International Journal of
Science and Engineering Investigations vol. 1, issue 9, October 2012
ISSN: 2251-8843

Analysis of Environmental Parameters which Affect the Performance of Wireless Communication System: Cognitive Radio

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Abstract-Nowadays, the growing demand of wireless applications has been shown that spectrum shortage increased due to the evolution of the radio communication. As the available radio spectrum which is limited and precious resource so it's proper and better utilization is necessity. Resent survey found that there are many areas of the radio spectrum that are occupied by authorized user, which are not fully utilized. Cognitive radio is a talented technology which provides a novel way to improve utilisation efficiency of available electromagnetic spectrum. It proposed as a way to reuse this under-utilised spectrum in an opportunistic and non-interfering basis. But there are many operating parameters which affect the performance and efficiency of the wireless system either on small or large scale. In this paper, we have studied and understand environmental operating parameters and their affect.

Keywords- *Cognitive Radio, Spectrum, Parameters, Path Loss, BER, SNR, Battery Life, Power Consumption*

I. Introduction

The available electromagnetic radio spectrum is a limited natural resource and getting jam-packed day by day due to increase in wireless devices and applications. It has been also found that the allocated spectrum is underutilised because of the static allocation of the spectrum. Also, the conventional approach to spectrum management is very inflexible in the sense that each wireless operator is assigned an exclusive license to operate in a certain frequency band. And, with most of the useful radio spectrum already allocated, it is difficult to find vacant bands to either deploy new services or to enhance existing ones. In order to overcome this situation, we need to come up with a means for improved utilization of the spectrum creating opportunities for dynamic spectrum access.

The issue of spectrum underutilization in wireless communication can be solved in a better way using Cognitive radio (CR) technology. A Radio in which communications systems are aware of their environment and internal state, and can make decisions about their radio operating behaviour based on that information and predefined objectives. The environmental information may or may not include location information related to communication systems [1]. Fig. 1 shows the basic concept or cycle of cognitive radio. Cognitive radios are designed in order to provide highly reliable communication for all users of the network, wherever and whenever needed and to facilitate effective utilization of the radio spectrum. The regulatory bodies are trying to search a method where secondary (unlicensed) systems are allowed to opportunistically utilize the unused primary (licensed) bands commonly referred to as white spaces. Cognitive radio can change its transmitter parameters based on interaction with environment in which it operates.

The cognitive radio can adapt for different task such as spectrum regulator, network operator and user objectives. The spectrum regulator has generally allocated all the spectrum there is to existing users, and now finds it difficult to provide spectrum for new applications and users.

Cognitive radio includes four main functional blocks: spectrum sensing, spectrum management, spectrum sharing and spectrum mobility. Spectrum sensing aims to determine spectrum availability and the presence of the licensed users (primary users). Spectrum management is to predict how long the spectrum holes are likely to remain available for use to the unlicensed users (secondary users). Spectrum sharing is to distribute the spectrum holes fairly among the secondary users bearing in mind usage cost. Spectrum mobility is to maintain seamless communication requirements during the transition to better spectrum.

Among all other functions, Spectrum sensing is believed as the most crucial task to establish cognitive radio networks. The various spectrum sensing techniques includes primary transmitter detection, cooperative detection and interference detection.

II. Cognitive Radio Parameters

A primary feature of a cognitive radio is its ability to adapt to the surrounding environment. Cognitive radios become possible when the components within the radio permit the modification of the control parameters. Frequency, instantaneous bandwidth, modulation scheme, error-correction coding, channel mitigation strategies, system timing, data rate

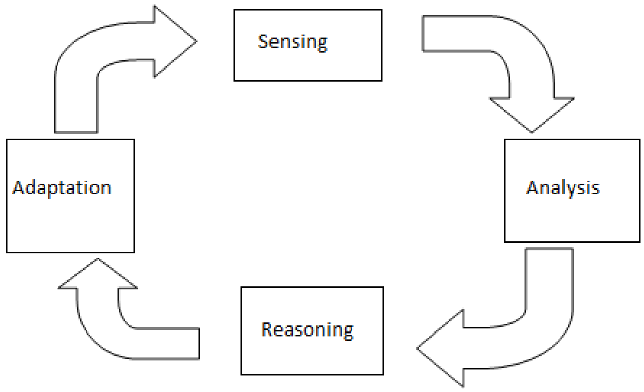

Figure 1. Cognitive Radio Cycle [5, 10]

(baud timing), transmit power, and even filtering characteristics are operating parameters that may be adapted.

There are many operating parameters which are used or adapted by cognitive radio for proper functioning and performance. The main classification is: Environmental Parameters and Transmission Parameters

A. Environmental Parameters

The Environmental variables inform the system of the characteristics and features of the surrounding environment. This information is used to aid the cognitive controller in making decisions. These variables are primarily used as inputs to some methods or technique or algorithm, so it is essential to accurately estimate them. These characteristics include: internal information acquired using sensors within the cognitive radio and external information from local cognitive radios within the same network.

We consider an example for explanations that how a cognitive radio analyze and adapt different operating parameters for better result. A cognitive radio engine and a taxi driver have similar and comparative environmental parameters for proper functioning. There is an interesting analogy between these two intelligent agents.

The environmental capabilities of Cognitive Radio are:

- Senses, and is aware of, its operational radio environment
- Can dynamically and autonomously adjust its operating parameters accordingly
- Learns from previous experiences
- Deals with situations not planned at the time of initial design

Similarly, the environmental capabilities of Taxi Driver are:

- Senses, and is aware of, the driving environment
- Can dynamically adjust the driving operation accordingly
- Learns from previous experiences

Deals with situations not planned at the time of initially learning to drive.

It is apparent that both intelligent agents observe the environment and become aware of their situations; make in situations decisions according to their observations, anticipations, sensing, analyzing and experiences; and then execute intelligent adaptations to reach their goals or destinations.

a) Path Loss

The Amount of signal degradation lost due to the channel path characteristics. In other words it is the reduction in power density (attenuation) of an electromagnetic wave as it propagates through space. It is also known as path attenuation. It is a major component in the analysis and design of the link budget of a telecommunication system. This term is commonly used in wireless communications and signal propagation. Fig. 2 and 3 shows the path loss due to many reasons reflection, refraction and diffraction.

TABLE I. COMPARISON OF TWO INTELLIGENT AGENTS TAXI DRIVER AND CR ENGINE

Agent Type	**Environment**	**Performance Measure**	**Sensors**	**Actuators**
Taxi Driver	Roads,Climate, Traffic, Customers, Pedestrians etc	Safe, Fast, Legal, Comfortable trip, Maximize Profits, Minimize collisions etc	Cameras, Sonar, Speedometer, GPS, Engine sensors, accelerometer etc.	Steering, Accelerator, Brake, Signal, Display, Horn etc.
CR Engine	Spectrum Information, SU, PU, Jammer, RF Noise, Interference etc.	Spectrum utilization, fast, reliable, legal, cost-efficient, minimize interference etc.	GPS, Antenna, BER, Quality of service etc	Transmission power control, MAC, etc.

CR= Cognitive Radio, SU= Secondary User, PU= Primary User, BER= Bit Error Rate, GPS= Global Positioning System, MAC= Medium Access Control

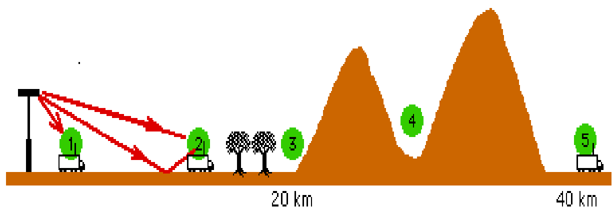

Figure 2. Path Loss due to Reflection, Refraction, Diffraction [7]

Path loss may be due to many factors such as:

- Free-space loss
- Diffraction
- Reflection
- Refraction
- Aperture-medium coupling
- Absorption
- Terrain contours
- Environment (urban or rural, vegetation and foliage etc.)
- Propagation medium (dry or moist air)
- Distance between the transmitter and the receiver in the system
- Height and location of antennas.

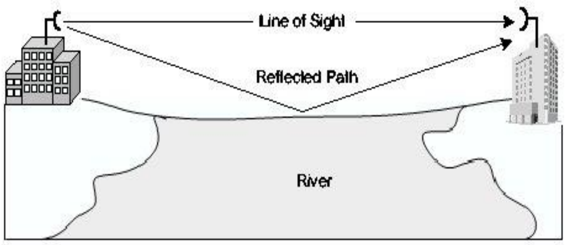

Figure 3. Path Loss due to Reflection [7]

Path loss normally includes propagation losses caused by the natural expansion of the radio wave front in free space (which usually takes the shape of an ever-increasing sphere), absorption losses (sometimes called penetration losses), when the signal passes through media not transparent to electromagnetic waves, diffraction losses when part of the radio wave front is obstructed by an opaque obstacle, and losses caused by other phenomena.

Path loss in dB:

$$L = 20\log_{10}\left(\frac{4\pi d}{\lambda}\right)$$

Where L is the path loss in decibels, λ is the wavelength and d is the transmitter-receiver distance in the same units as the wavelength.

b) Bit-Error- Rate (BER)

In digital transmission, the number of bit errors is the number of received bits of a data stream over a communication channel that has been altered due to noise, interference, distortion or bit synchronization errors in the system. The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a considered time interval. In other words BER is the percentage of bits that have errors relative to the total number of transmitted bits. This parameter is denoted by the symbol of BER.

BER is a unit less performance measure, often expressed as a percentage (%). The bit error probability is the expectation value of the BER. The BER can be considered as an approximate estimate of the bit error probability. This estimate is accurate for a long time interval and a high number of bit errors.

Example: Let us assume that there is 10 bit sequence which is transmitted from transmitter side:

1 1 1 0 0 0 1 1 1 0

we get the following received bit sequence at receiver side:

1 0 1 0 1 0 1 1 0 0

Then the number of bit errors (the underlined bits) is in this case 3. So the bit error rate or ratio is given by:

BER= (No. of incorrect bits in the bit sequence)/ (Total no. of bits are transmitted)

$$BER = \left(\frac{3}{10}\right)$$

$$= 0.3$$

So the bit error rate is .3 or 30% of total bits which are transmitted from transmitter to the receiver in the communication system.

In a communication system, the receiver side BER may be affected by:

- Transmission channel noise
- Distortion
- Bit synchronization problems
- Interference
- Attenuation
- Wireless multipath fading
- The BER can be improved in several ways by:
- Choosing a strong signal strength (unless this causes cross-talk and more bit errors)
- Choosing a slow and robust modulation scheme or line coding scheme
- Applying channel coding schemes such as redundant forward error correction codes.
- Reducing interference and attenuation

c) Noise Power

In telecommunication system, the noise power means from the following:

- Measured total noise per bandwidth unit at the input or output of a device when the signal is not present.

- Power generated by a random electromagnetic process.
- Interfering and unwanted power in an electrical device or system.

In communication systems, the noise is an error or undesired random disturbance of a useful information signal, introduced before or after the detector and decoder. It is a summation of unwanted or disturbing energy from natural and sometimes man-made sources. Noise is, however, typically distinguished from interference, for example in the signal-to-noise ratio (SNR), signal-to-interference ratio (SIR) and signal-to-noise plus interference ratio (SNIR) measures. It is measured in decibels and represented by the symbol of N.

d) Battery Life

The estimated energy left in batteries is called battery life. In electricity, a battery is a device consisting of one or more electrochemical cells that convert stored chemical energy into electrical energy. There are two types of batteries: primary batteries (disposable batteries), which are designed to be used once and discarded, and secondary batteries (rechargeable batteries), which are designed to be recharged and used multiple times.

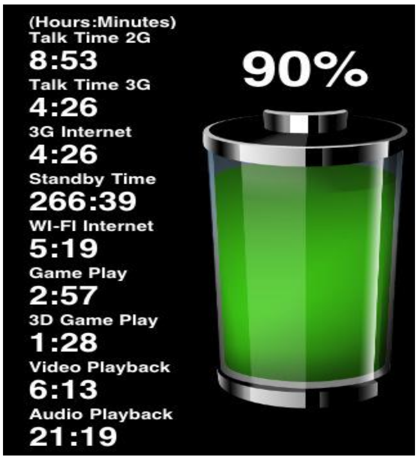

Figure 4. Battery Life [7]

Batteries come in many sizes, from miniature cells used to power hearing aids and wristwatches to battery banks the size of rooms that provide standby power for telephone exchanges and computer data centres. The fig. 4 gives the information that if a battery has the capacity of 90% than it can be used for many tasks with their time period. For 21 hours and 19 minutes if we listen the audio songs. It can be used for 4 hours and 26 min on 3G internet etc.

In a modern battery-powered communications system design, the following points are considered:

- Number of battery cells
- Voltage change from charge to discharge
- Finding components with adequate performance at an operating voltage that fits within the available supply range
- Minimizing the current drain

Finally, regulated voltages must be supplied to critical sections of the circuit; and the system must turn components off and on to reduce the total energy used and maximize battery life.

e) Signal-to-Noise Ratio (SNR)

Signal-to-noise ratio is a measure used in science and engineering to quantify how much a signal has been corrupted by noise. It is defined as the ratio of signal power to the noise power corrupting the signal. A ratio higher than 1:1 indicates more signal than noise. While SNR is commonly quoted for electrical signals, it can be applied to any form of signal. In other words SNR is the ratio of the signal power to the noise power. It is denoted by the symbol of SNR. Fig. 5 gives the interpretation of signal and noise. The noise makes the signal weak and creates the interference.

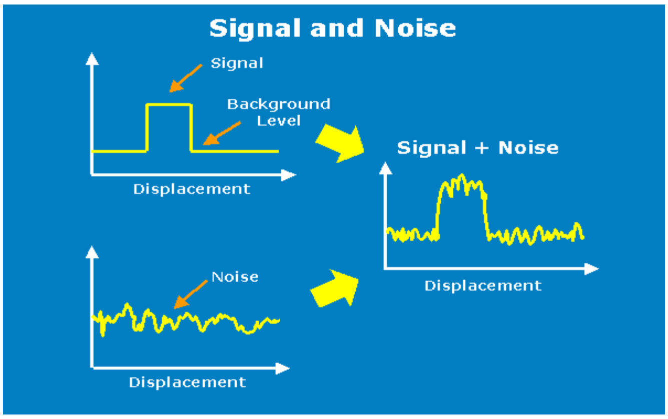

Figure 5. Signal and Noise [7]

Signal-to-noise ratio is defined as the power ratio between a signal (meaningful information) and the background noise (unwanted signal):

$$SNR = \frac{P_{signal}}{P_{noise}}$$

where *P* is average power.

f) Power Consumption

The energy consumption has recently become an important consideration for wireless communication protocols. The shrinking size and increasing density of next-generation wireless devices imply reduced battery capacities, meaning that emerging wireless systems must use energy more efficiently than ever before. The energy-intensive nature of wireless communication has recently stimulated protocol and MAC developments that explicitly seek to reduce the energy consumed by the communication subsystem.

Saving energy is a very critical issue in wireless sensor networks (WSNs) since sensor nodes are typically powered by batteries with a limited capacity. Since the radio is the main cause of power consumption in a sensor node, transmission/reception of data should be limited as much as possible. The power consumption of current configuration should be analysed because to remove the possibilities of the failure of the system due to power.

g) Spectrum Information

As this is well known that, light, colors, AM and FM radio and electronic devices make use of the electromagnetic spectrum. The frequencies of the radio spectrum that are available for use for communication are treated as a public resource and are regulated by national organizations such as the Federal Communications Commission in the USA. This determines which frequency ranges can be used for what purpose and by whom.

Spectrum access is primarily limited by regulatory constraints, and recent measurements show that spectrum occupancy is low when examined as a function of frequency, time, and space. Cognitive Radios may sense the local spectrum utilization either through a dedicated sensor or using a configured SDR receiver channel. Using this information it may create increased spectrum access opportunities.

One of the primary considerations for such a cognitive application is non-interference with other spectral uses. If the regulatory body is allowing cognitive radios to utilize the unoccupied "white space," increased spectral access can be achieved.

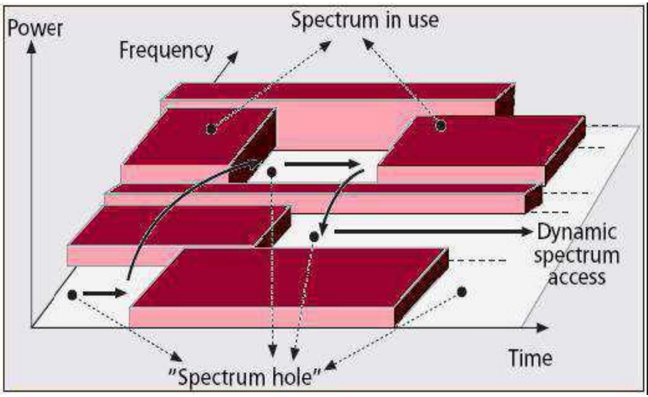

Figure 6. Spectrum occupancy Information [8]

The CR can examine the signals and may extract detailed information regarding the use. Fig. 6 shows the spectrum is occupied or not by using different techniques. By estimating the other uses and monitoring for interference, two CR may get-together at an unoccupied "channel" and communicate. Wireless communication spans the spectrum from 9 kHz to 300 GHz.

III. Conclusion

In a wireless communications environment, the radio system may want to achieve several desirable objectives such as: Minimize Bit-Error-Rate, Improve the overall BER of the transmission environment, Increase the overall data throughput transmitted by the radio, Decrease the amount of power consumed by the system and also reduce the radios interference contributions. Hence by considering the environmental parameters effectively and efficiently, the performance of the communicating system can be increased.

Acknowledgment

We would like to express our gratitude to Mrs. Santosh Choudhary Associate professor and Assistant professors Tanushree Chauhan, Gosiya Nasreen, Neeta Sen, Konika Sharma, Kuldeep Swarnkar, Nikita Jain, Deepika Sahu and other members of CSE and computer application Dept. for their guidance and contributions. We would also like to thank our friends Manish Choubisa, Kamal Kant Hiran, Akhilesh Saini for the valuable information they provided us. We would like to thank our family members for their love and care. At last but not the least we would like to thank everyone, just everyone!

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