Prediction on Proactive Channel Sensing Strategy for Cognitive Radio

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Abstract **– Sensing optimal idle channel for future transmission is the hot research topic in Cognitive radio (CR) network environment. CR Network performance greatly depends upon the waiting time of the Cognitive User (CU) for getting free channel from licensed band. Probability of available free channel will be less when arrival rate of primary user to their allocated licensed band is high. So the effective channel selection and switching strategy needed to overcome this issue and increasing throughput of the data transmission over cognitive radio network. In this paper focusing prediction on channel selection scheme pro-actively and comparing the performance with existing reactive prediction polices.**

Keywords - SDR (Software Defined Radio); Channel Switching; TWT; Proactive Channel Prediction; Switching Cost.

I. INTRODUCTION

Cognitive Radio (CR) is a recently growing wireless technology enabling flexible and efficient usage of unused spectrum in the radio environment by applying intelligent in existing traditional wireless communication. Radio network users are characterized by authorized and unauthorized users. This paper explains the opportunistic channel access to unlicensed user also named as Cognitive user (CU). Recent revolution in communication increased the unlicensed radio devices (cordless phones, battle field radio device, remote sensors etc). At the same time one survey telling licensed spectrum users like (GSM 900, Bluetooth, WLAN, etc) are utilizing just 25% of allocated resource. So some intelligent is needed in existing wireless communication for providing reliable service for CU [1].

Performance of the Cognitive Radio fully depends on waiting time and propagation time. In most cases propagation or transmission time negligible for end-to-end data transfer. So waiting time for new channel makes the delay in the Cognitive environment [2]. When we consider multi-user Cognitive radio network, we can't accommodate all secondary user (SU) at the same time. That time our Cognitive user will sense the idle authorized channel i.e., primary user (PU) and continue the targeted data transfer without disturbing the primary users. If PU arrival rate is high then waiting time for CU will make considerable delay in system because of the changing traffic pattern of primary user. In order to resolve the scarce spectrum problem, better *free channel management* strategies should be adopted in Cognitive radio wireless networks [3].

Spectrum handoff mechanisms can be generally categorized into two kinds, according to the decision timing of selecting target channels as either the proactive-decision spectrum handoff or the reactive-decision spectrum handoff [4].

Proactive-decision spectrum handoff

In the proactive-decision spectrum handoff, the targeted primary channels for future spectrum handoffs are determined before data connection is established according to the arrival rate of primary users, which are obtained by the long-term traffic observations [5]. Then, the SU can immediately change to the predetermined target channel whenever it is interrupted.

Reactive-decision spectrum handoff

In the reactive-decision spectrum handoff, the targeted idle primary channel is searched by effective spectrum sensing strategies *after* the spectrum handoff request is made .Then, the interrupted SU can resume the unfinished transmission on one of the idle channels [6].

This paper focusing on proactively predicting channel usage behavior of primary user is the unique strategy. Existing sensing methods has to search all possible combination of target channels for obtaining optimal target channel among those, but this methodology is obviously complicated. When the sensing time and the handshaking time are too large, the reactive-decision spectrum handoff is worse than the proactive-decision spectrum handoff in terms of the extended data delivery time.

The reminder of this paper organized as follows basic system architecture in section 2,Delay on channel switching in section 3,Sensing strategies in section 4, Prediction on Proactive Channel in section 5,Simulation results in section 6 and Conclusion in section 7.

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II. BASIC SYSTEM ARCHITECTURE

Multiuser Cognitive radio network has ‘N’ number of Cognitive user (CU) and ‘M’ number of available idle channel. If primary user (PU) available in the allocated channel then probably that comes under possible target channel for the Cognitive radio device. After selecting any one free channel transmission will begin. There won’t be any interruption until PU comes back for transmission in its allocated channel. Because PU has high priority over that channel, it won’t wait at any case. That’s the pre-condition for all strategies in Cognitive radio. Variety of channel sensing and decision making strategies are available. The basic operation sequence in Cognitive radio sensing scheme described as follows,

A. Unauthorized channel transmission

If the secondary frequency spectrum occupied by all other Cognitive user then only unauthorized transmission over primary user areas. i.e., M > N.

B. PU arrival or interruption

If PU wants its channel while SU transmission then immediately SU terminate the connection and make that channel available for PU reliably.

C. Connection drop

Using time-out acknowledgement from the operating channel Cognitive user identifies the connection drop. Until Cognitive user getting new idle channel target data will be waited in transmission buffer [3].

D. New optimal channel shift decision

Applying effective environment sensing protocols and strategies Cognitive user continues its transmission from that new optimal free channel. Prediction based shifting makes the transmission 55% extra efficiency compared to traditional sensing scheme. Every strategy will take the parameters like total service time, waiting time, handshake time and shifting time [7].

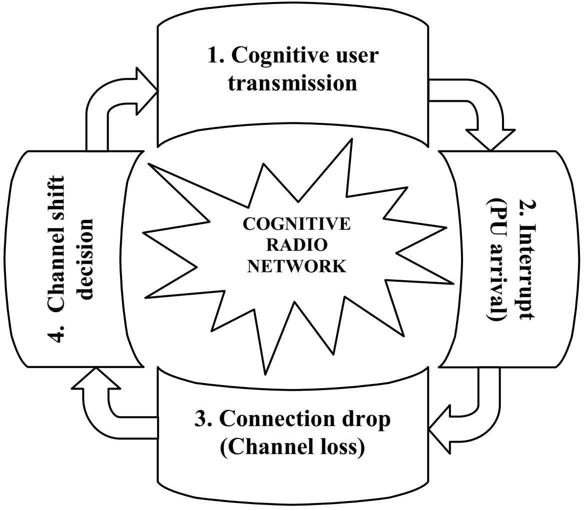

Fig1. Cognitive radio Operation cycle

III. DELAY ON CHANNEL SWITCHING

In Multi-user hierarchical Cognitive network, performance measure is the throughput vector, with each component being the throughput of an individual Cognitive user [8]. The time for channel sensing can be large, especially when there are a large number of candidate channels to be sensed and each has a small probability to be available [2]. There are two performance vectors involving to decide the channel sensing scheme in slotted mode.

- Propagation time
- Waiting time

Propagation delay is negligible when compared to Total waiting time in each packet transmission. So in this paper fully investigate the waiting time and its major factors. In CR networks time to wait an idle channel on the multiple handoff delay affecting more in each hop. Which leads in effective data transfer, especially in case of video streaming timely delivery is much importance. Following factors are major consideration for total waiting time in Cognitive radio network.

A. TWT (Total waiting time)

Let we assume total no of PU channel ‘n’ in the Cognitive radio network, taken the propagation delay(P_t) factor negligible one up to some minimal threshold value. Then easily we can define the total delay by calculating total waiting time. Here Pre-condition is $P_t < \partial(t)$, where minimum threshold $\partial(t)$ is measured as delay made by 20% of the primary users in the system [2]. Then waiting time only the delay factor, the following equation for calculating the total waiting time for end-to-end transmission over Cognitive radio network, from this channel switching time only making major delay in busy traffic times of PU. Each and every time slot waiting time will be considered here,

Total waiting time (TWT):

$$W(t) \triangleq \sum_{T=\mathrm{def}}^{n-1} (\boldsymbol{\mu} + h + S)_T \qquad (1)$$

Where,

n-1 – Total number of PU channel
μ – sensing time
h – Handshaking time
S – Channel switching time
Def – default channel of CU

The above generate equation suitable only for the condition at least one free channel in the primary radio network. In certain situation like heavy traffic in primary user side then no free channel found after sense all channels finally CU stayed on its default channel again. That time h=0 and S=0, there is no hand-off and channel switching. After some time CU may get its default channel itself for transmission. Then the total waiting time calculated only by duration which CU stayed in default channel. If CU could not able to get default channel again then search again for another PU channel from default channel. That time equation (1) will get additional waiting time W_{busy} Modified equation as follows,

$$W(t) \triangleq W_{busy} + \sum_{T=def}^{n-1} (\boldsymbol{\mu} + h + S)_T \qquad (2)$$

Each and every factors or variable in the above two equation has specific feature. If we concentrate to reduce those factors then easily we can minimize the total waiting time of the CU) for that only we going to produce effective schemes.

IV. SENSING STRATEGIES

In each time slot, an SU needs to spend time on channel sensing ensure that PU's are not present. After completing a sequence of sensing action on different free channels is specified. Then Figure out optimal sensing strategy i.e., which channel is the best choice to be sensed and when sensing should be terminated [9]. Suppose all channels are busily utilized by primary user then the total sensing time will reach the high value i.e., at that time (n-1) number of sensing operation will take to decide the end of the free channel sense. Because of it has to sense all possible PU channels.

Instead of sensing all possible combination of PU channels using optimal sensing schemes we can reduce the overall sensing time greatly. Generally sensing schemes classified into following three cases.

A. Sequential sense

Cognitive radio sense the primary channels sequentially from default channel. If any free channel detected then immediately shift to that channel and will continue its transmission [9]. Total sensing time depends on number of time slots taken to reach target channel. If's' time required to sense one time slot then multiple of total number of channel and t will give the total sensing time μ.

$$\mu = \text{total no. of channels sensed} \times t \qquad (3)$$

where,

t – one timeslot time

B. complete sense

Here sensing process will terminate after sensing all possible combination of primary user (PU) as we mentioned above. If any free channel sensed by Cognitive radio then CU will make entry to the temporary table. After finishing all sensing process CU will decide optimal channel for transmission. Continue the interrupted transmission with that optimal channel.

Total sensing time for this case is

$$\mu = (n-1) \times t \qquad (4)$$

C. Prediction based sense

It is interesting and could potentially make it feasible to predict the absence of PU's with high accuracy. It greatly helpful for avoiding unnecessary sensing of available channel also useful to get optimal channel for interrupted transmission. Of course, we have to consider incorrect prediction will lead interference with unavailable PU's. Later we will analyze different strategies used for prediction. Here the total sensing time will be too small comparing to previous cases, if first attempt itself the predicted channel is available and optimal, so single time slot enough for sensing then the equation (4) will be,

$$\mu(\text{without incorrect prediction}) = t \qquad (5)$$

But most of the time in multiuser Cognitive radio network at heavy traffic situation all prediction values won't be correct. That time following equation will have the total sensing time as follows,

$$\mu(\text{with incorrect prediction}) = t + (m \times t) \qquad (6)$$

Where,

m – Total number of incorrect detection
t – one timeslot time

V. PREDICTION ON PROACTIVE CHANNEL SENSING STRATEGY

In the existing prediction strategy whenever PU interrupts the current operating channel of CU, then only CU will initiate the prediction and finds the optimal channel for long time transmission. Instead of predicting new free channel after request from PU, we can apply the pro-active handoff policy to the new channel prediction. To reduce the interference with PUs, a CR could switch proactively to a new channel before the PU appears in the current band. In [5] discussed about pro-active mechanism and its potential advantage over other mechanisms.

However, in certain cases CU could not able to get better available channel than the current operating channel, because of PU arrival rate may high in the PR network at heavy traffic time. At that time without making any pro-active shifting simply continues the transmission through current operating channel. After arrival of PU for its transmission then only CU will decide change to the other optimal transmission channel using prediction.

A. An illustrative example for proposed model:

Let we Consider four PU channel ch1, ch2, ch3, ch4 for explain proposed model. Fig3 shows an example proposing channel sensing scheme with different channels each has different behavior. Basically it follows time slot based transmission. So the channel handoff performed proactively in currently transmitting channel. Each step described as follows,

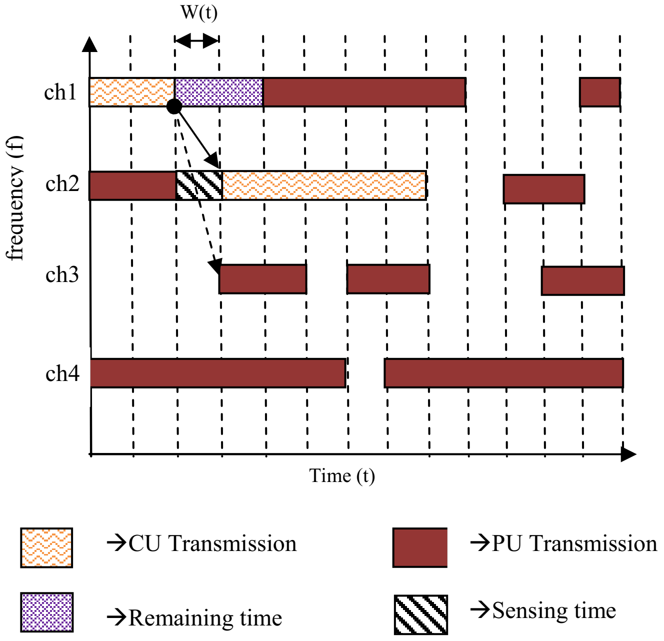

Fig2. Prediction based proactive channel switching

Step 1: In beginning, CU established at its default channel CH1. When an interruption event occurs, CU performs spectrum sensing to search the idle channels.

Step 2: In CH1 up to four time slots CU can continue its transmission. When we use pro-active sensing policy, every timeslot CU will check the free channel availability for getting better quality channel than current.

Step 3: After transmitting two timeslots CU detects two available free channels CH2 and CH3. Both are capable to receive the interrupted transmission from CU. but our basic idea proposed here is predicting better quality channel compared to interrupted channel.

Step 4: even more than one free channel sensed by CU, that won't be considered for channel handoff. If the sensed channels no long time transmission compared to current channel.

Step 5: CU apply prediction algorithm on detected free channels then selects better quality channel. Thus we found CH2, compared with CH1 remaining time CH2 has long time for CU transmission.

Step 6: if our predicted channel CH2 already used by any other PU, and then detects that prediction error by MWT. CU Immediately diverted to back up channel list.

Step 7: Back- channel list may have the already used CH1 also some other free channel like CH3. From those channels again prediction algorithm will apply selection factor and CU will decide the future transmission channel.

Step 8: In this entire process CH4 not involved, because PU utilizing behavior in this channel not favor for CU.

Step 9: At the end of all data transmission, CU will reach its default channel again and reconfigure its SDR for default channel.

A. Advantages of prediction strategy

Compared with reactive mechanism here channel decision not only depends on the availability of channel also considering the long survival time of deciding channel. If sensing strategy uses random or sequential channel selection schemes then their ineffective decision leads frequent channel shift. Multiple shifts cause high range of packet loss ratio. We need not wait for PU arrival for channel shift, because while transmission itself CU may get best predicted channel. This method not only supporting pro-active decisions, if no availability of better channel compared to current simply continue its transmission up to PU arrival [10].

VI. SIMULATION RESULTS

Two types of users can utilize each channel in this simulation model: Primary Users and Cognitive User. MATLAB simulink software was used here for simulating two-channel system i.e., high priority primary user and low priority cognitive user. Block diagram which was used for simulation has so many basic blocks like modulation and random noise generator. Fig.3 shows basic building block for cognitive sensing. Our proposed prediction strategy implemented in hole finder algorithm block. Channel type used here is AWGN with signal-to-noise ratio 10dB.

Total number of switches required to transfer the data when different range of primary users in system showed in Fig.4. There are three types of sensing strategies which are discussed prior in this paper. If the primary users count increases then the probability of available channel occurrence will improve. So at right last in graph we are getting minimal number of switches. But if the arrival rate of primary user increases rapidly in future that will cause higher rate of channel switches. We tried upto 3000 primary user for our simulation.

TABLE 1
SIMULATION CONFIGURATION

Parameter	Value
Total number of channels	9
Average usage time	100ms
Average idle time	100ms
Time for channel switching	10ms
Packet size	160 bytes
Packet Transmission time	20ms
Traffic type	Poisson
Channel type	AWGN

In complete sense strategy it has to sense entire channel then comparatively choose optimal one. Randomized sensing strategy will suit only when availability of primary user is more than 25%. Compared to other sensing strategies prediction based sensing policy gives better result from first. Because this model sensing only available channels and avoids to sense unnecessary used channels. So for proactive channel switching strategy with prediction is best choice for achieving optimized result.

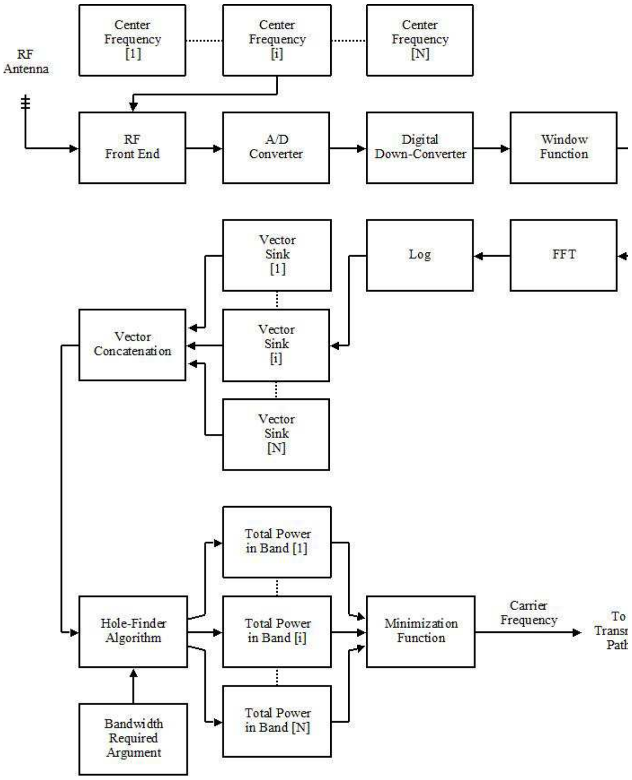

Fig. 3. Block diagram of the spectrum Analyzer and hole-Finder

Arrival rate of primary user is an important factor in channel sensing strategy. Here we are considering arrival rate up-to 20%. In Fig.5 if arrival rate increases accordingly total waiting time (TWT) also keep going upward direction. It indicates high range of arrival rate results inefficient channel switching. We can apply prediction in both proactive as well as reactive strategy. Predicting optimal channel proactively gives better performance compared to reactive strategy from low arrival rate to high.

For larger values of arrival rate, the interrupted users with random or complete sensing method must spend much more time to wait when it changes its operating channel because this target channel likely is busy. Thus, the total waiting time for proactively prediction method is considerably low. From the simulation results it is infer that combination of proactive sensing strategy and predictive channel switching achieve better performance for different arrival rates of primary user. It gives the Cognitive radio system without signal to noise ratio and data loss because in intermediate buffer queue [3] amount of waiting data will be reduced.

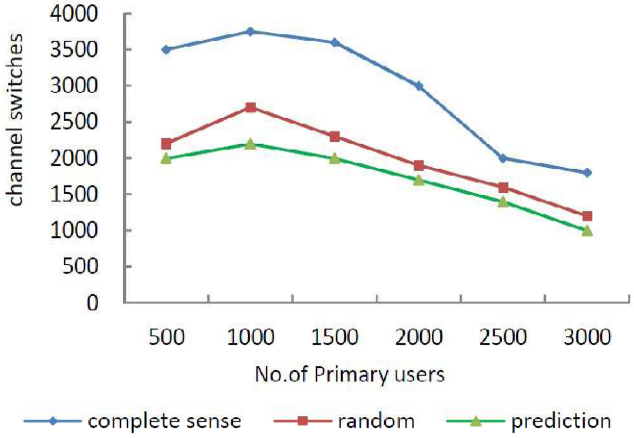

Fig 4. Amount of channel switches requiring for different sensing methods

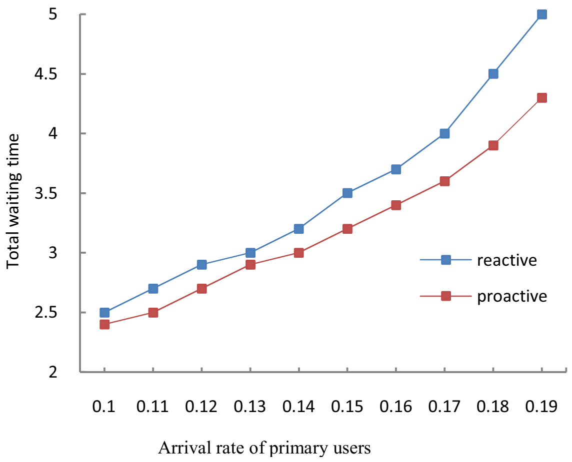

Fig 5. Comparison of the Total waiting time for proactive and reactive sensing strategies

VI. CONCLUSION

In this paper so far it has been discussed about throughput factors involved in total waiting time (TWT). In that considered switching time factor, for minimizing that proposed prediction based channel switching on proactive strategy. Also we investigated more sensing strategies and their contribution to increasing throughput and resolving nature of interference. In the future work will be focus on prediction model for our proposed solution. Based on past history information we can predict the each and every channel property along with fault tolerance model for incorrect prediction based on history values.

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