New Strategy for Cognitive Radio Systems

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ABSTRACT

This paper initials with a brief discussion of future applications in wireless communications and of challenges posed to cognitive radio. It creates new thinking on using adaptive blind source separation algorithm to identify the primary user. The statistics of cognitive base station are provided by new embedded real-time database Berkeley DB. An innovative cloud storage strategy for multiple base stations' real-time measurement information, proposed in this paper, is to achieve primary user's accurate statistics. The proposed methodology can make great improvement on the MIMO system performance in the cognitive radio networks by taking new distributed cognitive engine framework with Hadoop cluster multi-nodes. Another contribution of the proposed approach was the benefit to the cognitive performance which can be characterized by the probability of spectrum coexistence on the basis of building up a distributed cognitive framework system of cognitive multi-user nodes under homogeneous network spectrum sharing environment.

Keywords: Cognitive Radio Network (CRN), Cognitive MIMO Radio, Adaptive Blind Source Separation, Berkeley DB, Hadoop cluster, Cloud Storage.

1 INTRODUCTION

Cognitive Radio (CR) is a new radio system concept. It is a revolutionary technology of improvement on the spectrum usage in wireless communications. It is an intelligent radio which is able to sense its environment, and adapts its physical operation parameters accordingly to satisfy its system requirement [1]. In cognitive radio networks, cognitive (unlicensed) users need to continuously monitor spectrum for the presence of primary (licensed) users. Overview the three main steps of the cognitive cycle: spectrum sensing, spectrum analysis, and spectrum decision, we will extend our previous studies on adaptive spectrum sensing in cognitive radio [2]. As a key technology enabling cognitive radio, spectrum sensing plays an important role in detecting an occurrence of incumbent or available radio frequency [3]. Cognitive radio will be able to seek and use in a dynamic way the frequencies for network access by automatic detection of vacant bands in radio spectrum [4].

In 2007, the main goal of IEEE 802.22 working group for wireless regional area networks is to establish a CR-based standard that allows unlicensed users to utilize the bands allocated to TV broadcast services in a non-interfering fashion. The proposed schemes for allowing unlicensed operations in the TV bands prevent interferences to TV reception. The low frequency analog TV band (54-862MHz) has some attractive features for wireless broadband services such as achieving long-distance transmission. On the other hand, the CR procedure defined uses a learning algorithm (the composition, as well as the actualization of the database) and a reasoning algorithm (taking measurements and determining an idle resource almost instantaneously). Both algorithms are currently under investigation for use in a CR. Local Geolocation Database broadcast by a cognitive base station should include the information about absolute bandwidth, center frequency, altitude accuracy, altitude, latitude accuracy, latitude, longitude, longitude accuracy, frequency unit, altitude unit, dimension accuracy unit, local time, local time format, time source, date, date format, location estimation method, waveform, user type with a licensed and several unlicensed CR users. The Geolocation Database and local Beacon techniques utilizes these location information [5].

According to the Geolocation-Database scheme, licensed users (i.e., TV transmitters) are equipped with location estimation and sensing device to estimate their current location information. Licensed users provide their spectrum and location information to the FCC central database. The FCC database broadcasts available channel information along with the location information of the licensed users. On the other hand, unlicensed users are also equipped with location estimation and sensing device to estimate their current locations. Unlicensed users cross-check their locations with the location of licensed users can send their spectrum requests along with location information to the cognitive base station. In such a case, the cognitive base station allocates channels to users and broadcasts the Geolocation Database. Two concerns regarding this scheme are the reliability of current Geolocation technologies and the performance of the FCC central database.

In the depicted CR system with the modular, scalable structure, the main component of this structure represents the experiential database containing knowledge gathered in the past. For the current transmission, a request vector can be sent to the experiential database to obtain the most appropriate transmission constellation based on past information. Besides, transmitters radiate power and the imperfections of propagation, electromagnetic waves mutually interfere. Therefore, attention must be paid to the power level. For interference avoidance, such as finding the appropriate spectrum hole to conduct a transmission or employing beam forming or MIMO.

The existing signal processing technology cannot deal with sensing information in the real-time mode, especially CR sense air interface in the whole spectrum. For one thing, Cooperative spectrum sensing can improve the efficiency of detection. But it is difficult for existing theoretical algorithms to implement. For another, the realization of dynamic spectrum allocation will be restricted by many policies, standards and access protocol. All these drawbacks are primarily due to its simple model which is much distinction with the real environment, adaptive identify idle channel and control scale of users and access opportunities then realize the rational utilization of spectrum are thoroughly needed to explore.

The paper is organized as follows. In Section II, the sketch of research context is described. Three potential problems stated are proposed in section III. In section IV, the analysis of rationale and methodology are carried out. In section V, conclusions are given. Finally, future work is presented in the last section.

2 SKETCH OF RESEARCH CONTEXT

Spectrum sensing techniques include matched filtering, energy detection, cyclostationary feature detection and signal specific feature detection schemes as well as wavelet based edged detection and cooperative spectrum sensing shown in **Figure 1**. Secondary user should ensure high probability of detection (90%) and lower probability of false detection (10%). Sensing method needs to be chosen depending on SNR, spectral bandwidth to scan, computational complexity and minimal scanning time to meet the specified sensing accuracy. Sensing frequency is also an important design parameter and is dependent on the maximum allowable interference duration.

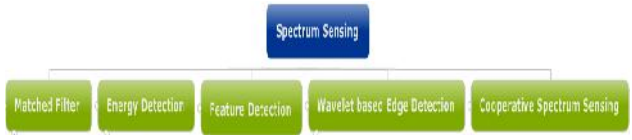

Figure 1: CR spectrum sensing techniques

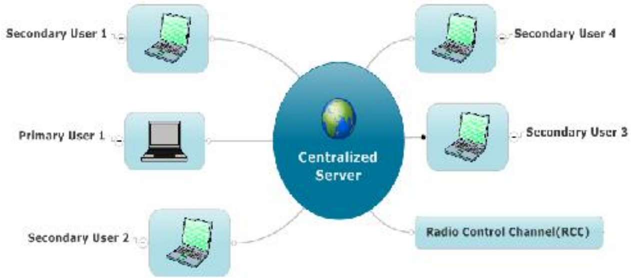

Figure 2: Centralized spectrum sharing

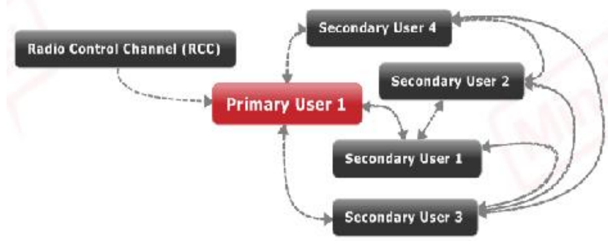

Figure 3: Distributed spectrum sharing

Cooperative detection can be implemented either in a centralized or in a distributed manner that shown in **Figure 2** and **Figure 3**. In the centralized manner, the secondary network base station plays a pivotal role to gather all sensing information from the secondary users and detect spectrum holes. On the other hand, distributed solutions require exchange of observations among secondary users.

In cognitive radio networks, cognitive (unlicensed) users need to continuously monitor spectrum for the presence of primary (licensed) users. Allowing the cognitive users operating in the same band to cooperate can reduce the detection time and thus increase the overall agility. The existing cooperation scheme with a two-user cognitive radio network increases the agility of the cognitive users by as much as 35% [6]. In cooperation scheme to multicarrier networks with two users per carrier, the decentralized cooperation protocol ensures asymptotic agility gain for arbitrarily large cognitive network population. In [7], sufficient conditions are developed for agility gain when the cognitive population is arbitrarily large. A practical algorithm in multiple cognitive user single carrier networks which allows cooperation between cognitive users in random networks is proposed.

The problem of equalization and blind source separation (BSS) in multiple-input multiple-output (MIMO) communication systems is under intense discussion [8]. MIMO uses multiple antennas at the receiver and the transmitter. The MIMO systems have received significant attention in the communication society, due to its achievable capacity gain. The high capacity gain in MIMO systems arises from exploiting the spatial and temporal diversity in the received signal from different antennas. In MIMO systems, it is possible to transmit several signals on the same bandwidth, without allocating a specific sub-channel to each signal. When multiple signals are transmitted over a MIMO channel, signal processing techniques are used not only to equalize the signals, but also to separate the transmitted sources at the receiver. For source separation, a multistage equalization and source separation technique is evaluated over variations of this channel model that can deal with the BSS problem [9]. The adaptive blind source separation and equalization for multiple-input/multiple-output (MIMO) systems, the constant modulus algorithm (CMA) used in MIMO systems (MIMO-CMA),the MIMO-CMA equalizer is able to recover one of the input signals, remove the inter symbol interference (ISI), and suppress the other input signals.

For avoidance of interference from primary user, unlicensed user must have capability to detect the status for primary user, since unlicensed users are likely to be out of primary wireless network, the different situations to sense primary user information should be classified to discuss. Analysis single or multiple nodes information and make a comprehensive decision on the impact on primary users from secondary users and its accuracy as well as real-time performance.

3 PROBLEM STATEMENT

Different from the existing approaches, we observe the current spectrum sensing limitation for practical cognitive radios. We identify the hardware constraints in two main aspects: (1) Sensing constraint: for a given geometrical area, spectrum opportunity of interest may span a wide range of bandwidth. However, at any given period, accurate and fine sensing can only be conducted within a small portion of spectrum. (2) Transmission constraint: spectrum used by secondary users has the maximum bandwidth limits and spectrum fragmentation number limits which stems from the number of radios and orthogonal frequency-division multiplexing (OFDM) technology limitations. These constraints bring new research challenges and also opportunities in cognitive MAC design. Here, we consider the common situations where secondary users are all equipped with a single cognitive radio. The cognitive radio cannot sense and transmit simultaneously, and discontinuous OFDM is used for spectrum aggregation but the maximum spread bandwidth and the number of fragments are limited. To protect primary users, a maximum detection time interval is used similar to that in IEEE 802.22, which represents the maximum time of interference from secondary signal a primary user can tolerate before it wants to use the spectrum.

These constraints and assumptions impose a limit on continuous transmission by secondary users and require the secondary users to sense spectrum before transmission. It is known that, only when a certain band of spectrum is sensed, the status of the band is known for secondary users. There is a tradeoff between spectrum opportunity and sensing overhead. For a single transmission pair, the more the spectrum is sensed, the more the spectrum opportunity can be explored, however, the larger the sensing overhead will be. A fundamental problem is how secondary users sense the spectrum intelligently (e.g., whether or not to sense further based on the current situation) and optimize the expected throughput.

3.1 WLAN hidden station problem and exposed station problem

It is universal acknowledged that due to wireless communication limitation on distance there are problems stemmed from hidden and exposed station. During the detection of primary user, these problems may interference system performance. It might be because it belongs to different networks it adopts DCF or PCF mode. However, it only leads to confliction under the same address code serial of primary user and secondary user. **Figure 4** shows the above depicted situation.

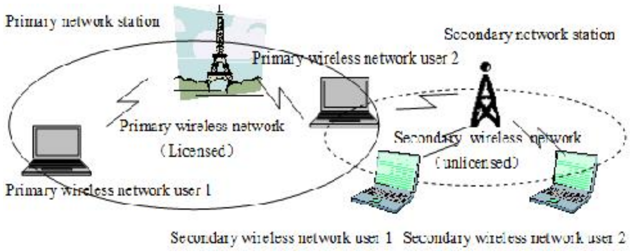

Figure 4: Wireless network structure on primary user location by two base stations

3.2 Signal strength fading and distortion caused by wireless channel

Due to NLOS obstruction, even if secondary user is included in the licensed wireless network, it might be difficult to detect due to transmission signal block or delay distortion. **Figure 5** shows that the primary user 2 might not aware of the inference from secondary user 1 since obstruction destroys the detection of primary network.

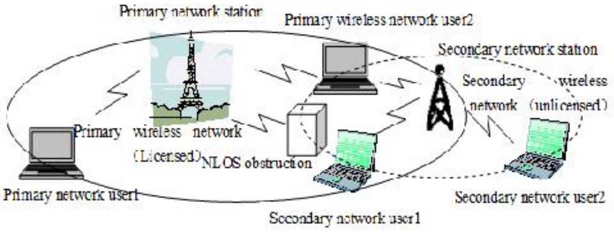

Figure 5: The difficulty of identification on primary network caused by NLOS wireless channel

Cooperative detection among unlicensed users is theoretically more accurate since the uncertainty in a single user's detection can be minimized. Moreover, the multi-path fading and shadowing effect are the main factors that degrade the performance of primary user detection methods. However, cooperative detection schemes allow mitigating the multi-path fading and shadowing effects, which improves the detection probability in a heavily shadowed environment.

Interference is typically regulated in a transmitter-centric way, which means interference can be controlled at the transmitter through the radiated power, the out-of-band emissions and location of individual transmitters. However, interference actually takes place at the receivers, as shown in **Figure 4 and Figure 5.**

3.3 Multiuser primary user identification problem in the multi-users conditions

CDMA blind detection algorithm makes use of spread-spectrum code to detect information. Therefore, we can consider feature detection. Blind detection algorithm is mainly focused on subspace method and minimum variance algorithm as well as high-order cumulant method such as adaptive blind multiuser detection based on weighted high-order cumulant. The subspace method has the disadvantage of performance of the algorithm and computational complexity, since it needs to make SVD on large matrix. Besides, accelerate the iterative rapidity of convergence, optimize the design with simple computational complexity are key problems emerging by the iterative searching process of large matrix and vectors in minimum variance method and high-order cumulant method.

4 RATIONALE AND METHODOLOGY

4.1 New Cooperative Spectrum Sensing Method: Adaptive blind source separation algorithm in Cognitive MIMO Radio

4.1.1 Cognitive MIMO Radio

It is widely recognized that the use of MIMO antenna architecture can provide for a spectacular increase in the spectral efficiency of wireless communications. With improvement of utilization as one of the primary objectives of cognitive radio, it seems logical to explore building the MIMO antenna architecture into the design of cognitive radio. The final result is Cognitive MIMO Radio that offers the ultimate in flexibility, which is exemplified by four degrees by freedom: carrier frequency, channel bandwidth, transmission power, and multiplexing gain.

4.1.2 Cyclostationary-based blind source separation algorithm

In our previous research work, we have focused on methods for feature sensing of primary bands in IEEE 802.22 WRAN systems. Specifically, multi-cycles detection, based on the correlation and covariance function of the cyclostationary signal, has been investigated. Assumed that sources are cyclostationary signals, novel cyclostationary-based blind source separation algorithm using high-order statistical properties to the bearing defect diagnosis from instantaneous mixtures should be investigated.

4.1.3 Adaptive blind source separation algorithm

Location information from primary user can be used to optimally apply multiple antenna elements to use beam forming or multiple input multiple output (MIMO) systems. Adaptive blind channel identification from the time domain into the frequency domain. In the problem of adaptive blind source separation (BSS) from multi-input multi-output (MIMO) channels, the novel adaptive separation algorithm can separate all source signals simultaneously by directly updating the separation matrix. We will propose a new spectrum sensing method for cognitive radio refrained from existing limitations and restrains by adaptive blind source separation algorithm.

4.1.4 Headings Adaptive blind channel identification algorithm

It can be used for the design of spectrum sensing and channel estimation in physical layer, and evaluation through existing cognitive platform. We can first analyze the convergence of the constant modulus algorithm (CMA) used in MIMO systems (MIMO-CMA). Our analysis will reveal that the MIMO-CMA equalizer is able to recover one of the input signals, remove the inter symbol interference (ISI), and suppress the other input signals. Furthermore, for the MIMO finite impulse response (FIR) systems satisfying certain conditions, the MIMO-CMA FIR equalizers are able to perfectly recover one of the system inputs. We will propose a novel adaptive algorithm for blind source separation and equalization for

Cognitive MIMO Radio systems. Our theoretical analysis will prove that the new blind algorithm is able to recover all system inputs simultaneously regardless of the initial settings. Finally, computer simulation examples will be presented to confirm our analysis and illustrate the effectiveness of blind source separation and equalization for Cognitive MIMO Radio systems.

4.1.5 Cognitive OFDM signal in spectrum sensing

Utilize Orthogonal code to achieve conditonal sharing bands when considering inter-space and inter-code factors add into time domain that make stationary channel allocation embedded into dynamic channel allocation.Besides,when networks overlapped, space seperation method by transmission power coverage can increase the population of unlicensed users in the sharing bands.

4.1.6 Cognitive Turbo Processing

Detection de cision algorithm utilize adaptation technology if considering turbo iterative that can store more valuable information. Turbo processing has established itself as one of the key technology for modern digital communications.Turbo processing has made it possible to provide significant improvements in the signal processing operations of channel decoding and channel equalization,both of which are basic to the design of digital communication systems.Compared with traditional design methologies, these improvements manifest themselves in spectacular reductions in FERs for prescribed SNRs.With quality-of–service(QoS) being an essential requirement of cognitve radio,it also seems logical to build turbo processing into the design of cognitive radio.Furthermore,adaptation technology is used to follow certain rules when new signal incoming while turbo iterative can explore more information by data mining in the exsiting signal.

4.2 New embedded real-time database for cognitive base station: Berkeley DB

CR systems are not limited to internal sensing, that is refers to wireless communication systems are able to measure the major propagation parameters and use it for adaptation since new sensing capabilities are emerging. CR systems are capable of taking advantage of these recently emerging sensing opportunities to better estimate the propagation parameters with the aid of a cognitive engine, which leads to improvement in overall system performance. Besides, recently emerging sensing opportunities can provide CR with novel awareness and adaptation options that cannot be achieved by internal sensing. The information obtained by internal sensing can be useful to improve the network and service performance. However, the use of this type of information is only possible when the sensing data is processed by RKRL (Radio Knowledge Representative Language). Cognitive engine cannot determine the context of the sensing data unless RKRL forms it. On the other hand, the presence of a cognitive engine along with external sensing capabilities allows CR systems to achieve cross- layer adaptation and optimization. CR systems are able to perform in the optimum range by incorporating the bits of information coming from external sensing into the cognitive cycle with the aid of RKRL.

The performance of database is crucial for the storage of detection information that ensures upper application calls data in physical layer. High performance database with superior accuracy and stability can aid CR systems accomplish sensing task more efficiency and effectiveness. CR should take measurements to ensure that the required information is up to date. According to our previous proposed location algorithm towards primary user based on scatter information in cognitive radio, we can develop a new database storage scheme in light of our existing knowledge base on the basis of RKRL.

Berkeley DB (BDB) is a software library that provides a high-performance embedded database for key/value data. Until 2012, Berkeley DB is the most widely used database toolkit in the world, with hundreds of millions of deployed copies. BDB stores arbitrary key/data pairs as byte arrays, and supports multiple data items for a single key. BDB can support thousands of simultaneous threads of control or concurrent processes manipulating databases as large as 256 terabytes, on a wide variety of operating systems including most Unix-like and Windows systems, and real-time operating systems. Embedded database possess superior performance on the storage and retrieval of real-time data. Based on previous research work, primary station location need measurement parameters from primary station and secondary station. Through Berkeley DB, scatter information can be considered to store into the embedded real-time database.

The task to find spectrum holes can be addressed by employing a receiver that scans a wide frequency range or to utilize a filter bank covering the whole range. The problem is that filter banks are complex and costly. The disadvantage of scanning is that the monitoring of a large spectrum region takes time, and it follows that the information retrieved is of a statistical nature. As long as the CR is not active, it scans the frequency range it may access, evaluates the measurements and stores the results in the form of statistical data about the spectrum occupation in local database.

This is collection of background knowledge. As soon as the CR wants to set up a connection, it looks into the database to identify a resource that is very likely idle. Then it takes a passive measurement to verify if resource is effectively free. If this measurement yields an idle resource is effectively free. If this measurement yields an idle resource, this is taken for transmission; if not, the resource with the next priority is taken from the database and verified. Consider using real-time database such as Berkeley DB to store real-time signal detection parameters and measurements and statistical data results as data storage in the physical layer that is used for the basis of spectrum analysis and decision.

4.3 New distributed cognitive engine framework: Multi-nodes Hadoop cluster combined with Cloud Storage Technology

Cloud storage technology is a new concept based on cloud computing, refers to a system with functionality of cluster application, distributed file system, collaborate work with different types of storage equipments in the network as well as data storage and service accessible to outside network. Cloud storage system is a cloud computing system focused on data storage and management.

Apache Hadoop is an open source software framework that supports data-intensive distributed applications.It enables applications to work with thousands of computational independent computers and petabytes of data. Hadoop was derived from Google's MapReduce and Google File System (GFS) papers. Hadoop is a top-level Apache project being built and used by a global community of contributors, written in the Java programming language. Hadoop is a framework written in Java for running applications on large clusters of commodity hardware and incorporates features similar to those of the Google File System and of MapReduce. It not only used to store distributed file systems but also design the distributed application framework worked on large cluster. HDFS is a highly fault-tolerant distributed file system and like Hadoop designed to be deployed on low-cost hardware. It provides high throughput access to application data and is suitable for applications that have large data sets.

Typically one machine in the cluster is designated as the NameNode and another machine the as JobTracker, exclusively. These are the actual “master nodes”. The rest of the machines in the cluster act as both DataNode and TaskTracker. These are the slaves or “worker nodes”. The master node will run the “master” daemons for each layer:

NameNode for the HDFS storage layer, and JobTracker for the MapReduce processing layer. Both machines will run the “slave” daemons: DataNode for the HDFS layer, and TaskTracker for Map Reduce processing layer. Basically, the “master” daemons are responsible for coordination and management of the “slave” daemons while the latter will do the actual data storage and data processing work.

From two single-node clusters to a multi-node cluster, we will build a multi-node cluster using two Ubuntu boxes in this paper. We will configure and test a “local” Hadoop setup for each of the two Ubuntu boxes, and in a second step to “merge” these two single-node clusters into one multi-node cluster in which one Ubuntu box will become the designated master (but also act as a slave with regard to spread data storage and processing to multiple machines), and the other box will become only a slave. It’s much easier to track down any problems it might encounter due to the reduced complexity of doing a single-node cluster setup first on each machine.

A small Hadoop cluster will include a single master and multiple worker nodes shown in **Figure 6**. The master node consists of a JobTracker, TaskTracker, NameNode, and DataNode. A slave or worker node acts as both a DataNode and TaskTracker, though it is possible to have data-only worker nodes, and compute-only worker nodes; these are normally only used in non-standard applications. The standard startup and shutdown scripts require ssh to be set up between nodes in the cluster. In a larger cluster, the Hadoop Distributed File System (HDFS) is managed through a dedicated NameNode server to host the file system index, and a secondary NameNode that can generate snapshots of the namenode's memory structures, thus preventing file system corruption and reducing loss of data. Similarly, a standalone JobTracker server can manage job scheduling. In clusters where the Hadoop MapReduce engine is deployed against an alternate file system, the NameNode, secondary NameNode and DataNode architecture of HDFS is replaced by the file system-specific equivalent.

For effective scheduling of work, every Hadoop-compatible file system should provide location awareness: the name of the rack (more precisely, of the network switch) where a worker node is. Hadoop applications can use this information to run work on the node where the data is, and, failing that, on the same rack/switch, so reducing backbone traffic. HDFS uses this when replicating data, to try to keep different copies of the data on different racks. The goal is to reduce the impact of a rack power outage or switch failure so that even if these events occur, the data may still be readable.

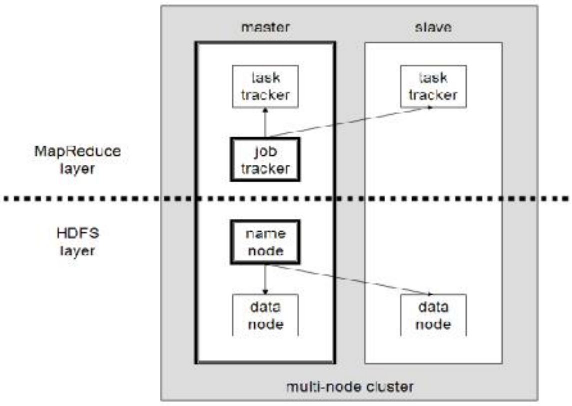

Figure 6: A multi-node Hadoop cluster

Before we start our new multi-node cluster, we have to format HDFS for the NameNode. We need to do this the first time is to set up a Hadoop cluster. The HDFS name table is stored on the NameNode's (master) local file system in the directory. The name table is used by the NameNode to store tracking and coordination information for the DataNodes. Starting the multi-node cluster is done in two steps. First, the HDFS daemons are started: the NameNode daemon is started on master, and DataNode are started on all slaves (master and slave). Second, the MapReduce are started: the JobTracker is started on master, and TaskTracker daemons are started on all slaves (master and slave).Running a MapReduce job of the single-node cluster, we will use a larger set of input data so that Hadoop will start several Map and Reduce tasks, and in particular, on *both* master and slave. After all this installation and configuration work, we want to see the job processed by all machines in the cluster.

Previous research results can be used as the example input data for the multi-node cluster setup. We will add four more Project Gutenberg etexts to the initial three documents mentioned in the single-node cluster. All etexts should be in plain text us-ascii encoding. Download these etexts, copy them to HDFS, run the location algorithm example MapReduce job on master, and retrieve the job result from HDFS to local file system. When we want to inspect the job's output data, just retrieve the job result from HDFS to our local file system.

To achieve wide-band spectrum sensing, cooperative spectrum sensing optimization problem is significant for cognitive radios and networks. Cognition, collaboration, and node diversity are the main criteria that can be used to classify CWNs (cognitive wireless networks).These networks consist of two major parts, which are the central cognitive engine and nodes. IEEE 802.22 base station manages a unique feature of distributed sensing. Since large amount of data need storage, we will consider using cloud storage technology to store multi-user cooperative detection location information. In the new era of cloud computing, we will design Hadoop distributed structure used for storage of real-time data from TOA and AOA detection. A cognitive system with multiple users in cooperative spectrum sensing is just like a multi-node Hadoop cluster system. Slave nodes can be regards as cognitive nodes in that Multi-node Hadoop cluster will be empowered the feasibility of designing CRs with sensing capabilities. In the cooperative cognitive network, if primary user can be replaced by mater nodes, the secondary users can be equivalent to slave nodes in the multi-node Hadoop cluster. The optimal cooperative spectrum sensing algorithm can obtain the promising detection performance. We will propose a feasible network sensing and sharing framework among homogeneous networks in collaborative sensing.

5 CONCLUSION

This paper is the first step of an endeavor to embark on a comprehensive study on adaptive blind source separation algorithm for cognitive radio systems. It is important to see several factors that influence the application of adaptive blind source separation algorithm practice in cognitive MIMO radio. Adaptive blind source separation algorithm has many applications, including MIMO systems, electrocardiography, radar signal, aeronautics engine vibration signal etc. My objective is the development of cognitive radio system with adaptive blind source separation algorithm which will aid cognitive users to enhance detection performance in the application of cooperative spectrum sensing.

6 FUTURE WORK

In the CWN (cognitive wireless network) framework, under real network environment (complex wireless channel, different wireless coverage and user location), we will develop a CR system based on existing cooperative spectrum sensing method, combined with the latest adaptive blind channel algorithm and blind source separation algorithm to detect the existence of licensed users and evaluate inference with high accuracy.

Moreover, we will develop a novel real-time database to simulate the workflow and procedure of FCC central database with previous retrieval information from transmitters to make a complete construction of experiential database of physical layer in modular, scalable CR structure. On a further note, test the performance of real-time database according to CR system application requirements.

On the above basis, we will make endeavor to build up a distributed cognitive framework system of cognitive multi-user nodes under homogeneous network spectrum sharing environment.

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