Spectrum Sharing with Underlay Constraints in Cognitive Radio Networks

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ABSTRACT - In this work, we examine the secondary service's possible capacity for overlay and underlay access schemes. Then, in contrast to the underlay technique, we suggest a novel mixed access strategy in which the secondary service transmits during idle periods without regard for the interference threshold limitation. In contrast to the overlay method, the mixed strategy transmits with a probability p(a) during busy periods, subject to satisfying the interference threshold criterion. The parameter p(a) is a supplementary service parameter that can be changed depending on the spectrum state. Furthermore, we demonstrate that the secondary services can modify probability to identify an appropriate access strategy well with goal of maximising the attained throughput depending on the interference induced by the principal service transmitter at the secondary service receiver. The suggested spectrum-sharing methodology described in this study based on decreased system complexity compared to the system in which applied interference at the primary receiver is necessary for spectrum sharing. We also provide a small power allocation technique for the underlay strategy whose obtained capacity is extremely near to the secondary service's maximum attainable capacity.

INTRODUCTION

The number of connected users is growing every day, and bandwidths are getting increasingly congested, particularly in heavily populated urban areas. If the current situation continues, massive spectrum scarcity will arise in the near future. To avert this catastrophe, new technology must be adopted. Advanced techniques such as IMT Advanced[1,2] and 3GPP Long Term Evolution can help to lessen the increased spectrum consumption to some extent. Although they help to minimise spectrum shortage to some level, other strategies must be implemented. Spectrum sharing is one way for maximising spectrum utilisation. Sharing can occur in a variety of ways, including sharing with the same operator, sharing with another operator, sharing licenced spectrum with unlicensed users, and so on. Spectrum sharing between licenced and unlicensed users is demonstrated by cellular subscribers sharing spectrum with ad hoc users[16].

The underlay paradigm is aware of the interference generated by all users. It requires concurrent transmission of primary and secondary systems only if the interference created by the SU at the PU is less than some tolerable level.

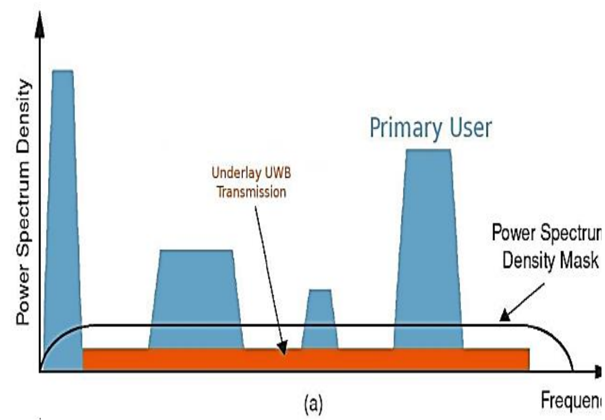

Figure 1: Details of Cognitive Radio Underlay model

BACKGROUND AND RELATED WORK

Typical transport protocols keep a bandwidth utilization to represent broadband services and cannot send more packets than its CWND (congestion window) size without acknowledgment. TCP Tahoe [7] use a lengthy start phase for establishing a connection or restarting after a packet loss. Initially, the sender sets the congestion window to one and increases it by one for each acknowledgement received, increasing the congestion window exponentially until a packet loss occurs. When a packet is lost, it signals that the network is congested, and the congestion window is set to 1. TCP Reno includes a quick recovery technique in which, unlike TCP Tahoe, when three duplicate acknowledgments are received, the congestion window size is halved

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rather than set to 1, and the transmitter transmits the missing segments quickly[15]. TCP Reno detects overcrowding immediately and improves performance in the case of a single packet loss, but it performs similarly to TCP Tahoe in the situation of several packet losses in a single window. TCP New Reno is an improvement over TCP Reno that allows for rapid restoration from numerous dropped packets in an unified platform. TCP Vegas estimates network capacity using round trip time and alters the poor onset and congestion control phases of TCP Reno[3].

METHODOLOGY

Underlay cognitive radio models are often analysed with the premise that the unlicensed user's encoder, known to as the cognition encoder, understands the information is then stored to be delivered by the primary codec during the next transceiver phase[14]. This assumption is frequently underlain idealism in practical systems. This assumption also holds true when the main transmitter communicates its data input to a secondary transmitter in advance, which may be performed in a distinct frequency range.

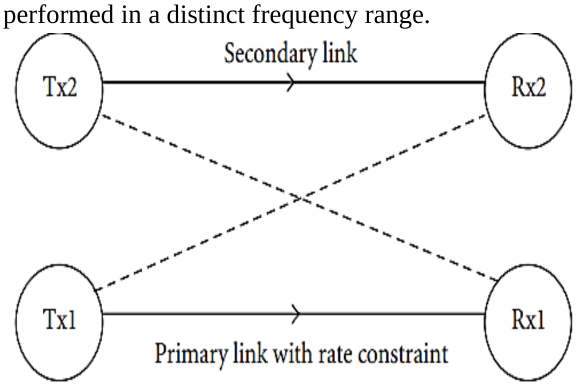

Figure 2: Underlay Cognitive Radio Channel Quality Information

TWO-USER UCR WITH PARTIAL MULTIUSER CQI

In practise, the primary transmitter-receiver pair may operate in frequency-division duplex (FDD), with the transmitter Tx1 periodically sending training sequences to the receiver Rx1 to assist channel estimation and coherent detection/decode[7]. Through a feedback channel, Rx1 tells Tx1 about the CQI of the Tx1-Rx1 link. We presume that Rx2 can connect with Tx2 via a feedback channel on the secondary user side. Based on the given system description, we propose the following rationale for assumptions about CQI knowledge:

- Rx2 is the secondary receiver that is listening in on the dialogue between Tx1 and Rx1. Rx2 can then estimate the CQI of the Tx1-Rx2 link.
- We presume that Rx1 uses a basic shared codebook, such as repetition code, to provide CQI feedback. Rx2 can then obtain CQI about the Tx1-Rx1 link by detecting the prime user's feedback channel[17].
- Rx2 requests that Tx2 deliver a training sequence across the principal spectrum at the start of cognitive communication. This provides CQI with knowledge about the Tx2-Rx2 link[4].
- Rx1 may predict the Clinical guidelines of the Tx2-Rx1 connection if necessary, however due to an upper-layer protocol, this information is not shown in its feedback channel[5].

ANALYSIS OF UNDERLAY-CR SIMULATION

Simulation of underlay waveforms in AWGN channel conditions is shown. Between primary and secondary users, perfect synchronisation is assumed. The performance metric of analytical versus simulated P(b) versus Eb/No is utilised to validate these waveforms[13]. When the secondary user is perfectly synchronised with the primary user, there is no interference from the secondary user to the primary user when the secondary user uses an overlay waveform; thus, the performance of the non-contiguous overlay waveform secondary user follows the theoretical performance under AWGN channel conditions[6].

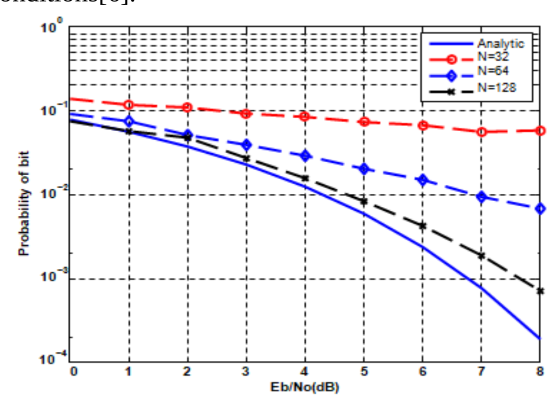

Figure 3: A secondary user, the performance of underlay NC-MCCDMA BPSK is evaluated. The primary to secondary user power ratio is 10 decibels (dB).

In the case of the CR underlay, the primary and secondary underlay users will interfere with each other, resulting performance reduction. Three situations were studied in order to gain insight and knowledge of the mutual interference. The first two situations investigate the CR underlay waveform in the

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presence of primary user interference, whereas the third scenario investigates primary user performance in the presence of CR underlay interference[8].

The primary user in the first scenario is characterised as OFDM with BPSK modulation on a continuous 32 sub-carrier band. The underlay waveform is described as MC-CDMA modulated with BPSK[11]. The underlay waveform consumes substantially less power and spreads its spectrum while meeting its own performance needs and causing minimal disturbance to the primary user. Figures 3 and 4 show the effectiveness of an underlay unlicensed users in a Channel estimation with primary user interference. The underlay waveforms in Figure 3 and 4 has a signal strength of 10 and 20dB less than the licensed users. It can be shown that as the underlay waveform extends spectrally, its efficiency increases and meets the predicted minimum at N = 512. Similarly, in Fig. 5, the underlay waveform operated at 30dB compared to the primary users must extend its spreading length to 1024 to enhance its effectiveness and approach the hypothetical formulation[9].

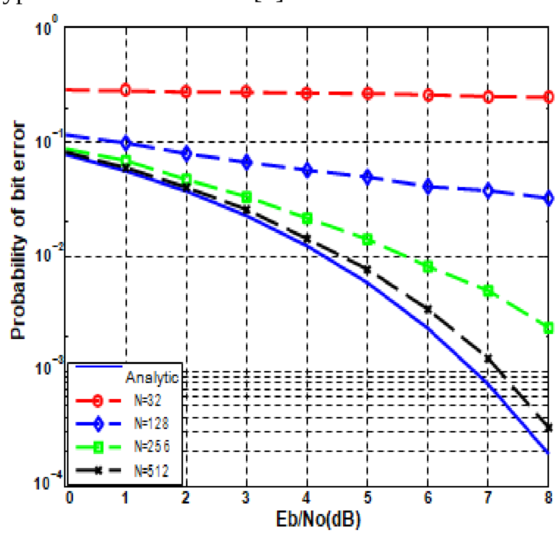

Figure 4: Performance of underlay NC-MCCDMA BPSK as a secondary user. Primary to secondary user power ratio is 20dB.

The results in Figures 6 to 12 allow for a comparison of theoretical and simulated BER performance of a secondary user utilising an underlay waveform. Figure 4.12 illustrates the results when the secondary user's transmission power is 20dB lower than the primary user's, and Figure 4.13 shows the results when the power differential is 30dB. The solid lines in Fig. 4.12 represent the theoretical BER performance of the secondary user specified by (4.15), the circles represent simulated results when the user continues to spread to 128 subcarriers, the stars represent simulation results when the secondary user spreads to 256 subcarriers, and the squares represent simulation results when the secondary user spreads to 512 subcarriers[12].

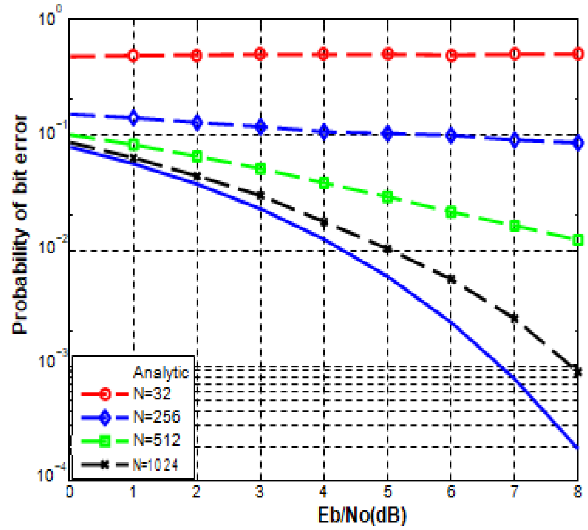

Figure 5: Performance of Underlay NC-MCCDMA BPSK as a secondary user. Primary to secondary user power ratio is 30dB

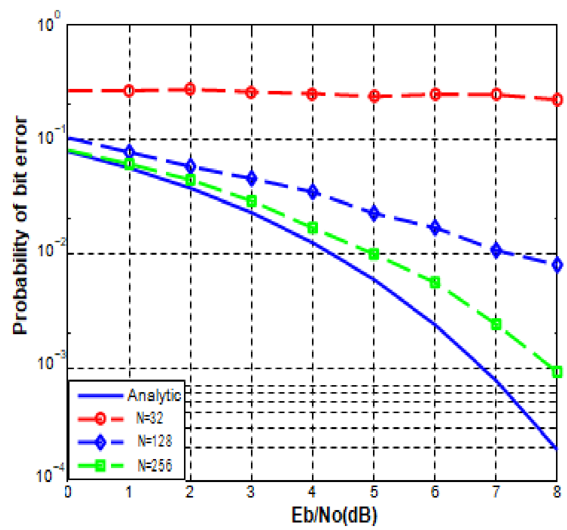

Figure 6: Performance of Underlay NC-CI/MCCDMA BPSK as a secondary user. Primary to secondary user power ratio is 20dB.

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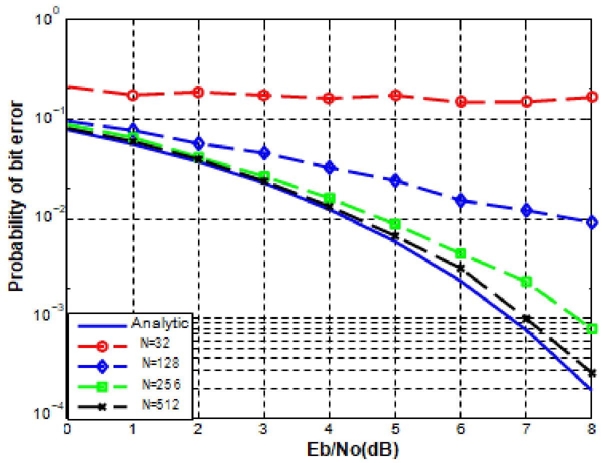

Figure 7: Performance of Underlay NC-TDCS BPSK as a secondary user. Primary to secondary user power ratio is 20dB

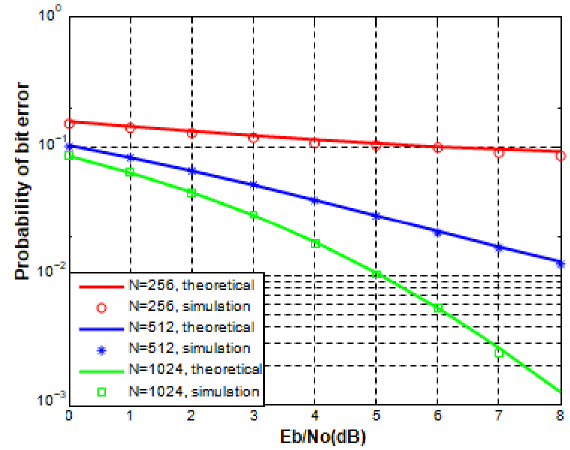

Figure 10: Comparing analytic with simulated results for Underlay secondary user per- formance (at power -30dB below primary user)

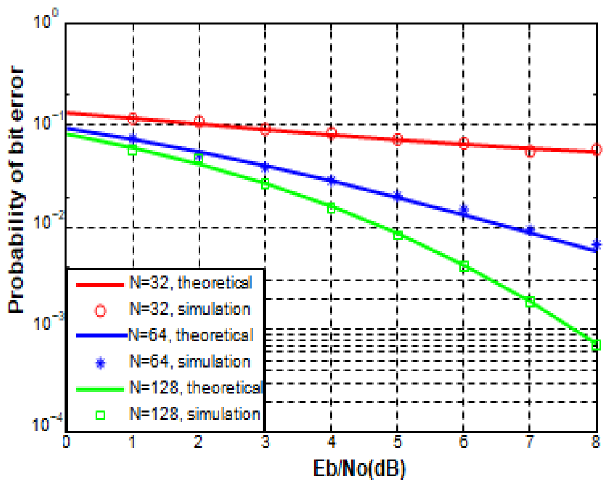

Figure 8: Comparing analytic with simulated results for Underlay secondary user performance (at power -10dB below primary user)

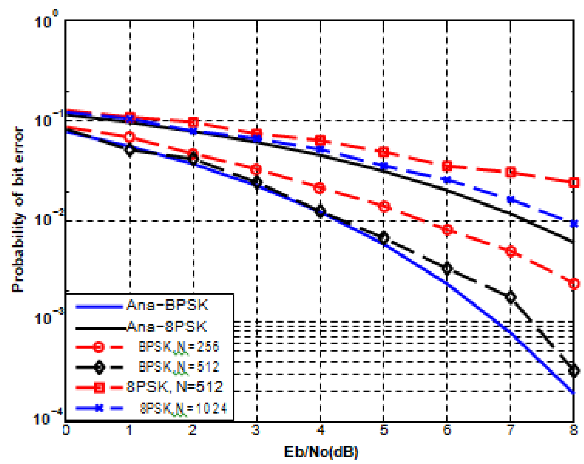

Figure 11: Performance of Underlay NC-MCCDMA 8PSK as a secondary user. Primary to secondary user power ratio is 20dB

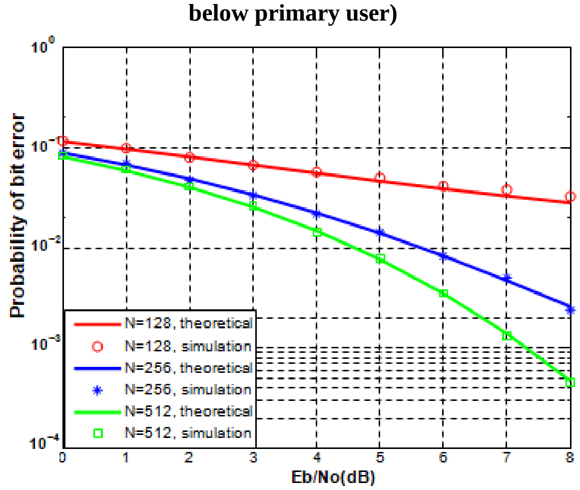

Figure 9: Comparing analytic with simulated results for Underlay secondary user performance (at power -20dB below primary user)

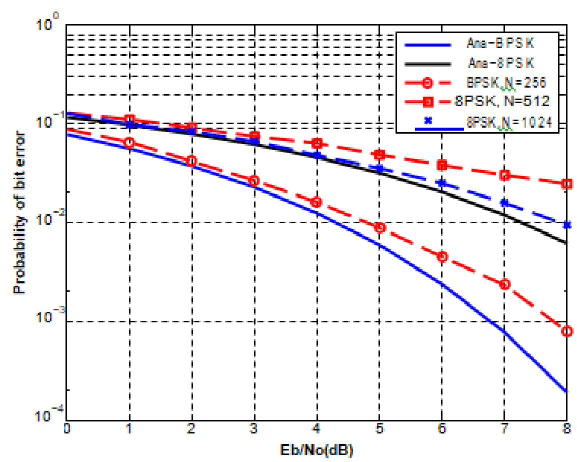

Figure 12 : Performance of Underlay NC-TDCS 8PSK as a secondary user. Primary to secondary user power ratio is 20dB

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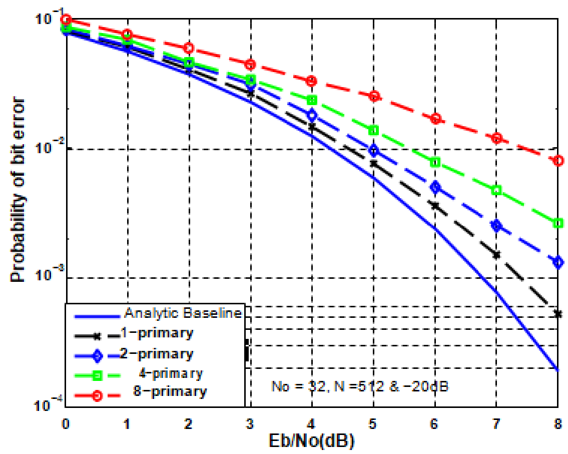

Figure 13: Performance of underlay NC-MCCDMA BPSK as a secondary user in the presence multiple primary users

It is assumed that 32 non-contiguous sub-carriers will be available for secondary CR users at any given time. The performance of four non-contiguous underlay waveforms is shown in Figures 5–7. Non-contiguous waveforms such as NC-MCCDMA, NC-OFDM, NC-CI/MC-CDMA, and TDCS employing 8PSK and BPSK modulation fit the theoretical expressions of 8PSK and BPSK modulation under AWGN network conditions, according to the analysis.

Multi-path Fading Simulation Analysis of UnderlayWaveform

The waveforms of an underlay-CR in a frequency selective fading channel are shown in this section. Multi-carrier waveforms implemented include NC-OFDM, NC-MC-CDMA, CI/MC-CDMA, and TDCS.

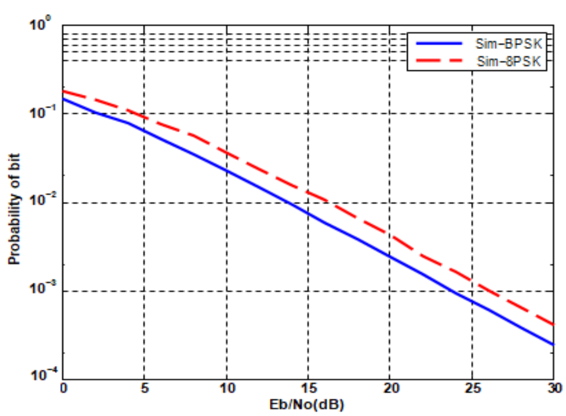

Figure 14 : Underlay NC-OFDM waveform performance in a Frequency Selective Fading channel

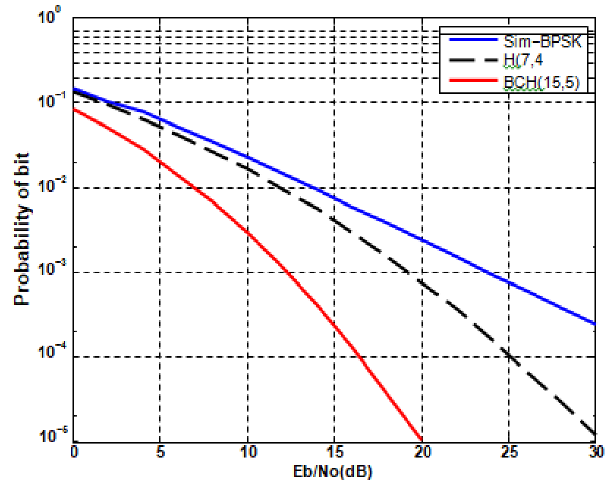

Figure 15: Underlay NC-OFDM waveform performance with channel coding in a Frequency Selective Fading channel

The efficiency of NC-OFDM with both 8PSK and BPSK modulated signal is depicted in Figure 8. Because NC-OFDM transmits a unique pattern on each subband and each sub - carrier undergoes flat fading, the diversity advantage from microstrip bandpass mixing is enhanced[10].

Figure 9 displays an OFDM waveforms that employs channel coding to maximize on spectrum heterogeneity.

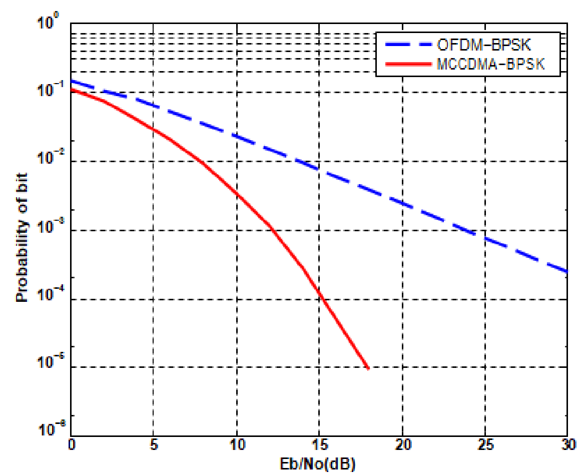

Figure 16: Performance of NC-OFDM and NC-MCCDMA waveform in Frequency Selective Fading channel.

Figure 10 depicts the performance of NC-OFDM-BPSK and NC-MC-CDMA BPSK modulations. The outstanding performance is attributed to the eight-fold spectral selectivity increases obtained by applying the MRC diversity technique.

CONCLUSION AND FUTURE WORK

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Quality control professionals should aim for more than just preventing customer complaints. Daily routines have yet to be designed for all conceivable applications. Both unused and underutilised spectral regions must be employed to maximise channel capacity and increase spectrum efficiency. A soft decision SMSE structure for core network waveforms suitable for CR-based application domains has been extended from a developing SMSE framework based on hard choice spectrum utilisation. Given a predefined set of SD-SMSE design factors, the Cognitive Radio-based SDR is capable of dynamically producing underlay waveforms to meet the needs of the user.

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