentioned are the main goals of this thesis:

- To study different spectrum handoff schemes.
- To model and analyze different spectrum handoff schemes
- To model and analyze total service time
- To compare random handoff model with new switching handoff model and select the appropriate
- To compare types, that is, proactive and reactive handoff schemes.

III. Methodology

To accomplish the prediction of real world behavior either of the two following methodologies can be used:

a) simulating the system

b) use of theoretical analysis

The theory that's the queuing theory, besides simulation experiments, is from the main standard methodologies in the computer engineering and telecommunications. Simulation approach is incorporated when the system's mathematical model is very complex, whereas, theoretical analysis approach seems to be cheaper and faster solution. However, simulation approach is an expensive and lengthy solution. In our thesis both methods have been employed to examine the proposed models. For the simulation approach, the event simulator MATrix-LABoratory (MATLAB) package tool has been used to investigate the delay performance measures, like the cumulative handoff delay, the handoff delay, the total service time, and several others. MATLAB is extensively and commonly used in simulating and analysing communication networks and it gives good approximations for exponentially distributions traffic. For the theoretical analysis approach, the widely known queuing theory is used to model the corresponding proposed models. The subsequent subparts will provide us with some ideas regarding the theoretical analysis approach, concerning this topic.

IV. Results

$$E[T]newsw = E[X_s] + E[N]\left[\frac{\frac{1}{2}\lambda_p E[(X_p)^2] + \frac{\rho_s}{(\lambda_p+\mu_s)} + \frac{\lambda_p^2 E\left[(X_p)^2\right]}{2(1-\rho_p)} E[X_p]}{\left[1-\left[\frac{\lambda_p}{(\lambda_p+\mu_s)}\right]-\rho_p\right]} + T_{sw}\right] \dots$$

$$Ws,proactive = \left[\frac{\frac{1}{2}\lambda_p E[(X_p)^2] + \frac{\rho_s}{(\lambda_p + \mu_s)} + \frac{\lambda_p^2 E[(X_p)^2]}{2(1-\rho_p)} E[X_p]}{[1-\rho_p-\rho_s]} + T_{sw} \right]$$

$$E(Tproactive) = E[Xs] + E(N)(Ws,proactive + ts)$$

$$W_{s,reactive} = \left(\frac{\lambda_p (t_p \mu_s + \lambda_p \mu_s E[X_p])^2 + (\lambda_s - \lambda_p t_p \mu_s) E[X_p]}{\mu_s^2 (1 - \lambda_p E[X_p])} \right)$$

$$E(Treactive) = E[Xs] + (Ws,reactive)$$

$$E[Trandom] = E[X_s] + \frac{E[N]}{2} Y_p + \frac{E[N]}{2} (W_s + T_{sw}) \ldots$$

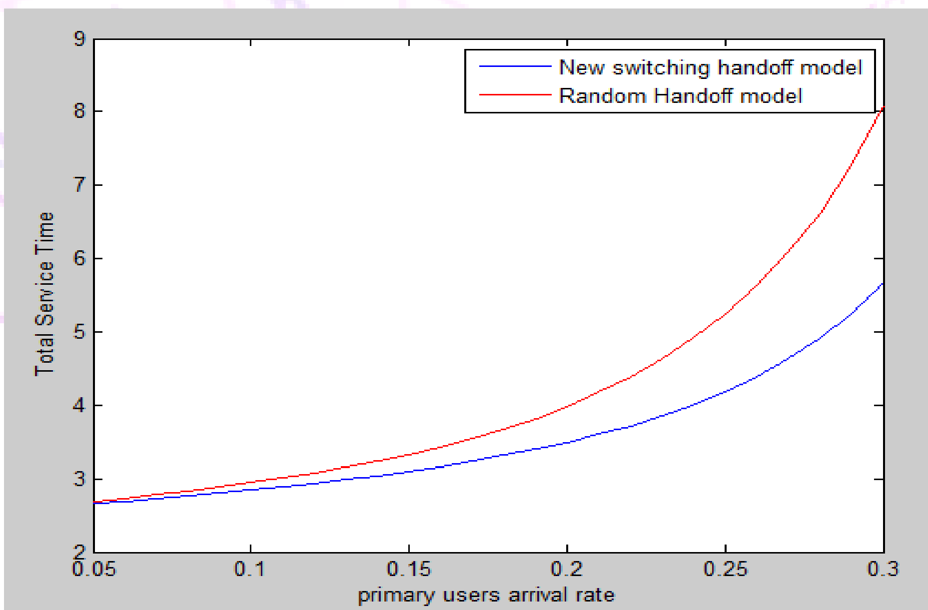

Figure: Comparison of Random and New switching handoff scheme.

Here we see that the total service time of new switching handoff scheme is lesser than the random handoff scheme, the difference increasing with increase in primary arrival rates. Obviously SWH-NEW has the most minimal total handoff delay for the activity stacks between (0.05-0.18). On account of SWH-NEW, handoff clients change their working channel at whatever point an interference occasion happens - as clarified already. While, in the instance of RAH-NEW, the plan chooses the target channel for spectrum handoff arbitrarily and does not consider any genuine powerful choice components, consequently, SWH-NEW performs better as a result of the way that it considers the inventive lead to pick the target channel.

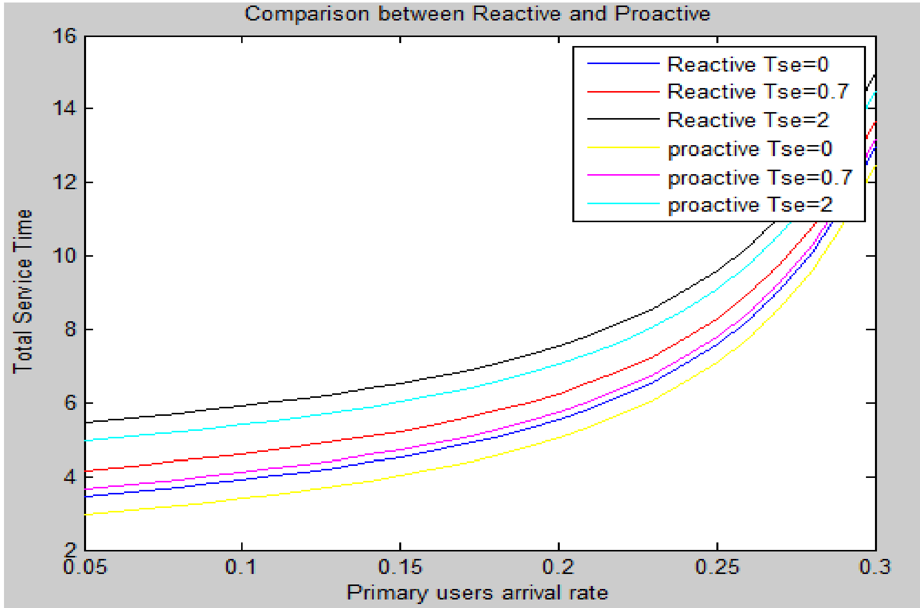

Figure: Comparison of Proactive and Reactive handoff scheme.

Between proactive and reactive handoff schemes, proactive exhibits the least cumulative handoff delay and least total service time, because no time is wasted in spectrum sensing, and spectrum decision making, unlike the proactive handoff scheme in which the target channel is preselected.

So, from the curves, after analyzing the total service time of SWH-NEW, RAH-NEW, and REH-NEW, it is concluded that the PRO-NEW handoff scheme is the best handoff scheme in terms of total service time and handoff delay.

V. Conclusion

Due to the growth and spread of wireless devices in the unlicensed spectrum bands, such as ISM, the bands become more and more crowded and therefore affect the performance of the wireless networks negatively. Thus, the cognitive spectrum access principles are required to utilize the existing spectrum bands more efficiently. The OSA technique is a step towards solving the issue of the spectrum being underutilized in today’s wireless networks. Based on OSA, wireless networks can reuse the remainder of the spectrum which is not being used by the spectrum owners therefore, the efficiency of using the spectrum for wireless networks will be improved. However, several challenges need to be resolved in order to gain from the advantages of such innovate spectrum management techniques. Spectrum sensing, spectrum decision, spectrum sharing, and spectrum mobility (handoff) are examples of such challenges.

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