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Feasibility Investigation of Cognitive Radio Systems

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Abstract

Efficient use of the scarce radio spectrum is important for accommodating the rapid growth of wireless communications. This thesis investigates the feasibility of *Cognitive Radio* (CR) to exploit unoccupied frequencies for an enhanced spectral utilisation. CR refers to a wireless architecture that enables dynamic spectrum access, where unlicensed devices are allowed to operate in *temporally/spatially* unused licensed channels. Extensive spectral opportunities have been identified from an intensive measurement study, indicating that a significant gain in spectral utilisation may be brought by a CR technology.

The main challenge for CR is a robust protection mechanism to guarantee an adequate *Licensed Users* (LU) system performance at all times. This requires a reliable spectrum sensing technique to accurately identify frequency opportunities; and an autonomous transmit power control algorithm that remains effective in severe fading environments. Cooperation among CR devices to assist the LU identification process is shown to be an imperative CR attribute for maximising the CR performance and the overall spectral utilisation. Cooperation is particularly important for a CR coexisting with a small-coverage LU system, in which an accurate LU detection mechanism is the predominant limiting factor of CR system performance. The consequences of insufficient CR collaborations are an expensive individual CR detector and a large CR-LU separation requirement, yielding a suboptimal gain in spectral utilisation. The effectiveness of cooperative detection largely depends on system application, channel characteristics, and CR detector sensitivity.

The feasibility of CR is evaluated via a simulated CR model using the achievable CR system performance and the corresponding operational requirements as performance metrics. The fundamental limit of permissible CR transmit power has been derived from an interference constraint imposed on the CR operation. Assuming the LU accepts a minor performance degradation (an outage probability $< 5\%$), it has been shown that a low CR system outage ($< 5\%$) may be achieved while simultaneously providing a reliable LU identification rate ($> 99\%$) with the modest detector specifications commercially available. Above all the CR feasibility is strongly subject to the signal characteristics and the heterogeneous propagation conditions in the CR deployment scenario. An algorithmic approach is developed which demonstrates that a practical CR system independent of LU cooperation may be feasible.

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List of Abbreviations and Acronyms

3G	Third Generation Mobile Service
16/64 QAM	16/64 Quadrature Amplitude Modulation
AP	Access Point
APD	Amplitude Probability Distribution
AR	Aeronautical Radio
ASO	Analogue Switch-Off
ATSC	Advanced Television Systems Committee
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BS	Base Station
CCI	Co-Channel Interference
CDF	Cumulative Distribution Function
CR	Cognitive Radio
CSI	Channel State (Side) Information
CTS	Clear To Send
DECT	Digital Enhanced Cordless Telecommunications
DTV	Digital Television
DVB-T	Digital Video Broadcasting - Terrestrial
EDGE	Enhanced Data Rates for GSM Evolution
FSK	Frequency Shift Keying
GMSK	Gaussian Minimum Shift Keying
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
i.i.d.	independent and identically distributed
ISM	Industrial, Scientific and Medical
LMR	Land Mobile Radio

LU	Licensed User
MS	Mobile Service
OFDM	Orthogonal Frequency-Division Multiplexing
PDF	Probability Density Function
PSD	Power Spectral Density
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RTS	Request To Send
SCF	Spectral Correlation Function
SINR	Signal to Interference plus Noise Ratio
SIR	Signal to Interference Ratio
SNR	Signal to Noise Ratio
TPC	Transmit Power Control
UHF	Ultra High Frequency
UWB	Ultra Wide Band
UMTS	Universal Mobile Telecommunications System
VHF	Very High Frequency
VSB	Vestigial Sideband Modulation
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WMP	Wireless Microphone
WRAN	Wireless Regional Area Network