# Proposal for Cognitive Radio Networks FPGA-Assisted Implementations for High Mobility Users

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***Abstract*— This paper describes the proposal foran FPGA implementation for vehicle mounted cognitive radio network which provide up-to-date and ready to use information for the nearby high mobility users.**

## I. Introduction

Transferring large-scale and continues data as a lower-rated secondary user is not an easy task due to higher computational resource and accuracy of information needed to allocate proper channels. The difficulty is also increased due to allocation of spectral resource for primary users (PUs) than the second users by The Federal Communications Commission. Considerable spectrum holes are resulted to due to the observed PUs usage due to underutilization. This challenge get even bigger when we have to take the mobility of the receivers and transmitters. More detail in this topic is included in the next sections.(Syed and Safdar 2017; Wu and Li 2017a)

CRN radios must be able to be a cognitive system which is able to learn and reconfigure as needed by changing the operating frequency as well as the transmission parameter. This Modification of the system is performed by using SDR based system. The computational capacity and flexibility of FPGAs can be added to increase the effectiveness of the SDR.

### A. Method of Detection

Energy Detection: This detection method is relatively easy to implement as well as computationally less intensive. In this method the average value of the signal, which calculated using FFT by changing it form time domain to frequency magnitude and squaring the value, which is used as a reference line to identify potential peak. The overall method is as follows: Data is converted from analog to digital, noise and adjunct signals are rejected using low-pass,time domain is converted to frequency domain using FFT, magnitude from FFT output is squared,squared value is integrated per given length, peak is detected using different option,output signal shows whether PU signal is absent or present. (Syed and Safdar 2017)

Cyclostationary Feature Detection: This works by employing the carrier frequency, symbol period, modulation type, and chipping rate. This method use spectral correlation function to evaluate the signal to identify the possibility of periodicity with comparing it with the predetermined threshold . (Syed and Safdar 2017)

## II. Methodology

In this system, the cognitive communication will be from cognitive base station radio which is mounted in the car to a cell phone and from cognitive base stations that is mounted in vehicle to other vehicle who has the same settings. The main purpose of communicating between vehicle to vehicle is to get a spectrum history, perform more power and computational capacity demanding work either horizontally or vertically to or from the user. This computed spectrum models should also be available for anyone with reasonable range that will be tested in the design. This information can also be used to transmit spectral information for low-flying drones.

Our system will focus have primary users and second users. The primary user will be a the primary user in the location that is sensed who has a priority and secondary users will be any those that are not related to the unique set of cars that our system operating from. In this setting, most of the computing need to be done on the vehicle, which our FPGA implementation will focus on. All the vehicle-to-vehicle communication is primary to transmit spectral information which can be measured at the time or could be from computed value.

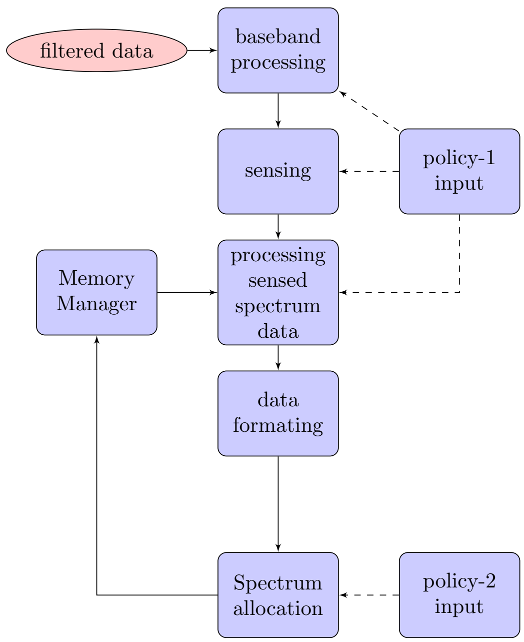
The on-vehicle FPGA [assisted] CR, Car A for simplicity, will have a system which will receive information from the car, Car B, which is coming from the opposite direction until it is out of range and keep repeating the same activity as it goes. Car A will also transmit the spectrum history to car B. The communication will also take the vehicle speed and other factors that affect the radio transmission in consideration. This information will be shared with other vehicles to compare for further spectrum management. Car A will sense its own spectrum history as well as receive and compare it with the cars that were coming from similar directions. All of this sensing and computation will be achieved using our FPGA design, with generous car real state and more than the user power availability assumptions. The hardware implementation will be performed on Virtex-5.

It is possible to add more assumptions as we go forward to simplify the system, including adding the interactions gap between cars passing in opposite side, possibly using easier to implement energy based sensing mechanism, and using stored geo-locations spectrum and doing predictive checking mechanism with controlled computational work, for example will update to other user only the deviations from shared geo-locations spectrum data by means of indexing. (Mohamed 2009)

As a work of Seyd et al work on the historically-assisted sensing shows, using historical data in combination with the live scanning will also save the energy usage which can be significant for mobile users. One suggestion they have is using a trigger point from the historical data to avoid scanning unnecessarily. (Syed and Safdar 2017)

### *A. Proposed Design Implementations*

Fig. 1. flow chart of proposed design for sensing and spectral management




*1) **Spectrum Sensing**:* Since this system is cooperative sensing system, we don't restrict the spectrum sensing that could be used. This system will receive different kind of spectrum information from different sensing mechanism. The sensed data will be aggregated based on the identifying index that will be attached to the system. This is discussed more in detail in data formating section.

The ideal assumption for simple design is usage of energy detection system for unknown spectrum and matched detection system as we are more aware of the surrounding's spectrum information.

Energy detection system is relatively easy to implement and they are able to detect unknown samples with reasonable accuracy compared to other systems that we are proposing to employ in this system. One of the main advantage of using energy detection systems in this scheme is to have a generate a useful data of the primary user activity.

The other spectrum sensing methods that are interested in are matched filter.The attractive aspect of matched filter is its effectiveness if predetermined information is provided. This method use correlations to compare with the threshold value. As more and more vehicles collect rich set of spectral information, the effectiveness of this method also increase.This system will require more hardware customization, which shouldn't be much of a concern as it can be achieved by reconfigurable devices.

## data format

| **data label** | **comment** |
|---|---|
| Unique id of car | This is randomly generated car id that will expire per count and speed consideration. This is to make sure no one car will send repeated information if there are other cars around, unless certain conditions are met which is sensory preference and both of the cars are stopped, or the previous sender is the only one in the proximity |
| Total error rate of the model | This will give us the accuracy of the model each car has that is computed by the transmitter by checking it with previously received data |
| Sensing method used | Identify the spectrum sensing method used to give priority for certain methods over the others to increase the accuracy of the information |
| Data source | Identify if it is copied from geo-locational data or sensed by the transmitting car |
| Type of data being sent | Identify if it is an updated of deviated geo-locational data or fresh sensed data |
| Time stamp | Identify the time sent using external resource |
| speed of the car sending it | this is fetched the transmitting car |
| Data from another car | Spectrum data sent from another car |
| Data from memory | Spectrum data from memory to be added to final decision data |

*2) Basic Data formating:* Our system is heavily dependent on having a specific information on the nature of the data that are passing back and forth. Having correct identification on the nature of the update, source, method used, and proper timestamps is critical in building overall models.

Our data is formated this way to increase the accuracy of our decision making while using limited computational resource. The following table shows the over all method of composing our data packet. More discussion will be included in proposed design.

*3) Spectrum Allocation and Sharing:* Since the main goal of this system is to communicate the spectral resources with other possibly DSP device that are looking for information to send large-volume of data without interfering with the PU, handing of the spectrum achieved as a last steps and getting feedback from the system as a means of updating the system.

One factor that will significantly affect the performance of the system that is getting the spectral information form our system is the frequency and the size of update. This need to be considered with inclusion of the speed of the car as well as the overall change of spectral information.

*4) Addressing Spectrum Mobility Issue:* The mobility issue in this system will be addressed by using the data from the car as well as calculation from change in transmission. Further approximation is needed to resolve this problem.

## III. Proposed design for Implementation and Discussion

As it is shown in figure 1, our system has two governing policy sets. The first policy sets the baseband processing, sensing and proper adjustment for processed data including sending out value for spectrum allocation. The second policy determines the spectrum allocation and the signaling to co-device that is waiting for possible spectrum information to send its data. Algorithmic pseudo-code implementation of our overall system is as follows:

**Algorithm 1:** Car ID verification using receiver one

**if** *unique id of the car is true* **then**
    decode the received package;
    store it in the memory manager;
**else if** *is the car only transmitter or is the car has the best sensing mechanism or does the sender car timestamps is greater than X than the receiver or is the car not blocked in the high frequency id list in from fast access memory;*
**then**
    decode the received package, update the counter for the id for later in fast access memory
**else** log car id and receive another package;

## IV. Note on FPGA Implementation

This part is left out do to the complexity it brought to be finished on time.

**Algorithm 2:** using receiver two

**switch** *error rate of received spectrum model* **do**
    **case** *less than lower threshold value* **do** use the model data to allocate;
    break;
    ;
    **case** *greater than the lower threshold value but less than the higher threshold value* **do** start spectrum sensing with a check;
    **case** *greater than the higher threshold value* **do**
        start spectrum sensing without a check;
        update the car id not be eligible for second update;
        break;

**Algorithm 3:** spectrum sensing

**switch** *threshold value* **do**
    **case** *acceptable predetermined filter* **do**
        do the sensing based on predetermined spectral information which sue matched or cyclostationary filter;
        do that;
    **case** *unacceptable for matched filter or greater than the threshold value* **do** do matched filter or other modified sensing that expect prior information;
    **case** *last value* **do**
        do energy sensing;
        break;

## V. Future Works

Means of data training, including added machine learning from stationary cognitive network station where the vehicles get their information, adding encryption means of communication between cars to avoid possible intrusion by unwanted subjects, analysis of optimal frequency of transmission, and inclusion of multimedia source in the FPGA are some of the future work that will be added to this system.The other feature that will be added is using multiple antenna to receive a signal to compare timestamps among different sender to get more update information. Other works that are proposed in energy harvesting mechanism, like Fan Zhang et al work, could also implemented. Different prediction method could also be studied using the feedback from the DSP system. To avoid too much noises and possible cancellation, the transmission from each car within specified geolocation could be adjusted automatically using FPGA resources. Other implemention that will be added to this system is admission control for the cars. Similar work has been shown in Kalil et al work. (Zhang et al. 2017; Wu and Li 2017b; Kalil et al. 2017)

## VI. Conclusion

## References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