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Quality Enhancement and Reduction in Hand-off Latency in Cognitive Radio Network

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Abstract: Cognitive Radio (CR) has immerged as the solution for spectrum inefficiency and spectrum scarcity. In many research papers so far, various frameworks and infrastructures have been proposed for deployment of CR network. In this paper, we have come up with an approach to further enhance the quality of CR communications. In the proposed method, we employ the concepts of extended area accompanied by need-based usage of unlicensed spectrum. We concentrate more on explaining the framework concept than its mathematical modelling. The simulation results show improvement in switching latency during hand-offs and overall quality enhancement of the CR communication.

Keywords: Cognitive radio, handoff, extended area, spectrum pool, unlicensed spectrum.

I. INTRODUCTION

With the increasing number of wireless communication devices, increases the stress on wireless spectrum. Evolution of "Internet of Things" will drastically increase the spectrum demand in near future. According to a survey by Cisco, the number of wirelessly connected devices will reach 50 bn by 2020, which is 6-7 times the then projected world population. As the wireless spectrum is limited natural resource, the future demand for the spectrum will put forth the challenge of utilising the spectrum in a most efficient manner[1]. Cognitive radio technology provides a promising solution to this.

In classical mobile communication, when participation of licensed or primary users (PU) is less, part of spectrum band remains idle. Depending on time and location the spectrum utilisation ranges from 15% to 85%[3]. Cognitive radio devices can opportunistically exploit this unused spectrum. The basic idea of CR networks is that the unlicensed devices also called CR users or Secondary Users (SU) share the licensed spectrum without interfering with the transmission of other licensed users also known as primary users (PU) [2]. If this band is found to be occupied by a licensed user, the CR user moves to another spectrum hole to avoid interference.

As per FCC proceedings, in future CR technology can be used by licensed service provider to increase spectrum utilisation or by voluntary agreement between licensed service provider and third party.

II. RELATED WORK

There have been several prior works on mobility and handoffs in cognitive radio environment. The most relevant ones are [6] and [7]. In [7], the author has presented the idea of utilizing the unlicensed spectrum bands as back up channels. The results show improved link maintenance and reduction in expected number of handoff on account of increased spectrum pool for SUs. But authors have not discussed SU mobility and cellular architecture. Also efforts to reduce inter-pool handoffs, which require RF front end reconfiguration, are not made. In [6], authors have proposed a spectrum aware mobility management framework for CR networks. This framework makes use of two types of cell coverages namely base area(BA) and extended area(EA) that overlaps with base areas of neighbour cells. The use of EA helps to improve the mobility performance significantly by maintaining the operating frequency of mobile users. The drawback of this framework is that, when the PU activity is detected in extended spectrum, the SUs in that EA immediately need vacate the band for primary user. In this case, SU loses its control channel and disconnects from its base station. SU now has to reconfigure its RF front end and scan across wide frequency range several times to observe an advertisement message broadcasted by the target base station. This results in high switching latency and may cause call drop. In our paper we propose a solution to avoid this scenario by using unlicensed spectrum opportunistically.

III. PROPOSED FRAMEWORK

In [base paper], cellular CR network is discussed. Each CR cell has single base station and operates in frequency pool which is not shared with its neighbour cells. Frequency pool is set of continuous frequency bands. SUs have to reconfigure their RF front end to switch from one pool to another because they are spread across wide range. In each CR cell, transmission power of one of the frequencies, called extended frequency is set higher than other frequencies, so that it can cover larger area called extended area (EA). EAs of distant cells, called extended neighbours, which use same frequency pool, slightly overlap with each other as shown in fig1. The extended frequencies of extended neighbours should not be the same to avoid interference. When SU crosses the BA of CR cell it moves to EA and starts operating on extended frequency. If PU occupies the extended frequency the SU in EA has to vacate its channels immediately.

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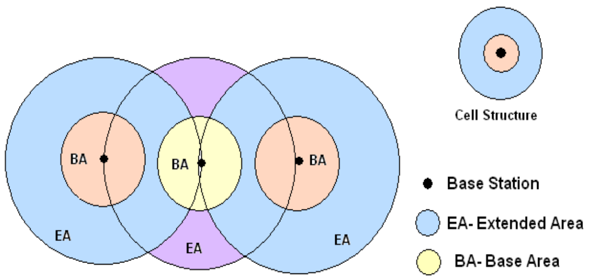

Fig.1: Spectrum pool based CR network architecture

The SU also loses its control channel because it cannot find any other frequency channel in that area. Thus it gets practically disconnected from its base station. The base station then gives this information to target cell. The target cell then broadcasts the advertisement message for SU through its control channel. In this scenario, SU has to reconfigure its RF front end till it hears the advertisement message and in every reconfiguration it has to monitor control signal for certain time. Due to multiple reconfigurations, latency is increased.

In our proposed framework, each CR base station uses unlicensed spectrum along with licensed spectrum. One of the unlicensed channels is extended to cover the EA. When the SU in EA loses its control channels due to PU activity, it will to resume its transmission on unlicensed extended frequency without doing multiple RF front end reconfigurations. To make this happen the SU should know the frequency of unlicensed extended spectrum at the time when PU activity occurs. This is achieved by sending frequency information of unlicensed extended spectrum through the control signal ever since the SU starts operating in EA. Thus in this case, the SU has to reconfigure its RF front end only once and hence the switching latency is reduced. The figure 2 illustrates this novel framework.

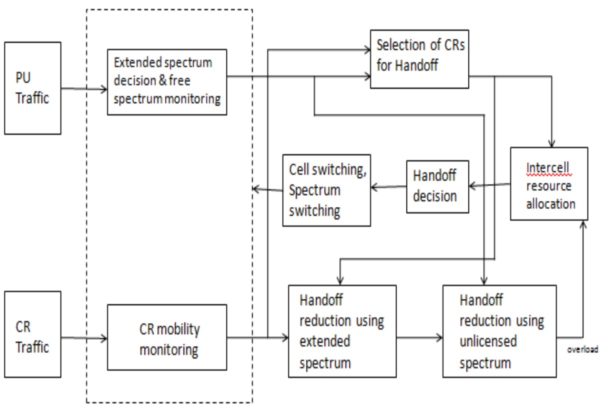

Fig. 2: The proposed mobility framework

IV. SIMULATION SETUP

In order to evaluate the performance of the proposed framework, we implement the network topology consisting of 19 cells. The transmission radius of each base station is 400m. and that of extended frequency band is 800m. The interference range is set to twice as that of transmission range. We consider four licensed spectrum pools and one unlicensed spectrum pool. Bandwidth of each licensed pool is 25MHz. Each pool contains 123 bands of bandwidth 200kHz each and remaining 400kHz are used as control channels. Further each band has 20 channels of 10kHz. We assume each PU uses 1 band i.e. 200kHz. For SUs, channel requirement varies from 60kHz to 200kHz to meet QoS.

We have generated PU traffic in four pools, each of which consists of 3 service providers and each service provider deploys its service using cellular network of 9 cells in the given area. The ON/OFF time intervals of PUs are exponentially distributed [4] [5] with means ranging from 20 to 100 sec. This results in overall licensed spectrum utilization of 50% to 60%. We have taken 200 active CR users for simulation. The CR user mobility is modeled using Gauss-Markov Chain model [8].

V. RESULT ANALYSIS

We have obtained simulation results by simulating for several times under different PU traffic conditions.

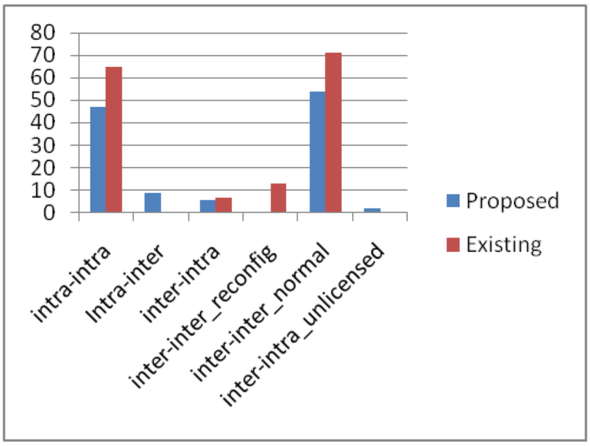

Fig. 3 Handoff summary with low PU traffic

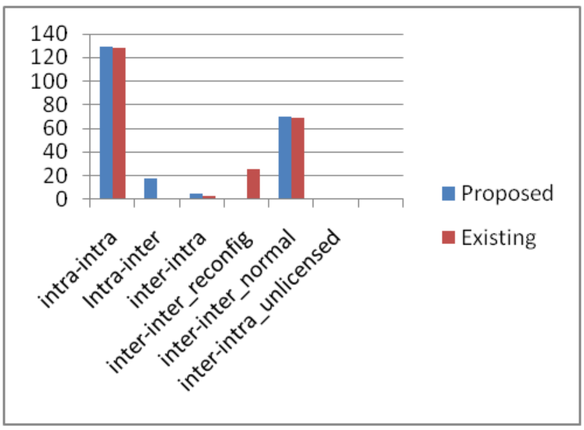

Fig. 4: Handoff summary with high PU traffic

The above graphs show that as the number of PUs increases, the number of handoffs also increases. But in our proposed shceme, we have avoided the intercell-

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interpool handoff which requires multiple RF front end reconfiguration, though PU traffic increases.

VI. CONCLUSION

The simulation result shows that our proposed framework avoids the intercell- interpool handoff which requires multiple RF front end reconfiguration. These handoffs are compensated by interpool handoffs to unlicensed extended spectrum where reconfiguration of RF front end is required only once. This results in reduced switching latency than that of the framework mentioned in [6]. Simulation results show that we can minimize the reconfiguration latency upto 60%. This will eventually result in smooth and reliable communication between CR users.

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