SCHEDULING IN COGNITIVE RADIO NETWORKS

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The fixed spectrum assignment policy in today's wireless networks leads to inefficient spectrum usage. Cognitive radio network is a new communication paradigm that enables the unlicensed users to opportunistically use the spatio-temporally unoccupied portions of the spectrum, and hence realizing a dynamic spectrum access (DSA) methodology. In this work, we focus on the research problem of allocating the spectrum and time resources to the users in a centralized cognitive radio network subject to the interference constraints.

1. INTRODUCTION

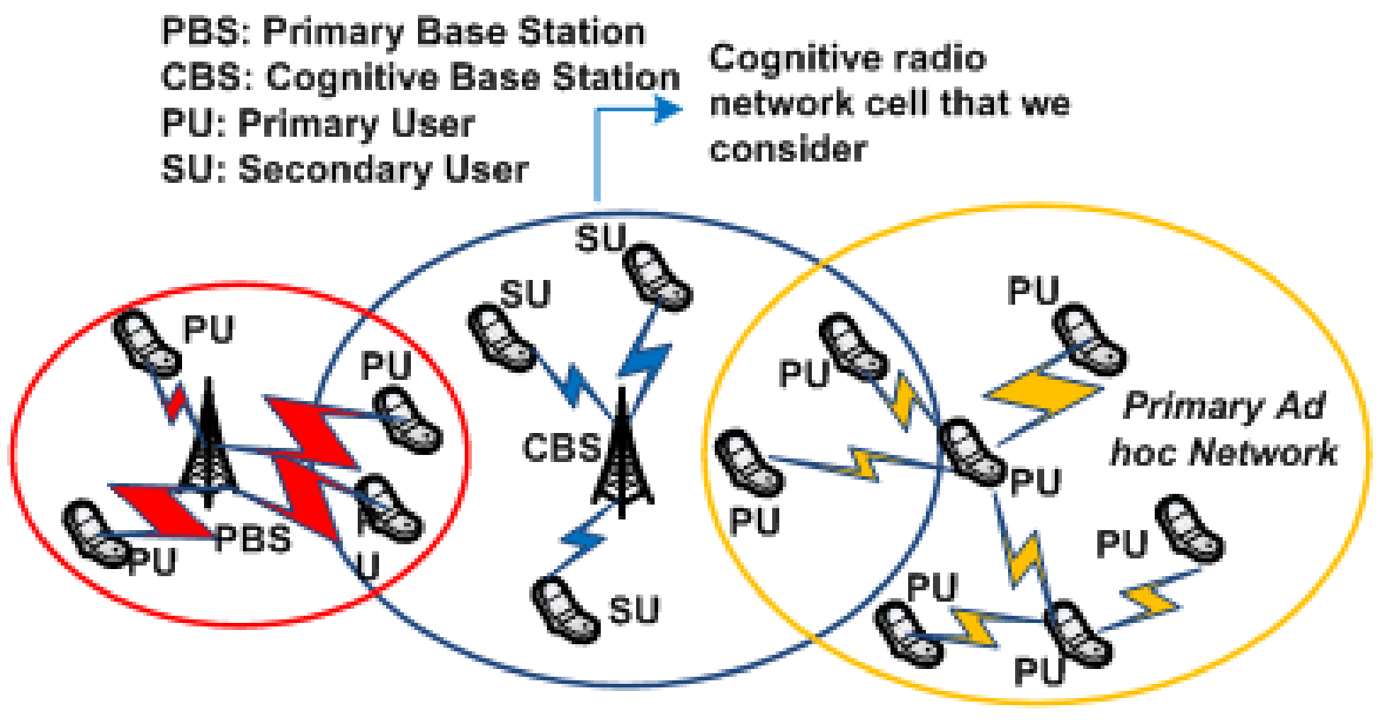
Recent studies exhibit that spectrum is sparsely utilized in some frequency bands, whereas it is overcrowded in other frequency bands. Some reseachers have recently proposed *dynamic spectrum access (DSA)* methods that enable the devices to opportunistically access the licensed frequency bands.

Cognitive radios are computationally intelligent devices that are capable of realizing the DSA concept. They can sense their environment and adapt their communication parameters in accordance with the network and user demands.

A cognitive radio network consists of *primary users (PUs)* and *secondary users (SUs)*. The former is a licensed user, and hence has exclusive right to access the spectrum, whereas the latter is an unlicensed user, which can opportunistically access the temporarily unused licensed spectrum bands provided that it vacates them as soon as a PU appears.

2. PROBLEM FORMULATION

We consider the following network architecture, where the scheduler resides at the cognitive base station (CBS):



Goals:

Determine
- Which SU will transmit
- How many packets
- In which time slot
- Using which frequency

Throughput Maximization Problem:

Maximize (totalNetworkThroughput)
Subject to
No interference is imposed on the PUs (1)
Reliable communication with the CBS is achieved (2)
No collisions occur among the SUs (3)

Max-Min Fairness Problem:

Maximize (minimumThroughput)
Subject to
(1), (2), and (3)

Proportional Fairness Problem:

Minimize (maximalDeviationFromProportionalShare)
Subject to
(1), (2), and (3)

Satisfied Users Maximization Problem:

Maximize (totalNumberOfSatisfiedUsers)
Subject to
(1), (2), and (3)

3. METHODOLOGY

Our solution to the first three problems consists of two stages:

Step 1: Determine the maximum number of packets that can be transmitted by each SU for each frequency using *Shannon's capacity formula for Gaussian channels.*

Step 2: Formulate the optimization problem as a *binary integer linear program (BILP)*, which can be solved by branch and bound algorithms.

We are currently investigating methods that can find the exact optimal solution to the satisfied users maximization problem. To this end, we are considering to utilize game theory.

4. RESULTS

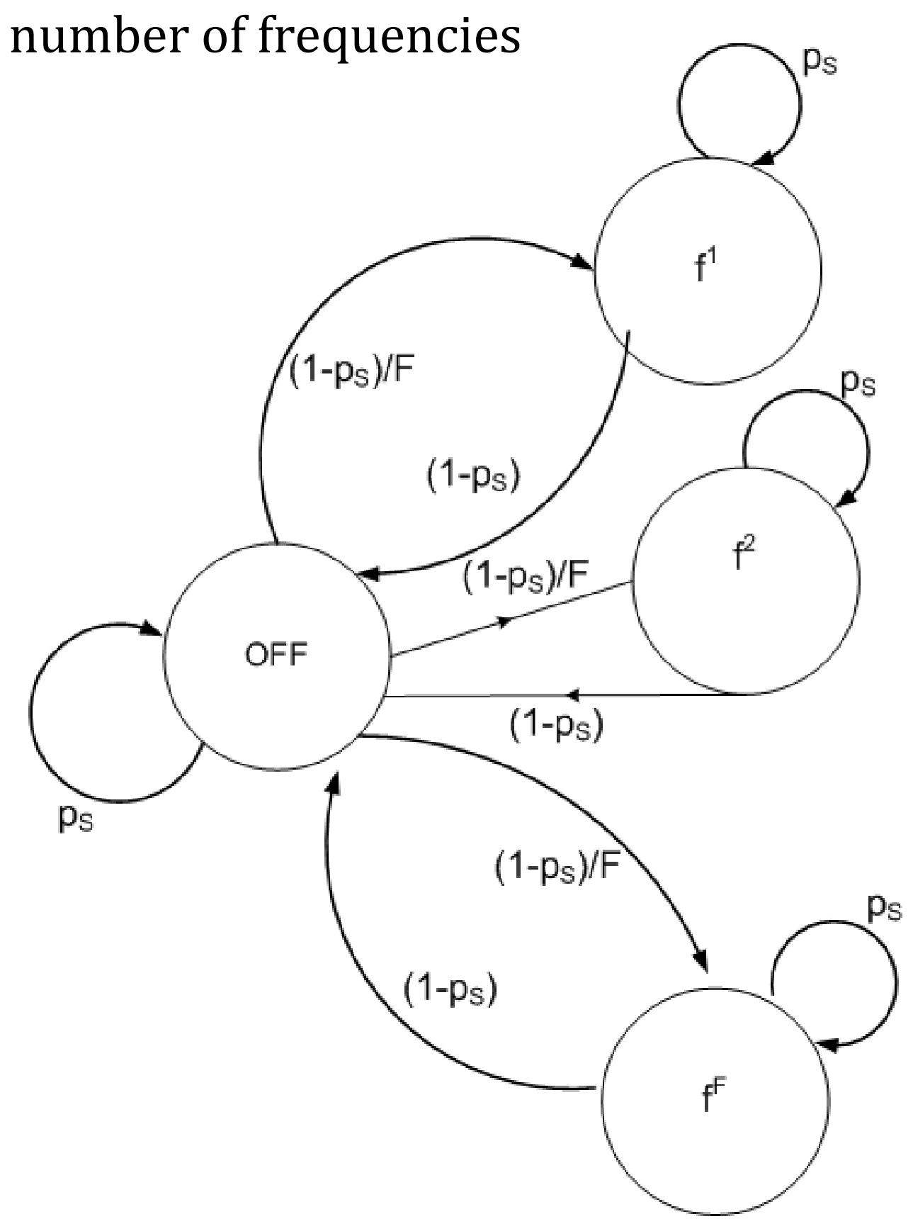
SIMULATION PARAMETERS

Cell radius	600 meters
Number of time slots per schedule	10
Schedule duration	1 second
Channel models	Additive white gaussian noise (AWGN)
Maximum tolerable interference for active PUs	0.01 Watt
Noise variance	10^{-6}
Mobility model	Random waypoint
Pause time for PUs and SUs	10 seconds
Probability of staying in the same spectrum state for PUs	0.9

PRIMARY USER SPECTRUM OCCUPANCY MODEL

p_S = Probability of staying in the same spectrum state

F = Total number of frequencies



2^6 EXPERIMENTAL DESIGN FOR THROUGHPUT MAXIMIZING SCHEDULER

Factor Name	Definition
A	Number of SUs
B	Number of PUs
C	Number of frequencies
D	Velocity of PUs
E	Velocity of SUs
F	Number of transceivers of the SUs

Factor Name	- (Low)	+ (High)
A	5	30
B	5	40
C	3	30
D	1 m/s	25 m/s
E	1 m/s	25 m/s
F	1	5

N-WAY ANALYSIS OF VARIANCE (ANOVA) AND REGRESSION

By eliminating the terms that are found to be statistically insignificant by ANOVA and the terms for which the confidence interval of the regression coefficients includes zero, we finally arrived at the following regression model where $R^2 = 0.9568$; i.e., the regression model explains %95.68 of the total variability in the data.

Term	Coefficient	95% Lower Limit for Confidence Interval	95% Upper Limit for Confidence Interval
β_0	135,611	131,3860	139,836
A	59,724	55,499	63,949
B	13,436	9,211	17,661
C	14,417	10,192	18,642
D	4,757	0,5318	8,982
AB	-17,451	-21,676	-13,226
AC	-16,094	-20,319	-11,868
AD	-6,042	-10,267	-1,817
BC	8,214	3,989	12,439
CD	1,611	-2,614	5,836
CF	3,842	-0,382	8,0679
ABC	-7,717	-11,942	-3,492
ACD	-5,949	-10,175	-1,724
BCD	4,163	-0,0613	8,389
ABCD	-4,431	-8,656	-0,205

FUTURE WORK

- Investigating the impact of the above significant factors with numerous levels
- Performance analysis of the fair schedulers
- Mathematical solution and performance evaluation for the satisfied users maximization problem.

5. ACKNOWLEDGMENT

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