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Performance evolution of PU and SU in an ARQ based Cognitive Radio with Channel Probing

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***Abstract** - In cognitive radio the main objective is to transmit secondary user in primary transmission band without serious degradation of primary transmission. This paper proposes underlay CR scheme in which secondary pair listens and probe before it transmit in primary transmission band, where secondary transmitter receives the ARQ feedback from primary receiver. While probing, secondary transmitter sends a packet through cross channel to get additional information about channel strength. To achieve better transmission the main channel and cross channel divided in six regions. For better spectrum sharing two methods are introduced in this paper, namely known as Aggressive method and conservative method. Both methods avoid outage in the primary. But the difference is conservative method leaves the primary operations altogether unaffected, while aggressive SHARP may occasionally force the primary to use two instead of one transmission cycle for a packet, in order to harvest a better throughput for the secondary. the performance of proposed system analysed and it is shown that the throughput for secondary can improved via proposed scheme , which creates a negligible effect on primary transmission.*

***Index Terms**—ARQ, cognitive radio, outage probability, spectrum sharing.*

I. INTRODUCTION

Cognitive radio is a one type of communication, in which secondary user automatically detects path for transmission by using ARQ and probing. CR is a radio in which communication system knows about its internal state and environment. They can make decisions about their radio operating behaviour by mapping that information against predefined objectives. Cognitive radio is further extension of software define radio. CR system is also known intelligent radio system. There are so many definitions of CR and definitions are still being developed out of that one is "A cognitive radio is a wireless communication system that intelligently utilizes any available side information about the" Activity, Channel conditions, Codebooks, Messages of other nodes with which it shares the spectrum. CR gives intelligent signal processing (ISP) at the physical layer of a wireless system, i.e. the layer that performs functions such as communications resource management, access to the communications medium. CR intelligently allows the transmission of secondary user within primary band without serious affect on primary transmission.

II. SYSTEM MODEL

We consider a transmission of proposed system according to fig1. At first the whole channel is occupied by primary transmission and this channel is used by secondary transmission only through spectrum sharing. The channel gains are shown by g12 from transmitter 1 to receiver 2, where the subscript value 1 denotes the primary and 2 denotes the secondary. Channel gains obey the exponential distribution with mean λ. The primary transmitter operates at a constant power Pp and the nominal spectral efficiency of Rp bits/sec/Hz. If the 1^{st} transmission at this rate and power is not successfully reached at primary receiver (indicated by a NACK from the primary receiver),the same packet once again transmitted with same power. Whether the transmitted packet not reached at primary receiver even after two transmissions, the primary declares outage and moves on to the next packet. Here we can use no of ARQ for the feedback but in this paper it is considered only two times to reduce complexity. The ideas and the analysis directly extend to any number of ARQs, but the number of various outcomes in the system grows with the number of allowed ARQs without any essentially new insights.

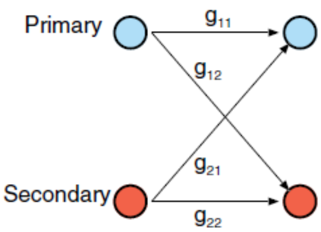

Fig. 1: system model

Therefore we limit the analysis in this paper to two ARQ rounds. Whenever the secondary is get activated for transmission, it has a power of Ps and transmits at a nominal spectral efficiency of Rs bits/sec/Hz. There is no involvement of secondary receiver in ARQ generation. Here primary transmit at constant power only secondary changes its power to adjust with the channel. In this paper fading interval taken much longer as compare to transmission interval. This system model focuses on the opportunities available for secondary user which IS curious to transmit. In this system model primary is constant with its parameter's but secondary always changes to adapt with channel.

III. COGNITIVE RADIO NETWORK METHOD

On the basis of available network side information CR look for underlay, overlay, or interweave their signals with those of existing users without significantly impacting their communication. In underlay method the interference caused by CR radio user on non CR user is below threshold level. In overlay systems, the cognitive radios use some signal processing and coding to improve the communication of non cognitive radios while also achieves some additional bandwidth for their own communication. In interweave systems; the cognitive radios opportunistically use spectral holes to communicate without affecting other transmissions.

Underlay method**:** The underlay method introduces techniques that allow secondary communications assuming that they have knowledge of the interference caused by its transmitter to the receivers of the primary users. In this method the interference caused by secondary user on primary it affordable till it is below certain threshold level. In the underlay method, the secondary user enters the primary spectrum only when its activity will not cause considerable interference or capacity penalty to the primary user.

Overlay method: In overlay method it allows the transmission of primary and secondary simultaneously in same channel as long as secondary help primary. In particular, in a cooperative scenario the secondary users may decide to assign part of their power to their own secondary communications and the remaining power to relay the primary users transmission.

Interweave method: The main motivation of CR is interweave method which is based on opportunistic spectrum sharing. the interweave paradigm, where a secondary user can opportunistically enter temporary spectrum holes and white spaces existing in both licensed and unlicensed radio spectrum. Fast and reliable spectrum sensing techniques are the key to the success of interweave cognitive radios.

IV. SPECTRUM HOLES

Spectrum hole is a unused part of spectrum band that can be used by unlicensed user. Spectrum hole is a basic need for CR. spectrum hole is detected by sensing primary band for the presence of primary user. Primary band also known as licensed band secondary band is known as unlicensed band. After sensing primary band by secondary user if it detects empty region that empty region is known as spectrum hole. And this region used for transmission by secondary user. In this way we can transmit primary and secondary transmission within same band. The important advantage of spectrum hole is, by using spectrum hole for transmission we are able to avoid underutilisation spectrum.

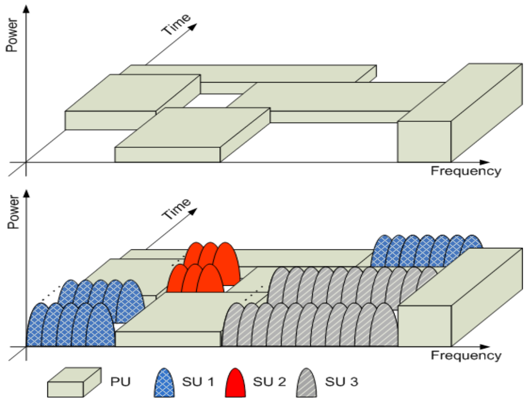

Fig. 2: spectrum holes

In above fig spectrum holes are shown by white spaces which are not used by user.

V. COGNITIVE CYCLE

Cognitive cycle shows how CR works and how can the system get the knowledge about channel condition? At first the radio takes information about its operating Environment through direct or through signal observation inspection, in practice the techniques of spectrum sensing (Observe), that detects the Spectrum holes. Due to this, Cognitive Radio devices are also popularly known as White Space Devices. After this the information which we got is then pre--processed and evaluated to determine the priority. Based on these observations, the radio will consider the alternatives (Plan) and chooses one by allocating the necessary resources in the right way (Decide). If the priority is normal, from the Plan status we go on to Decide and then to Act. Assuming, for example, that a change is deemed necessary in the waveform, the radio makes the choice by adjusting the available resources and generating the appropriate signal.

These changes also will affect the amount of interference created by the radio in the external environment. For this process, the radio uses theses observations and decisions to improve future operation (Learn) to be performed by creating a new type of operating status, generating new alternatives or creating new system of assessments of situations. This process is known as "Cognitive Cycle". After all these "steps", the cycle begins alternating with periods of rest, known as "sleep", in which the radio is in standby.

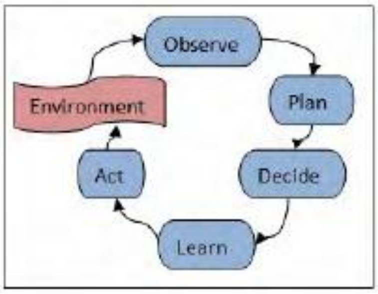

Fig. 3: cognitive cycle

VI. OPERATING REGIONS

The basic idea behind is to allow secondary to share the primary channel without affecting it. The channel state information is obtained with the help of ARQ. Now the secondary is able to exploit the opportunities that were not available earlier. To get the additional information about channel secondary sends one packet to probe channel via cross channel. The basic idea of SHARP is to exploit transmission op- opportunities for the secondary when possible, but also avoid driving the primary into outage (as a result of interference). Unfortunately, the channel states are not directly available to the secondary due to practical reasons. Secondary can only observe the ACK/NACK from the primary receiver secondary transmitter. The secondary also has knowledge of his own transmissions, therefore it can know whether the ACK/NACK of the primary was under the secondary interference or not. The possibility for the activation of the secondary depends on the relative strength of the direct channel h11 and the cross channel h21. We partition the direct channel h11- cross channel g21 plane into six regions; this partition is motivated by the amount of information that is available to the secondary. The regions are characterized below and shown in Figure 4.

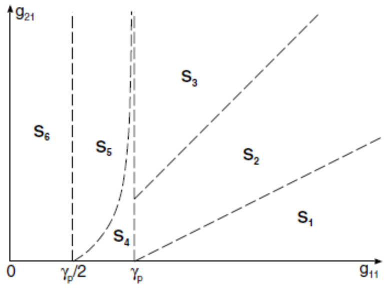

Fig. 4: operating regions

1. The primary channel supports the rate in one transmission without secondary interference. This is the best region for transmission of primary and secondary simultaneously. Under this condition, the secondary should always transmit.
2. The primary channel can support its rate in one transmission in the absence of interference, but needs two transmissions to succeed if there is interference. Under this condition, again the secondary can transmit at all times without pushing the primary into outage, but the throughput of the primary will be degraded.
3. The primary channel can support its rate in one transmission in the absence of interference, but in the presence of interference it cannot succeed even with two transmissions. Under this condition, the secondary can transmit every other time without causing outage for the primary, but the throughput of the primary will be degraded.
4. The primary channel takes two transmission interval compulsory but not one. It needs both interference free transmissions. It can also succeed in two transmissions as long as only one of the two transmissions is under interference. Under this condition, the secondary should transmit only every other transmission interval without any effect on the primary.
5. The primary channel can support its rate in two (but not one) interference free transmissions; it cannot support its rate with any interference (not even on one of its two transmissions). (7) Under this condition, the secondary should remain silent.
6. If h11 is sufficiently small, the primary is doomed to outage even with retransmission and even in the absence of any interference. Under this condition the secondary should transmit.

These six operating regions are denoted S1-S6 in Figure 2. We see that under some conditions, the secondary should stay silent to avoid pushing the primary into outage. Under some conditions, the secondary can transmit without any effect on the primary. Under some conditions, the secondary can transmit without causing outage to the primary, but it will slow down the primary and reduce its throughput because the primary will be forced to use re-transmissions. Based on these observations, we can devise two algorithms. In the aggressive SHARP, the secondary will transmit when- ever it is possible to do so without sending primary into outage, even if it will degrade the primary throughput. In the conservative SHARP, the secondary will only transmit when it has no effect on the primary.

VII. ARCHITECTURE

Receiver: CR system is the extension of software defined radio (SDR). The below fig 5 shows the architecture of cognitive radio.

Wideband LNA: LNA receives the signal from antenna. It used to attain required performance over a small band width. It is used to amplify low power signal which received from antenna .The amplified signal given to the mixer.
Mixer: combines the signal from LNA and frequency synthesizer and also removes unwanted noise from combined signal.
Frequency synthesizer: It is used to tune the frequency of received signal with the channel. In other words it synthesizes received signal frequency with the available channel frequency to communicate.
Low pass filter: It rejects the unwanted signal from received signal. It passes only low frequency signal and blocks higher frequency signal.
ADC: the output of low pass filter given to the analog to digital converter. And this A to D converter converts analog signal into digital signal for digital signal processing.
Digital signal processing and Demodulation: In this block received signals are digitally processed and demodulated to bring in required form. And finally output of this decoded and given to the user interface device.

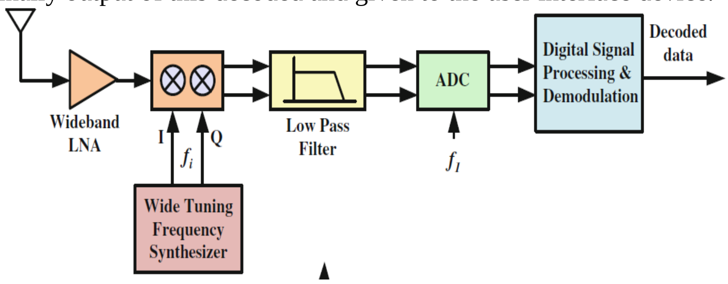

Fig 5: cognitive receiver

Transmitter: The entire component working as explained in receiver.

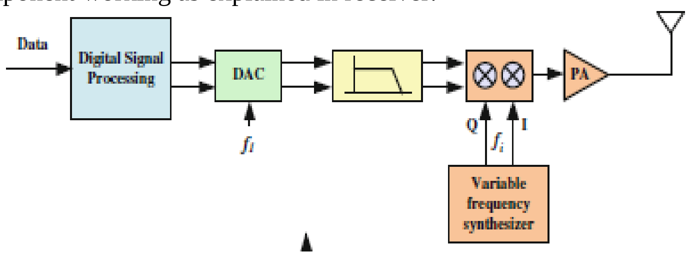

Fig 6: cognitive transmitter

Function of CR - The main functions of CR are Spectrum sensing, Spectrum sharing, Spectrum management, Spectrum mobility.
Aggressive method and conservative method-On the basis above discussion in this paper two algorithms are proposed namely known as *aggressive* method, the secondary will transmit whenever it is possible to do so without sending primary into outage, even if it will degrade the primary throughput. In the *conservative* method, the secondary will only transmit when it has no effect on the primary. First transmission rounds are candidates for spectrum sharing. The basic idea of this scheme is to exploit transmission opportunities for the secondary when possible, but also avoid driving the primary into outage (as a result of interference). Unfortunately, the channel states are not directly available to the secondary due to practical reasons. The secondary can only observe the ACK/NACK from the primary receiver.

VIII. RESULTS

In this section, we present some result of the proposed schemes. At first we will see the weak interface from the secondary transmitter to the primary receiver. The mean of the channel propagation gains are λ11 =4, λ21 =1, andλ22 =4. The rate thresholds are set to be Rp =1(bits/sec/Hz) and Rs =0.5 (bits/sec/Hz) for the primary and secondary user, respectively. Figure 7 shows the probabilities of the channel state falling in each Region, when the secondary user transmit at power Ps increases from 1 dB to 6 dB. In Figure7, the probability of Region S6 is a constant due to the fact that it is independent of secondary transmit power Ps, in this region absence of primary transmission as explained previous. We can be seen that the probabilities of Region S1 and S4 both decrease as Ps increases.

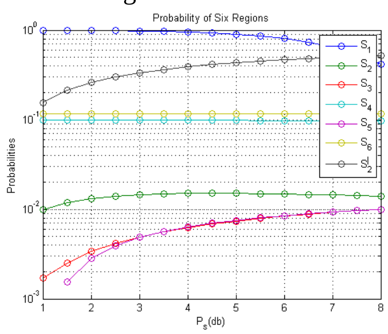

Fig.7: Probability for six regions

Figure 8 shows the achievable throughput of the primary and the secondary for various SHARP schemes compared to the legacy scheme with the same parameters. In terms of throughput both the primary and the secondary user. This is because in conservative SHARP the secondary is restricted from transmitting as long as it will affect the primary transmission. Therefore, it avoids the possible primary outage in Region S5, which may occasionally happen in the legacy scheme. Moreover, the conservative SHARP scheme adopts extra transmission opportunities in Region S1 and S6, so the throughput of the secondary user increases dramatically. This increase can be further enhanced if the aggressive scheme is applied as shown in Figure 8. In this case, the secondary deliberately slows down the primary transmission in both S2 and S3 when the primary transmission could be successful within two transmission slots. As a result, the throughput of the primary user is degraded compared to the conservative scheme. It can be also observed that the decrease of the probabilities of Regions S1 and S4 as shown in Figure 7.

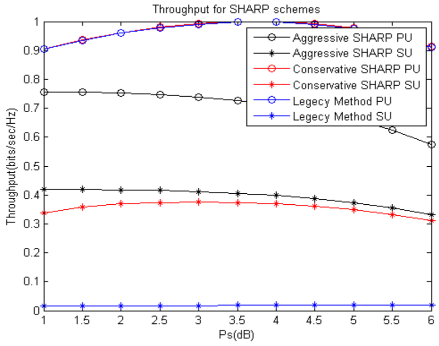

Fig. 8: Throughput for aggressive & conservative scheme

IX. CONCLUSION

This paper proposes a transmission scheme in which secondary can transmit in primary band without serious degradation of primary transmission, with help of ARQ from primary and probing from secondary. This scheme increases the performance of primary and secondary within same band hence the scheme name as Performance evolution of PU and SU in an ARQ based Cognitive Radio with Channel Probing. In this paper two spectrum sharing methods are introduced through which we can increase the performance of primary and secondary user known as Aggressive method and Conservative method.

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