ACKNOWLEDGEMENTS

First and foremost I am thankful to the almighty for the blessings towards me with good health, knowledge and patience throughout my research work.

I would like to express my sincere gratitude to my guide, philosopher and beacon Dr. B. Seetha Ramanjaneyulu for his valuable and constant advice and guidance during the entire course work. He is a good mentor with his immense knowledge, very inspirational and the perfect model of excellent teaching and guidance. His very enlightening and enthusiastic ideas leading to insightful discussions throughout my research will be a great source of motivation as and when I pursue my research goals in future years.

I would like to thank my doctoral committee members Dr.Chandra Mohan, Dr. Sk. Jakeer Hussain and Dr. Venkatesulu for their timely inputs and constructive suggestions during doctoral committee meetings.

I would like to thank my HoD Mr.T. Pitchaiah for the support given in completing the thesis work.

I would like to acknowledge the support and suggestions of Dr. G. Sreenivasa Rao Dean, Research &Development, and Dr. K. Vidhu, formerly Dean R&D.

I would like to express my thanks to Dr. S.D.Sasi kiran, a member of internal project on *Thesis and Project Evaluation* who has edited thesis in a very short notice.

I would like to express my sincere thanks to our beloved Chairman- Dr. Lavu Rathaiah, Chancellor- Dr. K. Rama Murthy Naidu, Vice-chancellor Dr. M.Y.S. Prasad and DE &M, Dr. V. Madhusudan Rao for providing me all necessary advanced research facilities and proper environment to successfully carry out my research work.

I would like to thank my colleagues, friends and students who have extended their support whenever needed and made my research experience a real.

Finally I would like to express my heartfelt thanks to my family members for their love, support, encouragement and cooperation in all respects.

Annapurna Kunchaparti

ABSTRACT

SUPPORTING REAL TIME TRAFFIC IN COGNITIVE RADIO NETWORKS

Data rates of mobile users have been increasing multiple times year- after- year. Number of mobile users is also increasing continuously. Providing wireless bandwidths in order to support these increasing data rate requirements and users has become a challenge, as almost all the frequencies that can be used by cellular systems are already allotted by the governments for various purposes. So the option left is to move to higher frequencies like the millimetre waves, but these higher frequencies have their own problems like propagation challenges and coverage distance issues. In this context, it is contemplated to use the available spectrum of sub- 6 gigahertz frequencies in efficient manner.

Research studies have revealed that some of the users allotted with spectrum are not using the whole bandwidth allotted to them, while some others are using the allotted frequencies at selected geographical locations only though the license has been obtained to use the allotted frequencies in the entire country. It was also found that some licensed users were using spectrum intermittently only and not for all the times of the day. In addition to the above, some frequencies that were allotted for terrestrial TV transmissions have become vacant after they have got converted from analog to digital modes which need less bandwidth. In this backdrop, researchers have explored to make use of these underutilized licensed frequencies of the spectrum for the transmissions of unlicensed users when the licensed users are not using them. This has given rise to the concept of a *dynamic spectrum access* or *opportunistic spectrum access* by the unlicensed users, who are called as *secondary users* in this context. Devices of these users have to observe the spectrum-usage on continuous basis and should use the frequencies, only when their licensed users (who are called as *primary users*) are not using them. Because secondary users need to carry out spectrum sensing, analysis and appropriate decisions based on the analysis, they are also called as *cognitive radios* and such networks are called as *cognitive radio networks*.

As secondary users depend on the opportunistic spectrum access only, and do not have their own spectrum resources, offering any deterministic services by them is a challenge. In this context, some mechanisms are needed to add quality of service (QoS) to

the transmissions of secondary users. Mechanisms like implementing the priorities, linking the prioritized allocation to the cost of the channel, prediction of available vacant spectrum and frequency reuse would be useful, in this context for realizing the objective. Some of these mechanisms are explored in this thesis work.

Blocking Probability and Dropping Probability are the metrics considered here to measure the QoS of secondary users. They refer to the aspects of non availability of channels to secondary users and forcible termination of their transmissions, respectively. The objective of the proposed work is to reduce these probabilities and optimize the bandwidth utilization. Four mechanisms are introduced in this thesis-work.

Firstly, transmissions of secondary users are categorized into four priorities with highest to lowest from SU1s to SU4s. The order of preference for channel allocation is carried out in that order. Pre-emption of low priority transmissions to accommodate high priority transmissions is included. Results are compared with two level priority cases that are reported in the existing literature. This mechanism is further modified in such a way that it accommodates queue-shifting, in which, a device that belongs to a priority class, will continue to compete for transmission opportunity in that class until its time deadline is reached. If it does not get transmission-opportunity till it is about to reach its time dead line, then it joins to competition in the next level priority class. Advantage of this method is that less time critical transmissions are kept off from high-priority class temporarily so that more time critical transmissions will be through without getting blocked from those less-critical devices which could wait for some more time.

An innovative method of bidding known as *Range-Bound Bidding* is proposed as second mechanism. Maximum value of the bid price is decided a priori, and is expected to be quoted by the users who need highest priority for channel allocation. All other bid prices are considered to be quoted at the sub-multiple values of it. This mechanism paves the way for one-to-one correspondence between priority type and bidding price. By fixing the maximum bid price a priori, confusion on the possible bid price at which channel could be obtained is alleviated. This will help in satisfying the relative QoS requirements of the devices. This proposed ‘range bound bidding’ is presented and the results are compared with other bidding mechanisms available in the literature.

Offering QoS to SUs is a demanding task as they need to utilize the channels only in the absence of PUs and the occupancy of PUs is random. Channel-prediction is

considered as the third mechanism that helps in improving the efficiency because transmissions of devices can be planned as per the availability of channels. ANFIS based prediction is used. In the fourth mechanism of the work, coexistence of the secondary users with minimum acceptable mutual interference is explored. Distances between the devices, power levels and the bit error rate (BER) that they cause to each other are used to decide about this coexistence and compared the results with the methods that adopt channel reservations.

Analytical models are built for each of the above mechanisms and simulation experiments are carried out using Matlab and simulink. Results obtained have shown improvement of blocking probabilities and also better utilization of spectrum bandwidth.
KEYWORDS: Cognitive radio networks, QoS, blocking probability, auction, prediction, frequency reuse.

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LIST OF SYMBOLS AND ABBREVIATIONS

ISM	Industrial Scientific and Medical
FCC	Federal Corporation Commission
PU	primary User
SU	secondary User
QoS	Quality of Service
MAC	Media Access Control
PHY	Physical
WRAN	wireless regional area network
USA	United States of America
VoIP	Voice over Internet Protocol
VCG	Vickrey Clarke Grooves
GSP	Generalized Second Price
RAT	Radio Access Technology
TDMA	Time Division Multiple Access
WCDMA	Wide Band Code Division Multiple Access
RT	Real Time
NRT	non-real time
SMDP	Semi- Markov Decision Process
M-LWDF	Maximum Largest Weighted Delay First
FIFO	First In First Out
FCFS	First Come First Serve
SUC	Secondary User Cleared

SUE	Secondary User Equality
SUPC	Secondary User Partially Cleared
Mbps	Mega bits per second
NE	Nash Equilibrium
BW	Bandwidth
PO	Primary Owner
SDR	Software Defined Radio
GBM	Generalized Branco’s mechanism
SP	Spectrum Provider
EUR	Exclusive Use Right
BER	Bit Error Rate
MSE	Mean Square Error
ANFIS	Adaptive Neuro Fuzzy Inference System
ARIMA	Auto Regressive Integrated Moving Average
NN	Neural Network
EBP	Error Back Propagation
GUI	Graphical User Interface
RMSE	Root Mean Square Error
RMSD	Root-Mean-Square deviation
AWGN	Additive White Gaussian Noise
CCI	co-channel interferer
LSA	Licensed Shared Access
SAS	Spectrum Access System