ISSN: 2321-7782 (Online)
Volume 2, Issue 10, October 2014
International Journal of Advance Research in Computer Science and Management Studies
Research Article / Survey Paper / Case Study
Available online at: www.ijarcsms.com

Smart Ad Hoc Networks: An Evaluation of Performance of Sensing Techniques

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Abstract: An ad hoc network (IEEE 802.11) typically refers to any set of devices where all devices have equal status on a network and are free to associate with any other device in link range. The decentralized nature of wireless ad hoc networks makes them suitable for a variety of applications. Ad hoc networks use an opportunistic communication technology to bid the resources such as channel for connection establishment and communication. The channel access techniques for wired networks like variations of ALOHA and CSMA may not work well with ad hoc networks. Cognitive Network uses Dynamic Channel Sensing and Allocation as the key technology that can be applied for ad hoc network to improve channel utilization. Primary users are allotted licensed channels that can be used at any time, where secondary users (SU) can bid for the free channels available. It searches for available bands by a sensing technology for unlicensed secondary users (SUs). When the licensed primary user (PU) is not using the channel bands, they are considered available and could be allocated to unlicensed SUs. Whenever the PU is present in the network, the SU will immediately release the licensed bands because the PU has an exclusive privilege to use them. Sensing is one of the most important functions in ad hoc applications. It involves the detection of primary user (PU) transmissions on a pre assigned channel. This paper evaluates two different dynamic channel sensing techniques in ad hoc networks. Simulation results show that cyclostationary detector performs better than energy detector especially at low SNR values.

I. INTRODUCTION

Networks can be classified into two major heads- wired and wireless networks. Ethernet (standardized in 1983 as IEEE 802.3) has largely replaced competing wired LAN technologies such as token ring, FDDI, and ARCNET. A wired network uses a physical medium for communication establishment. In most of the emerging trends wired networks are replaced by wireless networks so that a guided medium is not required for communication. A wireless network is any type of network that uses wireless data connections for communication between network nodes. Wireless networking is a method by which homes, communication networks and enterprise installations avoid the costly process of introducing cables into a building or as a connection between various equipment locations.

An ad hoc network often refers to a mode of operation of IEEE 802.11 wireless networks. It also refers to a network device's ability to maintain link status information for any number of devices in a 1-link (aka"hop") range, and thus, this is most often a Layer 2 activity. Because this is only a Layer 2 activity, ad hoc networks alone may not support a routable IP network environment without additional Layer 2 or Layer 3 capabilities.

In ad hoc networks, frequency is a limited resource[1]. Moreover, due to fixed channel allocation scheme its utilization is poor making the scarcity more severe. In accordance to a report by Spectrum Policy Task Force of FCC[6], the channel is under or scarcely utilized and this situation is due to the static allocation of the channel. Thus, to overcome the channel allocation deficiencies and the inefficient utilization of the allocated frequencies, it is necessary to introduce new communication models through which frequency bands can be better utilized, whenever the white space hole is available.

Resolving this problem, the idea of Dynamic Channel Allocation (DCA) policy has been developed [2]. DCA arises as a tempting solution to the channel congestion problem by introducing opportunistic usage of the frequency bands that are not fully occupied by licensed users. DCA is an exciting promising technology which not only has the potential of dealing with the inflexible prerequisites but also the scarcity of the channel usage. Such an innovative and transforming technology presents an exemplar change in the design of ad hoc systems, as it allows the efficient utilization of the channel by transforming the capability to dispersed nodes for channel sensing, active channel sharing and self adaptation procedure. To effectively implement the concept of dynamic allocation of channels in ad hoc networking applications, the system need the capability to perform certain functions such as opportunistic channel sensing, making decision on whether the channel is free or available for communication, channel sharing, and channel mobility.

An ad hoc user sequentially senses the channel and constructs an available pool of channels consisting of all the discovered channel holes in the channel sensing stage, and selects a channel from the available pool for its own transmission in the decision stage. In order to enhance the channel capacity, the ad hoc user may share the available channel with other ad hoc users via an appropriate channel sharing policy as long as channel sharing does not cause transmission collisions [3]. Moreover, the ad hoc user must evacuate its occupied channel when it is required by Pus according to a channel mobility policy to guarantee the priority of the PUs and protect PU transmissions .By making use of these four functions, ad hoc users can opportunistically utilize the unused licensed channel bands for their own communications.

The challenge is in the identification and detection of primary user signals amidst harsh and noisy environments. In this context, speed and accuracy of measurement are the main metrics to determine the suitable channel sensing technique for ad hoc networks. Speed and accuracy are important to answer the questions of which band is occupied and what instance. Accuracy of the estimation depends on channel resolution, bias or leakage and variance of the estimated power. Greater the channel resolution, more accurate the estimated power in each band. The bias or leakage is related to the side lobe level. A high side lobe level will reduce the accuracy of power estimated causing a spillover into neighbouring frequencies. Meanwhile, variance of the estimate relates to the variations in the power estimated in a certain channel band.

This paper discusses and evaluates the performance of two important channel sensing techniques termed as energy detection technique and cyclostationary detection technique. The section II describes general aspects of channel sensing while section III and IV discusses about energy detector and cyclostationary detector in detail. Simulation results are presented in section V.

II. Channel Sensing in Ad Hoc Networks

Channel sensing is based on a well known technique called signal detection. In a nutshell, signal detection can be described as a method for identifying the presence of a signal in a noisy environment. Signal detection has been throughly studied for radar purposes since the fifties. Analytically, signal detection can be reduced to a simple identification problem, formalized as a hypothesis test [5]:

We can dene for the possible cases for the dectected signal.

(1) Declaring H1 under H1 hypothesis which leads to probability of detection.(Pd)

(2) Declaring H0 under H1 hypothesis which leads to probability of Miss Detection.(Pm)

(3) Declaring H1 under H0 hypothesis which leads to Probability of False Alarm(Pfa)

(4) Declaring H0 under HO hypothesis.

Sensing spectrum is the most important factor of smart network, which is important step that needs to be performed for communication to take place. A number of techniques have been developed for detecting whether the primary user is present in a particular frequency band of the spectrum. Some particular characteristics of the signal to identify the signal even its type or some approaches use the signal energy. Some of the most common schemes employed for Spectrum Sensing are Energy Detection, Cyclostationary Feature Detector and Matched Filter Detection.

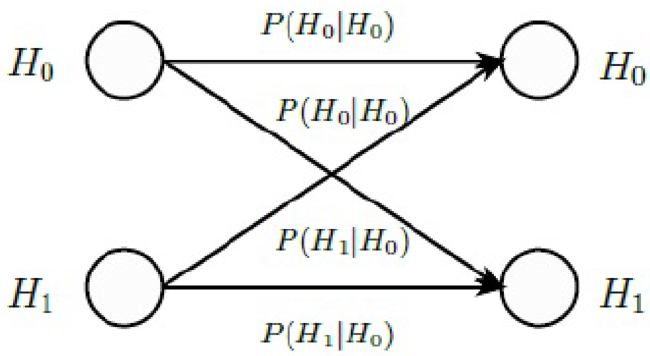

Fig 1. Channel Sensing Hypothesis

Among the above three methods energy detection is popular till now, but the major problem with energy detection method is that the poor performance under low SNR conditions and no proper difference between primary users and noise. Rather the MF maximizes the SNR the electromagnetic radio spectrum we have is a limited natural resource and getting crowded day by day due to increase in wireless devices and apps. Because of the static allocation of the spectrum it has been found that the allocated spectrum is underutilised. Also, the conventional approach to spectrum management is very easy in the sense that each wireless operator is assigned an exclusive license to operate in a certain frequency spectrum. With most of the useful radio spectrum already allocated, so it is difficult to find vacant bands to either to enhance existing ones or to encourage new service. In order to overcome this situation, we come up with a means for developed utilization of the spectrum creating opportunities for dynamic spectrum access.

III. Energy Detector

The implementation of energy detector is illustrated in the following figure. In this technique receiver does not have much information about the PU, only the value of white gaussian noise is needed to be known apriori to fix the threshold . Energy detection technique is simple and can be implemented efficiently because the receiver does not necessitate any prior information to detect the PU signal. The energy of the received signal in the specified band is compared to a pre-defined threshold. This comparison is used to decide the presence or absence of the PU signal. The threshold value can set to be fixed or variable, based on channel conditions [5].

Energy Detection is a non-coherent detection [6], where prior knowledge of pilot data is not required. Let us assume that the received signal has the following simple form.

$$y(n) = s(n) + w(n)$$

Where w[n] is additive white gaussian noise and s[n] is user's signal.

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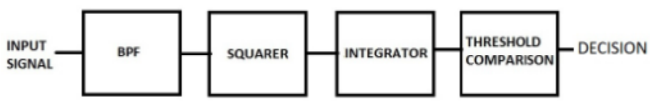


Fig 2 Energy Detecter

The decision metric M for energy detector is

$$M = \sum_{n=0}^{N} |y(n)^2|$$

where N is size of observation vector.The white noise I smodelled as zero mean gaussian random variable with variance σ^2_w wand signal is modelled as zero mean gaussian with variance $\sigma^2{}_s$ [8] We approximate the decision metric follows chi-square distribution with 2N degrees of freedom χ^2_{2N} and hence is modelled as

The signal is detected by comparing the decision metric with threshold (λ) which is kept by considering noise varianceand probabilities of false alarm.

$$Pfa = Q\left(\frac{\lambda - \sigma_w^2 N}{\sigma_w^2\sqrt{2N}}\right)$$

Where Q is given by

$$Q(x) = \frac{1}{2} erfc\left(\frac{x}{\sqrt{2}}\right)$$

Where erfc is the complementary error function given by

$$erfc(x) = \frac{2}{\sqrt{\pi}} \int_x^{\infty} e^{-t^2}\, dt$$

Energy detection technique has few limitations like, at low SNR does not perform well and cannot distinguish between signal and interference. Further, the performance of energy detection suffers in the case when power of the noise is unknown, decided the value of threshold based on noise power which varies continuously depending upon the temperature ,interference and other effects, so fixed threshold may create false alarm and miss detection[7]. Cyclostionary detection method overcomes some of these disadvantages.

IV. Cyclostationary Detector

Cyclostationary feature detection needs high computation complexity, the best detection point is determined through simulation analysis on different detection points, and then we intend combination detection method using multiple detection points to obtain better performance. Output validate the effectiveness of the suggested method Cyclostationary feature detection can be able to have high detection probability under low SNR, actually, it requires high computation complexity. When a transmitted signal is modulated with a sinusoidal carrier, cyclic prefixes (as in OFDM), code or hopping sequences (as in CDMA); cyclostationarity is induced i.e. mean, auto correlationshow periodic behavior. This feature is exploited in a Cyclostationary Feature Detector that measures a signal property called Spectral Correlation Function.

A signal x(t) is dened to be second order cyclostationary(in the wide sense) if its autocorrelation function, is periodic in time t for each time lag _ . These periodicities are examined using the cyclic autocorrelation function (CAF).

$$R_x(t,\tau) = E\{x(t+\frac{\tau}{2})x(t-\frac{\tau}{2})\} \qquad (5)$$

$$R_x^\alpha(\tau) = \lim_{\Delta t \to \infty} \frac{1}{\Delta t} \int_{\frac{-\Delta t}{2}}^{\frac{\Delta t}{2}} x(t+\frac{\tau}{2})x(t-\frac{\tau}{2})e^{-i2\pi\alpha t}\, dt \quad (6)$$

For cyclic frequency _ and measurement interval _t. Secondorder cyclostationarity gives rise to specic correlation patterns which occur in the spectrum of the signal. These patterns may be used equivalently to examine the cyclostationarity of the signal and may be analysed using the spectral correlation function (SCF).

$$S_x^\alpha(f) = \int_{-\infty}^{\infty} R_x^\alpha(\tau)e^{-i2\pi f\tau}\, d\tau \quad (7)$$

For Cyclostationary feature detector, assuming H0 as chisquare distribution of samples, probability of false alarm is given by

$$Pfa = \frac{\Gamma(\frac{\lambda}{2}, N)}{\Gamma(N)} \quad (8)$$

It follows that signals with overlapping features in the power spectrum can have non-overlapping features in the cyclic spectrum. Stationary noise such as Gaussian noise has no features at any cyclic frequency other than at zero. This means that a cyclic spectral analysis at a non-zero cyclic frequency of a signal of interest reveals its cyclic features without any component due to the noise. In fact, the only noise will be due to interference signals having the exact same cyclic frequencies and measurement noise which reduces as observation time increases. Here, we assume that the characteristics of licensed users signals are known and detect these signals under specific points [10].

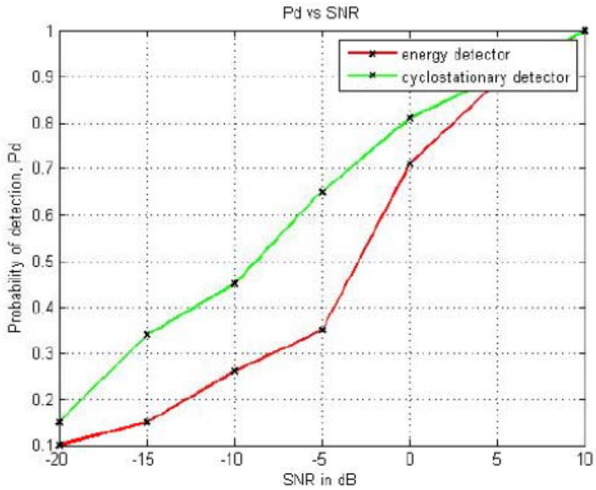
The disadvantage with cyclostationary spectrum sensing is its high complexity which results in high cost.

V. Simulation Results

The energy detector is implemented with the threshold set on the basis of probability of false alarm. Additive white gaussian noise is added to the primary signal. The received signal was passed through a bandpass filter corresponding to the required band of which occupancy information is required. The noise variance (power) was calculated and threshold is fixed. The samples were squared and the sum of that squares are taken. The sum is averaged and the value is taken as metric which is compared with the threshold for final decision. The probability of detection was plotted against probability of false alarm keeping SNR constant at different levels. Figure shows that as SNR increases, the detection probability at a particular false alarm increases.

In order to implement cyclostationary detector, power spectral density is estimated after finding the autocorrelation. The estimate is compared with a threshold to determine the presence or absence of signal.

The performance of energy detector and cyclostationary detector is evaluated by varying SNR values within 20dB to 10dB range. Figure shows that cyclostationary detector performance is better than its counterpart especially at low SNR values. However both the techniques appear to be converging at high SNR values.



VI. CONCLUSION

Opportunistic channel sensing makes ad hoc networks smart and intelligent. The performance of energy detector and cyclostationary detector is evaluated in presence of noise. Probability of detection is plotted against SNR. It is found that cyclostationary detector performs better than energy detector especially at low SNR. Energy detection has the advantage that no prior information about the PU is required it does not perform well at low SNR.

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