

# Analysis Of Energy Detection Spectrum Sensing Technique In Cognitive Radio

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**Abstract:** Cognitive radio is the emerging technique which can be used in wireless communication systems. This technique is utilized to expand the spectrum usage productively. In the process of effective utilization of spectrum, the main component used by cognitive radio is spectrum sensing technique. Since, maximum spectrum is assigned to primary users and it is under utilized hence, efficient utilization of spectrum is an essential issue. The unused band of primary users can be assigned for reuse to supply broadband network services without any interference. In our paper, energy detection concept is used to perceive the unused bands of the spectrum and make them available for the reuse purposes. With this concept we can determine the white spaces in the spectrum and assign to secondary users.

**Index Terms:** cognitive radio; spectrum sensing; energy detection; Signal to Noise Ratio (SNR); threshold; probability of detection; probability of false alarm.

## 1 INTRODUCTION

Cognitive radio is the latest technique which can address the spectrum scarcity problem in many efficient ways. Due to the expansive growth in the usage of wireless communication systems around the world, there is a great demand for spectrum resources. So, by initiating the spectrum's secondary use on an opportunistic basis makes wireless communication systems flexible, it can also provide a future support for the growth in traffic and also can enhance the demand in the traffic. Spectrum sensing helps in detecting the band containing the primary user information, so that we can assign the idle bands of the spectrum for secondary user's information without interference or data loss. There are various spectrum sensing techniques, In this paper among those several spectrum sensing techniques, Energy detection technique is explained in detail. The new concept, cognitive radio is put forth recently in a thought of improving the effective utilization the spectrum through a better sharing of the spectrum among several users. The terminals of cognitive continuously sense the availability of the spectrum and help its users without creating any harmful interference for the primary users effectively. The accessibility of the bands in the spectrum can be controlled by the location of the frail signal from the essential transmitter dependent on the neighborhood perceptions in intellectual radio. There are numerous normal ways for transmitter recognition, they are: Energy location, Matched channel identification and cyclostationary highlighted discovery [1]. But, In order to detect the primary user's presence in the spectrum using the matched filter detection technique, the secondary user must have prior information about the presence of primary user signal. Therefore, these kinds of techniques will need the receivers for every type of signals. In addition to this the power consumption and the implementation state of quality is too high and is very complicated [2]. Whereas the energy detection technique is most commonly used for spectrum sensing due to its simplicity in the implementation and computation.

Above all these it does not need any previous information about the presence of the primary terminal's signal [3-5], also energy detection is most efficient technique among all the available spectrum sensing techniques. Regardless of how the performance of the energy detection technique is becoming progressively worse due to the effect of uncertainty in noise, more specifically in low signal to noise ratio (SNR) conditions. At the same time the unseemly setting of the threshold detection can lead to a very significant rejection in the process of performing detection. Hence the finest threshold level which is based on the substitution between the probability of misdetection and probability of false alarm is derived [3-5]. Usually the aspiration of energy detection scheme mainly depends on the signal to noise ratio (SNR) of the received signal. Practically in many applications the signal that is received at each cognitive radio user might suffer from uncertainty because of fading and hidden primary terminal problem and also from shadowing. All these problems can be solved by cooperative sensing techniques [6]. Regardless of how, all of these proposals are based on conclusion that noise power is known absolutely. But, practically the noise varies with the location of terminal and time. This phenomenon is called as noise uncertainty and cannot be accurately estimated. To reduce the effect of the uncertainty in noise several proposals are been put forth [7-10]. There are few SNR thresholds under uncertainty in noise that can prevent achieving reliable primary user detection, and also increases the number of samples to infinity. Some of the authors proposed a new technique that uses dynamic threshold that can succeed in dealing with the noise uncertainty problem. Regardless how, the threshold detection in this technique has been conventionally determined based on the (CFAR) constant false alarm rate that can at most provide constant probability of false alarm rate even when SNR region is high where the strength of the signal is much stronger than the noise power, furthermore the minimization of errors in the spectrum cannot be guaranteed. Fundamentally, the outcome of the energy detection technique depends highly on the threshold detection and it's setting also on received signal's level of SNR. Therefore, another plan called optimal threshold based energy detection scheme was put forward [11-12]. However, the threshold level optimization which is based on minimizing the errors in spectrum sensing did not look attentively at the issue of noise uncertainty on detection performance. In this paper we have studied and put forth a new proposal to improve the performance of spectrum sensing

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by mainly paying attention on some of the drawbacks of energy detection, which includes poor performance because of noise uncertainty and threshold value selection. An optimized adaptive threshold level which is based on error function in spectrum sensing to identify the available channels in spectrum is proposed by many authors [13-14]. The optimization in detection which is based on average noise power without uncertainty is examined in detail first. And then the uncertainty in noise is taken into consider and a dynamic optimal threshold factor is developed for the reduction in the degradation of detection performance that is caused by noise uncertainty.

## 2 DESCRIPTION

### 2.1 Cognitive radio:

Cognitive radio improves spectrum utilization and increases communication quality and also can be programmed and configured dynamically [15]. Cognitive radio indicates the availability of the channels mechanically from the wireless spectrum, and then in an appropriate way it modifies the reception and transmission parameters so that at one location it can authorize more coinciding wireless communications from the given spectrum band. Cognitive radio network is complex multiuser wireless communication system to provide efficient use of radio spectrum [16]. The significant usefulness of Cognitive Radio (CR) is range detecting in which exactness and speed of estimation demonstrate to be the key pointers to choose the suitable range detecting procedure. Cognitive radio technology innovation has been acquainted with upgrade to remote the radio range and to tackle the spectrum range shortage issue. This cognitive radio is put forth recently in a thought of improving the effective utilization the spectrum through a better sharing of the spectrum among several users. The terminals of cognitive effectively and continuously sense the availability of the spectrum and help its users without creating any harmful interference for the primary users. Cognitive radio systems can identify the unused spectrum holes and provide these holes to the secondary user to make use of them by avoiding the interferences that might be caused by the primary user information [17]. To initiate the dynamic spectrum access these cognitive radio systems performs spectrum sensing to decide the presence and absence of the primary user information.

There are two types of cognitive radio systems

#### 1. Full cognitive radio

Full cognitive radio considers all parameters that a remote hub or system can know about.

#### 2. Spectrum-sensing cognitive radio.

Spectrum sensing cognitive radio is utilized to identify directs in the radio recurrence range.

#### 2.1.1 Working of Cognitive radio:

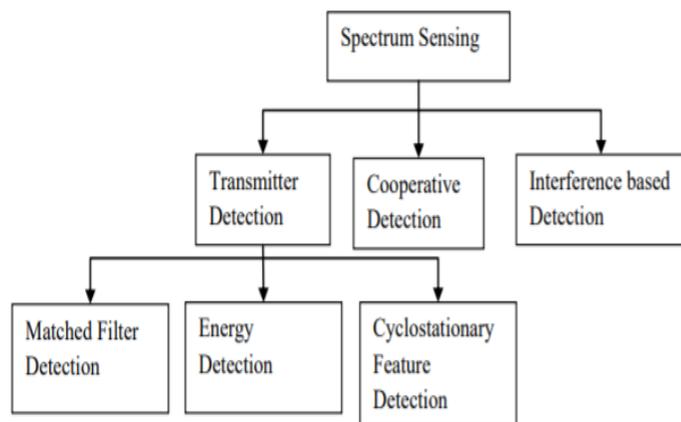
Cognitive radio once on the off chance that it can bolster the capacity of choosing the best accessible direct in the range, the next task is to make the network protocols adaptive to the available spectrum. Therefore, new techniques, functionalities are required in the cognitive radio network to support the bands efficiently. Some of the specific functions or tasks of cognitive radio networks can be classified by following: Spectrum sensing: This refers to the process of recognizing the unused range openings and sharing the range without interference with the primary client's data available in the

range. It is an important necessity of the Cognitive Radio network to be able to sense the holes in spectrum, recognizing essential clients is the most proficient approach to identify range gaps. These unused range gaps recognized by the range detecting procedure display various qualities not just incorporate range band data like the working recurrence and the transfer speed yet in addition time changing radio condition. But It is very complex for the cognitive radio to have a measurement of channel that is provide between transmitter and a primary receiver. Spectrum management: The target of this procedure is catching the best spectrum range that is accessible so as to meet the prerequisites of the clients. In cognitive radio networks, the unused spectrum bands available in the spectrum spreads over a large frequency range which includes both licensed and unlicensed bands. All these unused spectrum bands which are detected via spectrum sensing show different characteristics which not only include the spectrum band data like the system operating frequency and the bandwidth capacity but also time changing radio environment. Spectrum mobility: This is the process of maintaining the same seamless communication requirements mainly during the transmission to a better spectrum. It is additionally alluded as the procedure where the intellectual client trades its recurrence of activity. Intellectual radio system's optional client, to utilize the range in a powerful way by allowing the radio terminals, to work in the best accessible recurrence band. This approves idea of "Get the Best Available Channel" for the interactive communication purposes. Spectrum sharing: This alludes to giving a reasonable range planning strategy among the clients. In the open range use, Sharing is the significant test. This likewise gives the fair scheduling strategy among coexistent psychological cognitive radio clients. Therefore, to provide a catalogue for different challenges in the process of spectrum sharing, we initially build up the quantity of steps in range partaking in psychological radio systems. There are 5 major steps in spectrum sharing process, they are:

- Spectrum sensing
- Spectrum allocation
- Spectrum access
- Transmitter-receiver handshake
- Spectrum mobility

**2.2 Spectrum sensing techniques:** In this model, the secondary client first detects the recurrence band allotted to the primary client to distinguish the condition of the PU and afterward adjusts it's transmit control as per the recognition result. If the PU is inactive, the SU allocates the transmit power based on its own benefit to achieve a higher transmission rate. If the PU is active, the SU transmits with a lower power to avoid causing harmful interference to the PU. There are three different techniques for spectrum sensing, they are:

1. Non-cooperative spectrum sensing technique
  - Matched filter detection
  - Energy detection
  - Cyclostationary feature detection
2. Cooperative spectrum sensing technique
3. Interference based detection spectrum sensing technique



**Fig 2:** types of spectrum sensing techniques

### 2.2.1. Non-cooperative spectrum sensing technique:

This strategy is also called as primary transmitter recognition technique. Since it is complex to sense the primary receiver's position, therefore to detect the primary client data it is important to detect and recognize the sign sent by the essential transmitter. There are 3 sorts of Non-cooperative spectrum detecting strategies they are:

1. Energy detection
2. Matched filter detection
3. Cyclostationary feature detection

- ✓ Energy detection: This method figures the energy of the received signal for N specific samples as a square of magnitude of the Fast Fourier Transform (FFT) which is averaged over these N samples and then compares it to a predefined threshold value to obtain the decision of sensing technique. If the energy recognised is higher than the predefined threshold value, then the primary user is considered as present and if the energy recognised is lower than the predefined threshold value, then the primary user is considered to be absent. This technique is very simple as to implement this technique we do not require any prior information about the whereabouts of the primary signal, therefore making it even more straightforward and reliable than the matched filter and cyclostationary feature detection technique [18]. Regardless of how, the performance of this technique is highly dependent on noise uncertainty. Thus using of dynamic threshold degrades the noise power and the performance of the energy detection.

- ✓ Matched filter detection: Matched filter detection is a sort of range detecting strategy that matches and got signal examples with few pre collected pilots of same primary client signal stream. These saved pilots are convoluted with the received samples and then average over N samples is taken to compute the decision, which is then further compared with the threshold to obtain the sensing decision. if the threshold value which is predefined is lower than the result of the convolution, then it is considered as the presence of primary user signal, and if the threshold value is higher than the result of the convolution its considered as the absence of the primary user signal. This technique provides highest detection performance at lower levels of SNR, but the increase in the number of samples will decrease the detection

performance. Regardless of how, the matched filter detection need the prior knowledge about the primary user whereabouts, but in reality always this prior information about the primary user may not be available therefore making this technique unreliable and unpractical because there may be chances for interference and information loss.

- ✓ Cyclostationary feature detection: This is also called as the auto-correlation based sensing technique. It computes the correlated function with the time shifted version the N samples at lag zero of received signal to the received N samples signal. If the output of this correlated function is higher than the predefined threshold then that represents as the presence of the primary signal in the spectrum, otherwise if the threshold value is higher than the correlated function then it represents as the absence of the primary signal in the spectrum. Since the noise in the signal is uncorrelated and as this technique is auto-correlated the signal and noise can be distinguished. But, this technique is highly complex and unreliable as it need the prior information about the presence and whereabouts of the primary signal. Cyclostationary detection is the most composite technique in spectrum sensing when compared to the above three spectrum sensing techniques mentioned above.

### 2.2.2. Co-operative spectrum sensing technique:

This refers to the technique where the cognitive radio network's (CNR) share their individual sensing information in order to improve the overall sensing information about their primary user. This is also a solution to improve the detection performance, making it easier for the secondary users collaborate with primary user and the facility to collectively detect the spectrum holes. But, in this technique the cognitive radio network users have to perform the sensing technique only at particular periodic time intervals as the detected data will be quick because of various factors like mobility, channel weakness etc.

### 2.2.3. Interference based spectrum sensing detection technique:

This interference based technique is a totally new concept for the dynamic spectrum access. The cognitive radio hubs treat the authorized(licensed) clients and unauthorized clients within the similar network without interference. Higher interference prompts lower Signal-to-interference proportion (SIR), which implies that the lower limit is reachable for a specific sign's transfer speed. Not at all like the essential collector identification, the fundamental thought of impedance temperature the executives is to set up an upper obstruction limit for the given recurrence band in a particular geographic area. The performance of all above three sensing techniques mainly depends on the total number of samples and their sensing threshold. Taking large number of samples will improve the detection capability to maximum up to a certain value of SNR and the makes the cognitive radio more reliable. But the increase in the number of samples also increases the sensing time, for an instance the wideband sensing is impractical.

### 3. METHODOLOGY

#### 3.1 Spectrum sensing

The one of the most important components in cognitive radio is spectrum sensing which is used to sense the parameters that are related to the channel. It is used to detect the presence or absence of PU signal in cognitive radio. Where the secondary client will have access to the unoccupied spectrum band. The nature of spectrum sensing is a binary hypothesis-testing. Indication of primary user:

- $H_0$ : primary user is absent
- $H_1$ : primary user is in operation

#### Inputs in spectrum sensing:

- i.  $P_d$  – probability of detection is used to detect SU is present in the signal
- ii.  $P_f$  - probability of false alarm is used to indicate that the SU is present when the spectrum is free.
- iii.  $P_m$  – probability of miss detection which is used to detect that SU is present that the spectrum is free but the incumbent present.

Probability of detection,  $P_d$  and probability of false alarm,  $P_f$  are important for energy detection

$$P_d = P(\text{decision} = H_1 | H_1) = P(Y > \lambda | H_1) \quad (1)$$

$$P_f = P(\text{decision} = H_1 | H_0) = P(Y > \lambda | H_0)$$

Where  $\lambda$  is threshold and  $Y$  is the statistic decision.

#### 3.2 Transmission Detection:

Based on weak signal of primary transmitter the transmission detection is done. Basic model of transmission detection is defined as:

$$X(n) = \begin{cases} w(n) & \dots \dots \dots H_0 \\ y(n) + w(n) & \dots \dots \dots H_1 \end{cases} \quad (2)$$

Here  $x(n)$  is received signal,  $y(n)$  is transmitted signal and the noise is  $w(n)$ .  $H_0$  demonstrates that there is no primary client in a specific recurrence band. While  $H_1$  shows that primary client is exists in that recurrence band.

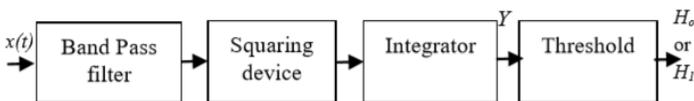


Fig 3: Block diagram for energy detection

Here  $x(t)$  is filtered with band pass filter in order to limit the noise and to select the bandwidth. After that the signal passes through a squaring device which is used to measure the received signal. And the signal passed through integrator which determines the observation interval,  $T$ . Now the output  $Y$  is compared with a value of threshold,  $\lambda$  and if the values are above the threshold, it is consider as primary user is present if not absent. For the given digital input signal of additive stochastic noise matched filter is the better way to maximize the output signal to noise ratio. Matched filter compares with final output signal with the threshold value and it correlates with time shifted version. In the block diagram the primary user  $x(t)$  signal is combined with a time shift version  $h(t)$  of the prior known signal  $s(t)$ . The last yield of the channel signal is contrasted and the edge worth will show that the primary client

is available.

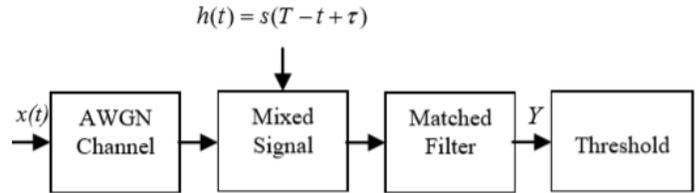


Fig 4: Block diagram of matched filter detection

Cyclostationary is the most compound technique in spectrum sensing among the three techniques. This technique makes use of no of cycles received by the primary user signal to spot the presence of primary users signal. This technique can discriminate the primary user from interference and noise.

#### 3.3 Quadrature Phase Shift Keying(QPSK):

QPSK is a form of phase shift keying in which two bits are combined and modulated at once, by selecting carrier phase shifts and are orthogonal to each other. In QPSK sin and cos capacities are utilized for balance. Balance is accomplished by changing the stage capacities. It permits the sign twice data as standard stage move keying utilizing a similar transmission capacity.

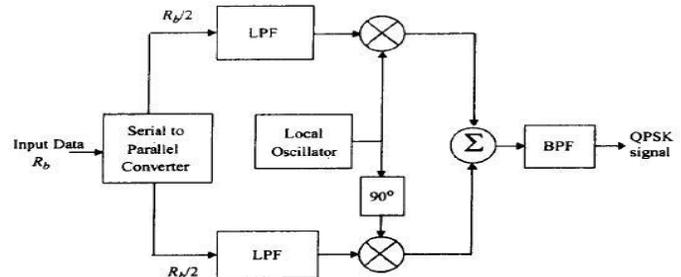


Fig 5: Block diagram for QPSK Modulation

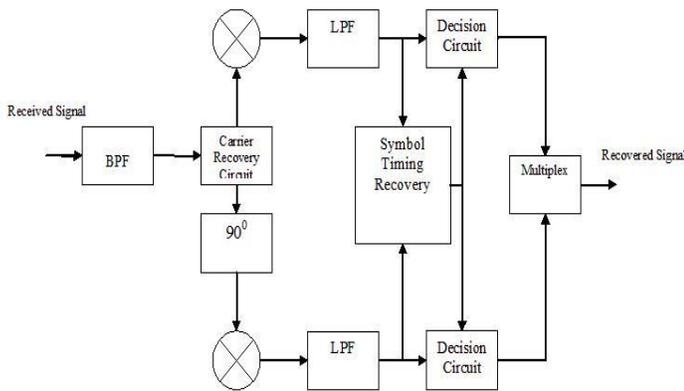
The transmitted signal for QPSK modulation is:

$$S(t) = A_c \cos(2\pi fct + \varphi(t)) \quad (3)$$

Where  $\varphi(t) = 135, 45, -45, -135$

$$S(t) = A_c \cos \varphi(t) \cdot \cos(2\pi fct) - A_c \sin \varphi(t) \sin(2\pi fct)$$

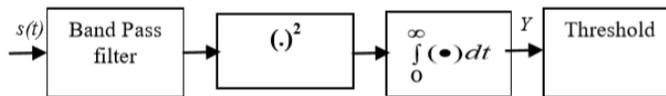
QPSK is an intelligent demodulator. In reasonable identification the bearer recurrence and stage must be comfortable with the collector. In the demodulator is increased with got signal. The duplicated yield is coordinated by utilizing an integrator. Edge indicator settles on a choice on each incorporated piece dependent on a limit esteem. At long last the bits are remapped to frame recognized sign.



**Fig 6:** Block diagram for QPSK Demodulation

**3.4 Energy Detector:**

To decide the signal power recurrence band in time domain, a band pass filter is requested to aim signal and the signal samples are measured. The below block diagram indicates that the implementation of energy detector. To assess the power of the received signal, the output of band pass filter is squared and integrated over an interval T.



**Fig.7:** Implementation of energy detector

$$T = \frac{1}{N} \sum_{n=0}^{N-1} (y[n])^2 \tag{4}$$

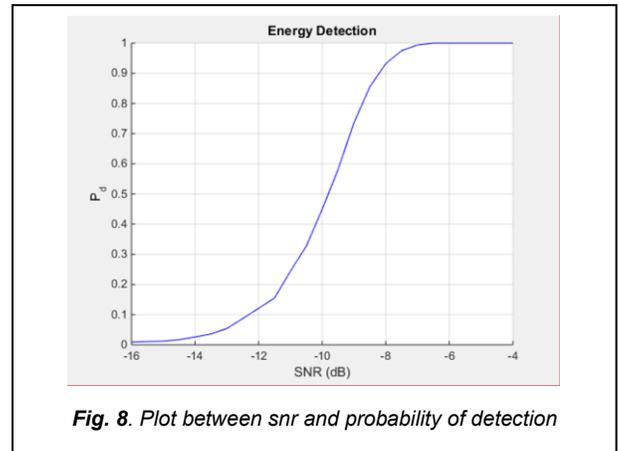
Where T is the output variable, y[n] is the received signal, N is the no of samples. Here integrator registers the vitality, Y from a particular perception interim over the identified sign. Finally, the output signal Y is compared with the threshold value in order to indicate whether a signal is present or not. The threshold value is set according to probability of the output Y when the noise is present.

$$P_d = P_r \{Y > \lambda | H_1\} = Q_u(\sqrt{2\gamma}, \sqrt{\lambda i}) \tag{5}$$

Where  $\gamma$  represent signal to noise ratio (SNR), and  $\lambda_i$  is the threshold value for  $i^{th}$  sampled signal. The basic exchange between probability of miss detection and probability of detection is,  $P_m = 1 - P_d$  where  $P_f$  has different inference in dynamic spectrum sharing.

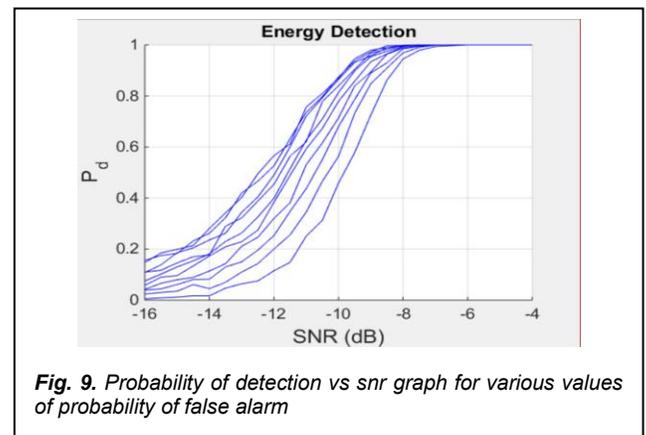
**4. RESULTS**

- Our goal is to plot receiver operating characteristic curve for simple energy detection, where the primary signal is the real Gaussian signal and noise is an additive white real Gaussian.
- For several values of snr we are observing the graph between snr and pd.



**Fig. 8.** Plot between snr and probability of detection

- ✓ From the above result we observed that with the increase in the probability of detection value the signal to noise ratio also increased.
- ✓ So, for accurate results in the energy detection the snr value must be as high as possible
- For varying values of  $p_f$  (probability of false alarm ) i.e; form range of 0.001 to 0.1 we observed.



**Fig. 9.** Probability of detection vs snr graph for various values of probability of false alarm

- ✓ From the above result we observed that with the increase in the probability of false alarm the probability of detection value decreased.
- ✓ This may lead to poor spectrum utilization.
- ✓ Hence, the probability of false alarm should be as low as possible for the accurate results, and also to protect the primary user data form secondary user's data interference.
- Also, since in the practical use we often receive signals from longer distances which might get degraded with the increase in the distance, as a result snr value will be low.
- So, to calculate the energy and find holes in the spectrum for lower SNR values, we can set double threshold technique.

**5. CONCLUSION**

The main motivation behind cognitive feature radio has been to extend spectrum utilization by permitting the secondary users to opportunistically access the band closely held by the authorized (primary) user.

## 6. FUTURE SCOPE

Radio networks may experience significant challenges in achieving reliable communication due to packet losses, collisions and contention delays, according to the authors of [17]. One of the most useful application is homeland security, especially when there is war situation or disaster.

## 7. ACKNOWLEDGEMENT

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