Signal Identification for Cognitive Radio

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***Abstract*— One of the most important aspects of cognitive radio (CR) is that it proposes methodologies to increase current spectrum efficiency. One way is to let the secondary users to unused parts of the spectrum for a given geographical space, at a certain time. This requires certain knowledge on the characteristics of the communications. If the signal types and communication technologies existing in the area are identified, then it will be possible to determine how to let the secondary users communicate through the medium in a safe, reliable way with high quality of service and, without interfering and harming the primary users' communication. Secondly, if the signal type of the primary user is known, alternative methodologies can be applied to allocate the secondary user. For instance, if the primary user's signal has the frequency hopping property, secondary user allocation can be done accordingly. Finally, regulation commissions have restrictions on some of the frequency bands indicating the type of the signal for that band. Intruding signals, which are not expected in the frequency band, can also be identified using signal identification. Several methodologies proposed previously [1], [2] for signal detection under spectrum sensing concept, however the concerns of these methodologies are to detect a signal in a given frequency spectrum but not to identify the signal or communication technology. Within this white paper, application of a tree based algorithm for wireless radio signal identification is introduced. The demonstration setup will be consisting of Anritsu's MT8220A spectrum analyzer and a laptop computer. Signals detected with the spectrum analyzer will be downloaded to the computer and evaluated for identification. Besides, classification of the wireless signals, some other information like carrier information, bandwidth, center frequency and power level, etc. will be given. Some statistical information about the monitored frequency spectrum will also be given.**

I. Description

A. Primary Technical Goals

One of the most important aspects of cognitive radio (CR) is that it proposes methodologies to increase current spectrum efficiency. One way that should be followed for this purpose is let the secondary users occupy the unused parts of the spectrum for a given geographical space. This requires a certain level of knowledge on the characteristics of the communications in the geographical area of interest. If the signal types and communication technologies existing in the area are identified, then it will be possible to determine how to let the secondary users communicate through the medium in a safe, reliable, with high QoS (Quality of Service) and, without harming the primary users' communication. Every wireless communication technology emerges through a series of steps. Mostly starts with the definition of the requirements for the technology, as a project, by a consortium or a group that is constituted by fore coming people, institutions, and companies who have expertise and/or knowledge on the related systems to the proposed technology (for instance, Wideband Code-Division Multiple-Access [W-CDMA] is based on the access technique proposed by ETSI Alpha working group in 1999). Because the channel to the transfer and receive wireless communication signals is our physical environment, characteristics of the signal traveling in the medium is strictly defined through the development of the project. Generally, the process is ended up with the commercialization of the technology, which also brings the solid definitions about the technical aspects such as frequency band requirements, data rates, frame lengths, modulation techniques, coding technologies, multiplexing schemes etc.

The solid definition of the technology, related to the transmitting signal, enables us to infer distinct features of the technology's transmitted signal. The proposed demonstration depends on a tree based algorithm that at a level of distracting signals properties we are able to distinguish the signal from the others. Moreover, it is required that there should be an inference mechanism depending on the common features of the signals. The proposed demonstration setup is running based on the assumption that the expected signal is known and the certain features of the detected signal is compared with what expected, but all kind of signals can be encountered. This forces the core algorithm of the demonstration setup to have common frame to decide the type of the signal. The common frame eliminates other types of signals depending on the expected values of the common features of wireless communication technologies. Finally to assure the match, the unique features of signal - if there is any, must be cross checked with the expected signal. Spectrum sensing concept proposes several signal detection methodologies however, besides the detection of wireless signals; identification of the wireless signals depending on the definitions of the wireless technologies and regulations provides some other information like multiple accessing methods, carrier information, signal bandwidth, center frequency, power level, etc., with some statistical information about the monitored frequency spectrum. These new parameters enhance the spectrum sensing capabilities of cognitive radios form various aspects.

Signal Properties	What is the bandwidth of the detected signal?
	What is the carrier frequency of the detected signal?
	Waveform Info: Does signal belongs to one of the current wireless technologies or not?
	If belongs to a technology which one?
	What is the signal single or multi-carrier signal?
	Power levels of the signals identified

TABLE I
IDENTIFIED SIGNAL PROPERTIES TO BE DISPLAYED

B. Description of Study

The main purpose of this application is to identify wireless signals indoor, outdoor, close or away from the base stations. The solid definition of wireless technologies enables us to infer distinct features related to the transmitted signal. Identification of wireless communications signals depends on the recorded communication data in the environment where secondary user will share with the primary users. This communication data may be consisting of set of complex numbers (I/Q Data) which carry the frequency, phase and amplitude information or just the spectral data that carry information about the power levels of the signals in the frequency spectrum. The application is developed to run on spectral data taking these criteria into consideration: a) computational simplicity, b) limitations of equipments and c) strictly defined regulations in frequency domain for wireless communications systems which constitute main parameters for signal identification.

Therefore the developed software works on spectral data and spectral characteristics of wireless signals are used for wireless signal identification; the decision tree simply constructed depending on signal bandwidth and center frequency and these parameters are estimated without any pre-requisite, expected bandwidth and center frequency (regulated by FCC) information is used only for signal classification. Besides single signal identification, the signal identification application is also capable of identifying multiple signals occupying given frequency spectrum. Information about the carrier numbers of multiple carrier signals (e.g., multi-carrier CDMA) and information about adjacent channel interference are also provided. Developed application also informs the user if the signal has low SNR value or not. Extracted signal information through identification process can be seen in Table I. The setup mainly consists of two parts: Hardware components and software components. Hardware components are: 1-) Hand held spectrum analyzer: BTS Master MT8222A of Anritsu Co. to capture wireless radio signals in the environment 2-) Laptop PC, to record the captured spectral data and to run the identification software 3-) Fire wire cable to connect the laptop computer and hand held spectrum analyzer for immediate data recording. Software components of the demonstration setup are: 1-) the software running on the BTS Master to detect and record wireless radio signals 2-) Master Tools^{TM} software of Anritsu Co. to record the spectral data to the laptop computer and 3-) signal identification software running on laptop computer.

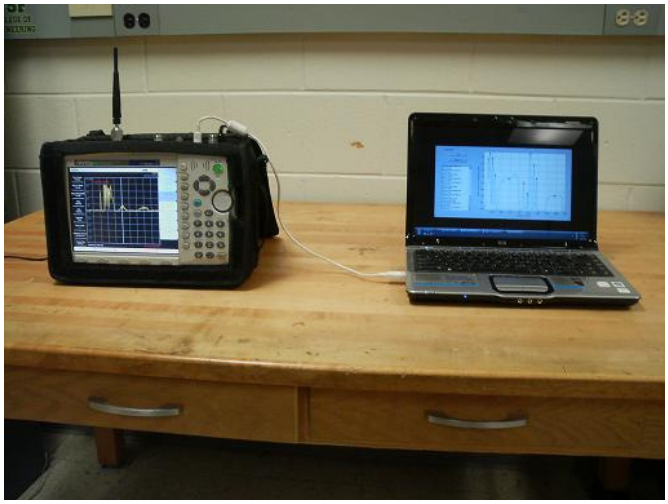

Fig. 1. Demonstration Setup

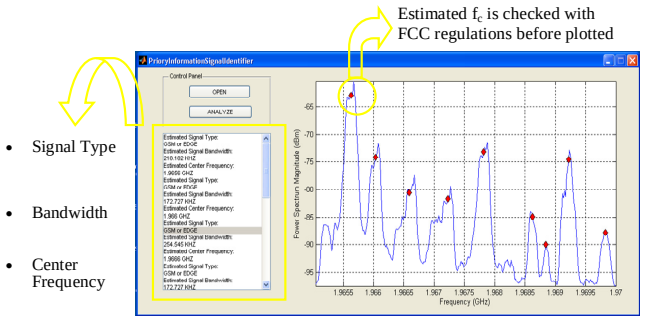

Fig. 2. Description of User Interface

First the BTS Master is connected to the computer via fire wire cable and initialized to the frequency spectrum that the spectral data is expected to be recorded. Then the spectral data is recorded to computer using Master Tools^{TM} software. After the spectral data is recorded, it firstly converted to appropriate format (.xls in this case) and then used as input to the signal identification software. Figure 1 depicts the demonstration setup and Figure 2 and Figure 3 are the description of user interface and example cases.

II. TECHNICAL SIGNIFICANCE

The proposed system invokes a tree based identification algorithm which uses a methodology for signal identification based on some previously determined criteria. As stated in primary technical goals section, the transmitted wireless signals must depend on some regulations and restrictions. These regulations and restrictions determine the criteria and the features of wireless signals. For instance, some parts of the frequency spectrum are reserved for certain types of communication technologies. Besides, the bandwidth occupation for each signal type is also defined by regulations.

Adding up the common distinctive properties of signals, the identification tree can be formed in an appropriate manner.

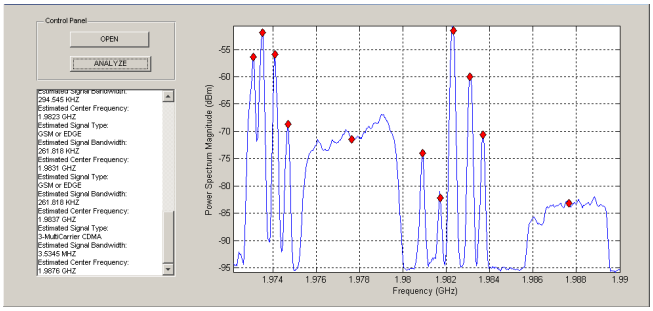

Fig. 3. An Example Case

Sequence of criteria on the decision tree used for signal identification is the most important part to decide. It is required to put a list of features and characteristics of the wireless signals to come up with the criteria that is used for distinguishing the type of the signal. Then, taking the whole set of criteria into consideration, elimination to reach to the criterion to put at the top of the tree is done by finding the criterion which has most different values on the signal types that will be identified. Then, the same sequence is repeated for remaining criteria. If two or more criteria are unique in the same level, the selection is made depending on the period of time that is required to extract the feature from the signal. Shorter extraction time means that the criteria will be located in a higher place on the decision tree.

Finally, the proposed system has the capability of identifying unclassified signals. If a signal could not be set to a place through the branches of the decision tree, the signal will be reevaluated in such a way that the branch of the tree that takes the signal out of the tree will be ignored and estimation technique will be applied to decide the signal type.

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