Spectrum Sensing in ISM Band Using Cognitive Radio

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Abstract

Wireless communication is one of the essential parts of contemporary technology. Although, the popularity of the wireless communication is growing day by day, the quality and data transfer rate is limited and wireless spectrum needs to be focused more clearly. The telecommunication workers and internet service providers are facing problem of the wireless spectrum in case of the large amount of data transfer rate with respective to the need of customer. The Cognitive Radio (CR) shortage has gradually inclined towards progress. CR ensures the efficient usage of under-utilized spectrum. Spectrum sensing performs the key functionality in identifying the free gaps in the spectrum. The aim of this research is to validate the under-utilization of unlicensed ISM band in the vicinity of Nawabshah. A spectrum analyzer is used to collect the raw signal data. The study of the free space in the spectrum is done with different techniques such as cycle stationary, feature detection, wavelet based edge detection and energy detection. The performance of all three techniques are compared and the optimum technique is suggested. Our in-depth analysis presented in this paper provides a critical review of the spectrum sensing methods and contract spectrum sensing.

Keywords—Spectrum sensing, Data Acquisition, Probability.

1 Introduction

Wireless communication spectrum needs to be utilized as efficiently as possible in order to cope with the modern challenges. We have to interrupt down the spectrum carefully and reason assumptions in order to assist us in developing spectrum operation prepare mo e frequency spectrum are widely used in telecommunication system for the efficient and rapid communication over network. This is important to make standard frequency range of spectrum that is 30 Hz to 300 GHz. In telecommunication system, a spectrum is a concept which is used to refer to some time frequency band. It is actually a specific frequency band which is called spectrum. This spectrum is divided into low frequency rang and high frequency range. However, each frequency band has certain boundaries usually called upper and lower limit.

An electromagnetic radio spectrum can be reflected as a feature asset. Radio spectrum is deployed with the help of different exceptional receivers and transmitters which are operated through means of numerous controlling government and agencies. Cognitive Radio (CR) is considered one of the candidate solutions for the spectrum practice problem at some distance like spectrum sensing strategies. Spectrum sensing takes dual method. Initially, accessible spectrum is sensing then its miles allocated to non-adjusted clients for effective use. The underutilized frequency sub-bands are generally referred to as "white spaces" or "spectrum holes". Spectrum gap could be characterized as a band of frequencies. It can not be used through an overhauled patron at a specific period and particular geographical position. There are a few specific measurements of spectrum detecting inclusive of code, attitude, space (geographical place), time and frequency. Significant number of spectrum sensing procedures exist to discover spectrum holes. The concept of basic spectrum frequency management and finding holes in spectrum is one crucial part of research.

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The study presented in this paper shows the use of spectrum sensing by electricity detection and wavelet transformation set of rules utilizing GNU Radio and GW-Instek Spectrum Analyzer with the aid of frequency and time measurements. The most capable method of analysis of all reachable spectrum sensing methods is displayed. Spectrum sensing of the CR is deliberated as the high component of spectrum. The difficulties in the frequency spectrum can be found via unused frequency bands.

2 Motivation

Cognitive radio is the developing innovation for supporting element range access. To identify the closeness of the primary clients in an authorized range is considered as an important issue for CR. In Cognitive radio, execution of the range detecting relies upon the detecting time and the combination plan. These plans are utilized when agreeable detecting is connected. In this proposition, range detecting systems, for example, vitality identification, coordinated separating location, cyclo-stationary recognition and waveform based detecting techniques are examined. Vitality recognition is most generally utilized as a part of neighborhood range detecting. This case study provides an outline about examination between various strategies. It also highlights the better technique for range detecting.

3 Related Work

The study of software defined radio and CR technology is an important aspect of research community. For instance, GNU radio is focused in terms of the CR [8]. Relevant literature demonstrates a number of techniques addressing the diverse parts of spectrum sensing and CR. Majority of continuous level regulated discussion is focused on the appropriate spectrum sensing. Procedures for CR, channel distribution and transmission power taking care of Physical (PHY) and MAC layer usage [9]. The important factor for any spectrum is to detect the underutilized bandwidth [10]. Consequently, a number of phases are accessible for the usage of CR as a SDR. One of them is Open source (SCA) usage Embedded (OSSIE) in [11]. The OSSIE supports the open source facility for the radio suite which can support SDR and CR operations. Different stages incorporate large power SDR (HPSDR) [25] and Flex Radio [26]. Nearby few distinct strategies which can be reflected as contrasting option towards range detecting. Among these strategies is cognizance empowering pilot channel (CPC) [6]. As indicated by CPC, the database of authentic manipulators to identify and use on the screen recognition spectrum is created by making next channel and spreading spectrum opportunities in auspicious way. Be that as it may, this results in extra infrastructure and utilization of alternative network referred to as CPC. That is not a better way to deal with spectrum shortage, as this results in additional overhead in radio supply.

4 System Methodology

In this study, quantitative and qualitative experimental and analysis procedures have been used to investigate the research problem in concern. We started work with survey literature of CR. Initially, the detailed study of cognitive radio pattern was conducted. Subsequently, after getting familiar with working values of CRs, we narrowed down the possibility to more precise area of concern, i.e. spectrum sensing. Spectrum sensing was selected for the reason of its vital role in making CR feasible. Additionally, sophisticated examination was conceded out on spectrum sensing to acquire information about existing state-of-the-art research in the capacity of spectrum sensing. On the basis of the information collected over a period of time, we demarcated research questions of our study. We prepared deductive and statistical hypothesis to address the research question. To reinforce our defined hypothesis and to inspire our answer, we first assumed that there are some white spaces in congested 2.4 GHz ISM band. The most crucial part of any CR is to discover underutilized bandwidth in obtainable radio spectrum in an efficient way. The underutilized bandwidth or spectrum holes should be created with least data about spectrum as it is challenging to contemplate entire measurements of radio spectrum, however, observing spectrum for spectrum holes. Research about entire available spectrum sensing practices was conceded out in terms of qualitative analysis. For experimental and quantitative exploration, we tried a GW Instek Spectrum Analyzer for sensing purpose and MATLAB for data analysis. Firstly, we collected signal information using Spectrum Analyzer for 2.4GHz ISM band. After collecting the real time data, we employed algorithms over MATLAB and collected outcomes in the form of raw data comprising of FFT values of spectrum in the order as shown in Figure 1. The information collected in real time was prescribed in tables so that outcomes could be observed in graphical manner. One of the key chores was to show the data in a graphical way so that all three measurements, i.e., gain, time, frequency could be taken under consideration at the same interval. For this persistence, we developed spectrograms and 3D-plots to acquire reasonable appreciative results and to confirm outcomes in contrast to hypothesis in

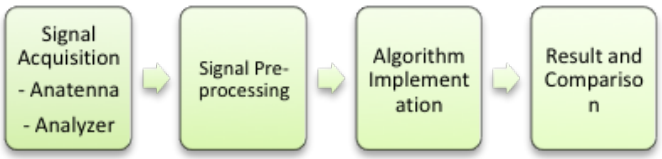

Fig. 1: Research Methodology

concern. In Figure 1, an antenna is a device (normally steel) for sending or receiving electromagnetic waves. In transmission, a radio transmitter applies a radio frequency to the terminals of the antenna and then the antenna radiates the strength from the antenna as electromagnetic waves. In reception, an antenna intercepts some of the electricity of an electromagnetic wave to provide a radio frequency at its terminals that is implemented to a receiver a good way to be amplified and demodulated. In some cases, the equal antenna can be used for each transmitting and receiving. A 2.4 GHz Antenna series covers 2300-2600 MHz band applications for IEEE 802.16 and 802.11 [12][13]. An analyzer is a device that analyses the given data. It examines in element the shape of the given facts and tries to discover styles and relationships between components of the records. An analyzer may be a piece of hardware or a software program application going for walks on a computer. A spectrum (plural spectra or spectrums) is a circumstance that is not always confined to a selected set of values but can vary infinitely within a continuum [14]. The phrase was first used scientifically inside the discipline of optics to explain the rainbow of colors in visible mild when separated the use of a prism. It miles the procedure of sampling signals that degree actual global physical conditions and converting the ensuing samples into digital numeric values that can be manipulated with the aid of a computer. The records acquisition systems, abbreviated as DAS or DAQ, commonly convert analog wave forms into virtual values for processing. The components of statistics acquisition systems encompass Sensors to transform bodily parameters to electric alerts, sign conditioning circuitry to transform sensor signals right into a shape that can be transformed to digital values, and analog-to-virtual converters to convert conditioned sensor indicators to digital values. Statistics acquisition applications are generally controlled by means of software applications advanced in the use of numerous popular reason programming languages including meeting, primary, C, C++, C#,

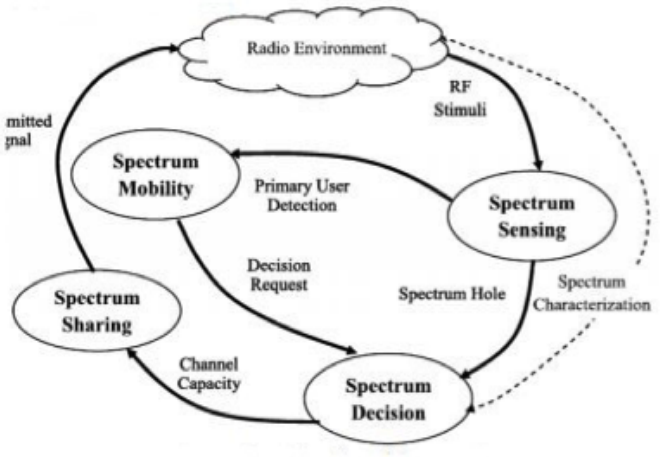

Fig. 2: Cognitive Cycle

Fortran, Java, Lab VIEW, Lisp, Pascal, and many others.

There are also open-source software programs providing all the important tools to acquire information from a specific hardware equipment. This equipment comes from the scientific community where complicated test requires fast, bendy and adaptable software. These programs are usually custom suit, however, greater standard DAQ package like the maximum integrated facts acquisition device may be easily tailor-made and is utilized in numerous physics experiments. There are four main steps in cognitive cycle, as shown in Figure 2 [15], by which we acquired signal data. The digital implementations provide more flexibility by means of spending FFT-based totally spectral approximations. Figure 3 displays the framework for virtual execution of a power indicator [4]. Electricity detector based technique is the best corporate technique of spectrum sensing due to small computational overhead. When primary person signal is indefinite or receiver can not acquire appropriate statistics about primary sign user, a power detection technique is used. This technique is ideal for identifying any indefinite zero-mean collection signals and must be imposed to cognitive radios (CRs). Procedure stream of energy detector in the received signal is passed by ADC after measuring the FFT constant form and average of observational interval. In order to decide primary user occurrence/non-occurrence, the output is compared to the predefined initial value. Figure 4 shows simulation the steps using MATLAB. These steps are defined as under.

- **Initialization-** After the completion of all basic configurations, carrier frequency bands, message frequency and sampling are initialized for the user.

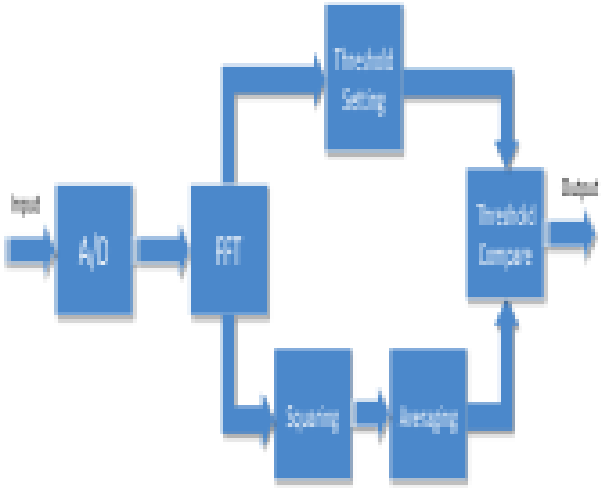

Fig. 3: Digital implementation of an energy detector

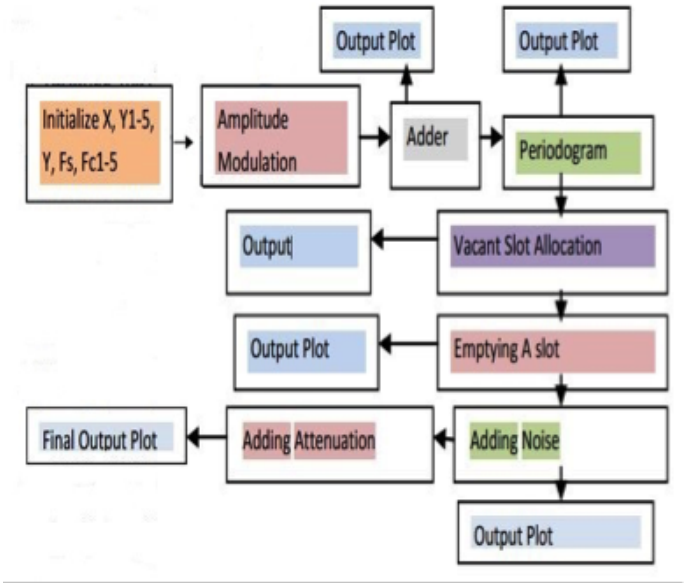

Fig. 4: Simulation Set up using MATLAB

- **Modulation-** The process of modulating data over elective frequency band by AM.
- **Adder-** Sum of totally modulated signals to generate the transmitting signal
- **Periodogram-** Estimation of power spectral density of conventional signal.
- **Vacant Slot Allocation-** Different Users are allocated to first spectral hole while it stretches.
- **Emptying a slot-** Ask a user to vacant the particular slot if all slots are busy.
- **Addition of noise-** The addition of noise is the amount which is to be added. .
- **Attenuation-** The status of the distorted signals which directly affects the single strength.

5 Results and Discussion

The data of spectrum, collected by using GW Instek, is stored in csv files. MATLAB tool can be an effective tool to import all these files for the processing. Algorithms and complete results are designed/generated in MATLAB 2014. The obtained results show the use of 2.4 GHz Wi-Fi channels in QUEST Nawabshah and also show the free spectrum holes and channels as well. The results are obtained by the implementation of 2.4 GHz center frequency. Further, it is evaluated for the results that vary from different spectral consequences below in detail.

Figure 5 illustrates the consequences achieved for 2.4 GHz ISM band with the use of frequency of 50 MHz, i.e. signal gain across ISM band in stages of 50 MHz starting from 2.3 GHz and completion at 2.550 GHz. Purpose of this graph is to monitor the improvement of the channel under observation. However, exact channel utilization of Wi-Fi (802.11) cannot be observed.

Spectrogram in Figure 66 shows the relationship between the time frequency affiliations to advance. In this regard, the spectral representation of signal with respect to the time is called spectrogram. This depicts the variations in spectral density of signal with respect to time. The highlighted bar in the graph shows various levels of loss and gain of energy values.

In order to find the availability of spectrum at the predefined threshold, the comparison of the color with time and frequency alliance can be analyzed. The instance of time and frequency spectrum holes are represented in red colors in this spectrogram. Here, we can simply observe channel operation in the QUEST WLAN. Each stem value in the spectrogram shows outcomes collected throughout distinct cycle of data for every step of frequency. The utilization of channel for CR can be exploited at the channel frequencies for which we have completely obtained data at certain instant of period t. The spectrogram shown in Figure 6 precisely depicts the spectrum holes in the form of red tiled apparent in existence of further shades showing diverse gain values of energy spectrum.

Results of energy detection, Cyclostationary Feature Detection (CFD) and wavelet based detection based on the possibility of primary user detection, possibility of miss detection and the possibility of false detection has been compared. In this discussion, we refer to Ho as null hypothesis. Ho shows that the Primary User (PU) has not occupied the channel and it can be utilized by a Secondary User (SU). H1 is the alternate hypothesis that shows that the channel is engaged by the PU.

5.1 Probability of False Detection

False alarm is a condition when PU is detected even when a free channel is essentially free. In other words, we can say H1 is declared under Ho hypothesis. This results in the wastage of channel resource. Therefore, the probability of false detection should as low as possible. Figure 7 shows the probability of false alarm detection with respect to SNR. It can be observed that the wavelet based detection outperforms the other two methods. Energy detection, despite being less complex, shows worst performance in terms of false detection.

5.2 Probability of Detection

It is possible that the primary user is occupying channel and it is detected as such. Ideally, the probability of detection can be as much probable for lower SNR as possible.

Figure 8 depicts the comparison of probability of detection of all three sensing techniques under consideration. It can be viewed that the probability of detection of wavelet detection is greater than rest of the techniques at lower SNR. Whereas, the energy detection requires more SNR for better probability of detection.

5.3 Probability of Miss Detection

Miss detection occurs when the channel is employed by PU, but it is detected to be idle. Miss detection results in the interference to the communication of PU. It is, therefore, the probability of declaring Ho under H1 hypothesis. For a better CR system, miss detection should be minimum.

Figure 9 shows the results of miss detection. In this case again, the wavelet based detection performs better at sufficiently lower SNR as compare to the Cyclostationary feature detection and energy detection.

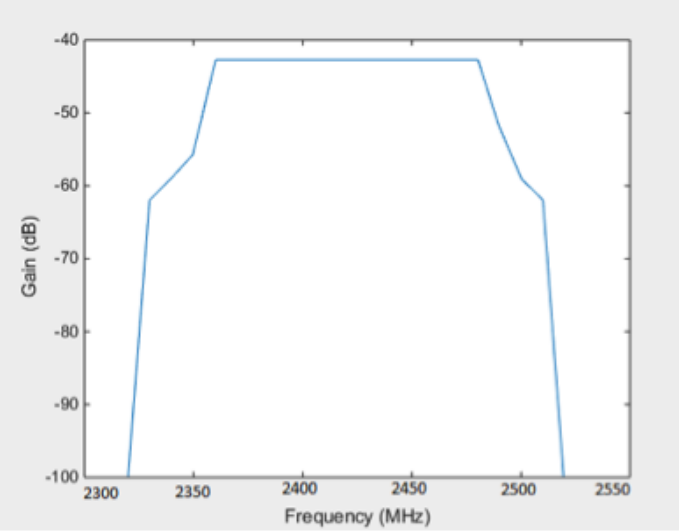

Fig. 5: Sensed signals bandwidth at 2.4GHz

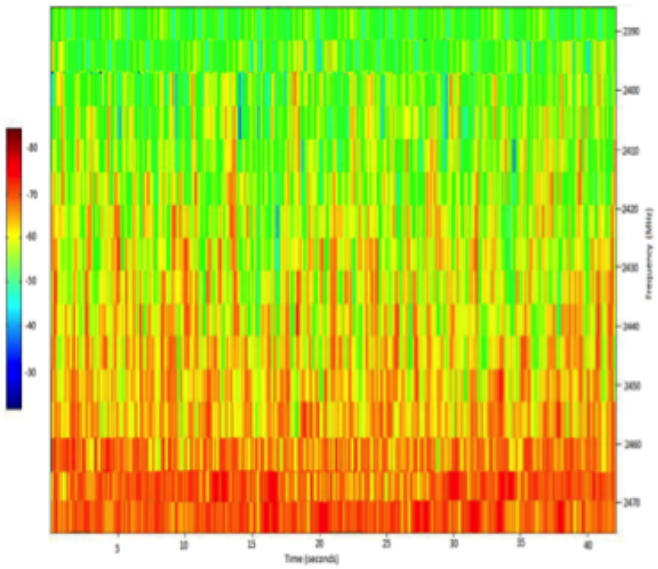

Fig. 6: Spectrogram of sensed signal

6 Conclusion

The study presented in this paper gave a comprehensive detail regarding implementation of energy detection, cyclostationary feature detection method, and wavelet based spectrum sensing. These three spectrum sensing techniques were analyzed for various SNR values. To find the spectrum holes in 2.4 GHz allocated ISM band, different number of simulations were performed. The statistics data were collected by using the GW-instek. The final qualitative investigation of the sensing techniques indicated that the wavelet based method is most consistent and accurate technique for spectrum sensing as it showed optimum results for primary User detection, miss detection and false detection for the lower SNR values. The material collected in the form of FFT bins, proved to be an effective technique of collecting data for spectrum sensing as it needs some signal processing procedures. Other work is implemented in GW-Instek. The obtained results showed that this is possible to discover an underutilized bandwidth in the spectrum apart from having earlier understanding of PU and SU. However, the Spectrograms, frequently utilized in acoustics and astronomy, can be used to detect spectrum holes as displayed in outcome by drawing spectrograms. The threshold level for few particular

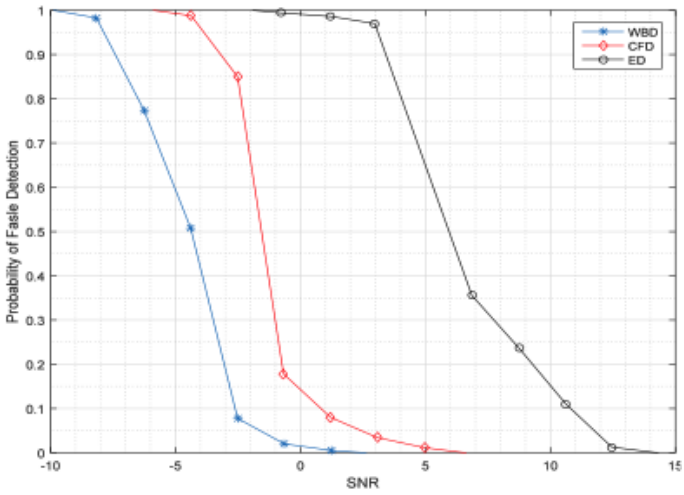

Fig. 7: Plot of Probability of False Detection Vs SNR

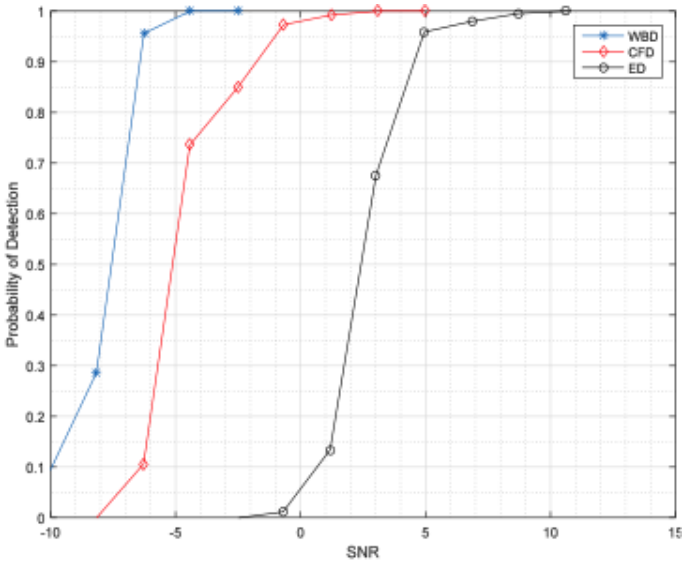

Fig. 8: Plot of Probability of Detection Vs SNR

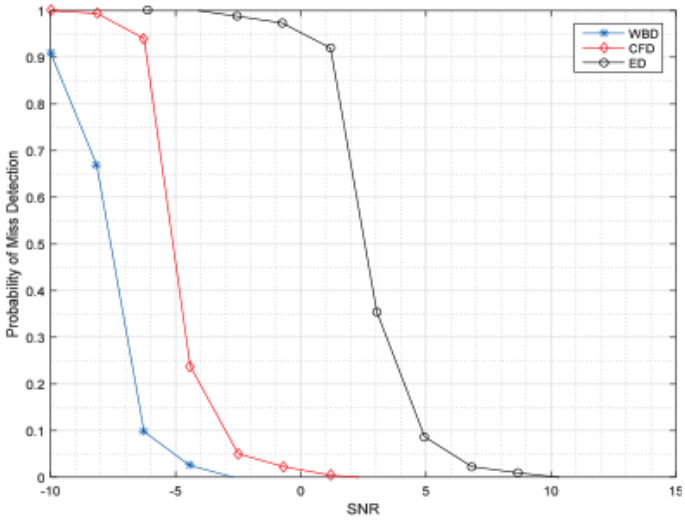

Fig. 9: Plot of Probability of Miss Detection Vs SNR

spectrums of frequencies consists of some features like receiver sensitivity and the number of energy transmitting/receiving nodes and dimensions occupied under consideration.

Proposed Research could be enhanced by performing similar experimentation for licensed frequency bands. The results obtained could be matched with ISM band results to acquire good understanding of an area of study. In order to find the availability of spectrum at the predefined threshold, the comparison of the color with time and frequency alliance can be analyzed.

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