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# Optimal Robust Estimator-Correlator for Spectrum Sensing in Cognitive Radio

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**ABSTRACT:** Cognitive Radio is wireless communication technology, which is used to increase spectrum efficiency. Increasing efficiency is necessary in order to fulfil need for maximum data rates, good quality of services and higher capacity. Multiple-input and Multiple-output (MIMO) communication technology has gained significant attention as it is a powerful scheme to improve spectral efficiency. Use of spectrum, which requires four main tasks- Spectrum Sensing, Spectrum Analysis ,Spectrum Allocation and Spectrum management . In this paper, we used spectrum sensing for primary user detection. Spectrum sensing involves, the spectrum usage characteristics across multiple dimensions such as time, space, frequency, code and determining what type of signals are occupying the spectrum. Spectrum sensing detects availability of radio frequency spectrum, which is essential to cognitive radio. Our work introduces multiple input multiple output (MIMO) cognitive radio network, estimation of signal co-variance matrix for non-coherent spectrum sensing. For that, Eigen value perturbation theory based approach is planned to design. This novel scheme has been further compared with other existing methods, the proposed technique is planned to simulate using NS2 software and MATLAB software.

**KEYWORDS:** Cognitive Radio (CR), Spectrum Sensing, Multiple-input multiple-output (MIMO), RECD, RSTD

## I. INTRODUCTION

The Radio spectrum is required for wireless communication systems, which is available in limited resource. For wireless applications, spectrum regulators have traditionally adopted fixed spectrum access (FSA) policy. Each part of spectrum is assign to one or more dedicated user with particular bandwidth. Because of this, only the assigned (licensed) users have the authority to use that allocated spectrum and secondary users does not allowed to use that spectrum. In most of the countries, maximum part available spectrum has been fully allocated, and led to the scarcity of spectrum [1]. Now a day's wireless technology was introduced which required spectrum therefore, solving the expected spectrum scarcity problem becomes increasingly important for wireless spectrum demands.

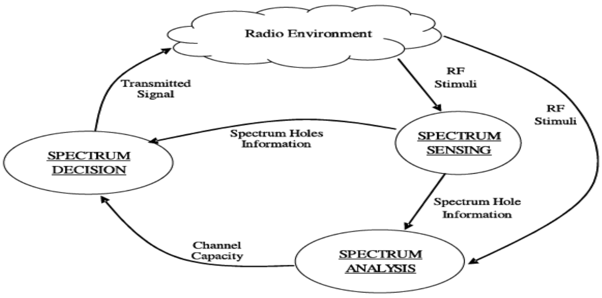


Fig. 1 Cognitive cycle

### *A. Spectrum sensing*

A cognitive radio senses the spectrum. Then finds spectrum band availability, the information related to its parameters and detects spectrum holes.

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*B. Spectrum analysis*

The analyses of the spectrum holes that are detected through spectrum sensing and their characteristics are estimated.

*C. Spectrum decision*

Cognitive radio first determines its capabilities e.g. the data rate, the transmission mode of nodes, and the bandwidth of the transmission. Then, the appropriate spectrum band selection is made from the spectrum holes determined in spectrum sensing. After that, the communication can be performed over this spectrum band. As we know that radio environment changes time-to-time, therefore cognitive radio should be aware of the changes of the radio environment.

If some primary user wants to communicate on the spectrum band, which is in the use of cognitive radio then the spectrum mobility function is invoked to provide a seamless transmission. Any changes occur during the transmission such as primary user appearance, user mobility, or traffic variation can activate this adjustment.

In this paper, cognitive radio (CR) is technology which is useful to reduce overcrowding of spectrum, by allowing secondary (unlicensed) users to opportunistically communicate over the licensed spectrum bands left by the primary (licensed) user for given instant of time. Cognitive radio, has emerged a technology for dynamic spectrum access (DSA) that allows secondary/ unlicensed users to opportunistically access the unused radio spectrum allotted to the primary/ licensed users [2] [3]. Cognitive radio (CR) and multiple- input multiple-output (MIMO) communication are the most promising solutions to improve spectrum utilization and efficiency. MIMO system boosts spectral efficiency by having multiple nodes that simultaneously transmit multiple data stream. By using MIMO, the same frequency is reused in the same geographic region to deliver great amount of data traffic than could be expected from SISO. MIMO techniques deliver significant performance enhancement in terms of data transmission rate and reduce the interference. By using multiple nodes at Receiver and Transmitter in a wireless system the rich scattering channel can be exploited to create a multiplicity of parallel links over the same radio band and thereby to either increase rate of data transmission through multiplexing or to improve the system reliability through the increased node diversity. To evaluate the performance of MIMO, optimal robust detector is used. Assumption is that optimal robust detector needs to know the noise and PU signal variances and channel gains.

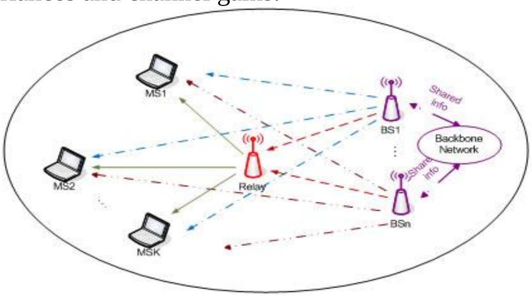


Fig. 2 MIMO model

## II. SPECTRUM SENSING

Spectrum sensing detects availability of radio frequency spectrum, which is essential to cognitive radio. A spectrum is nothing but a frequency band, which assigned to the PUs but is not used at a particular time. In some parts of the spectrum such as the frequency of TV band, such spectrum information can be broadcasted to the SUs. When such type information is not available to the SUs, then spectrum sensing [4] enables CR users for identify that spectrum, thus it protect the Pus from interfacing. Therefore, spectrum sensing is one of the important factors in CRN design. Fig 3 shows the diagram for basic principle [5] [6] of spectrum sensing which is useful detecting the availability of spectrum and protect the PUs from interfacing. In the figure, primary Tx first sends data to Rx which are dedicated in a particular licensed spectrum. A couple of CR (CR Tx and CR Rx) allow to access the spectrum for secondary communication. For protection of PUs, the CR Tx first needs to perform spectrum sensing for finding spectrum holes. After that, CR Tx is detected whether there is an active primary Rx is present or not. If not, then CR Tx allow to transmit CR Rx using the identified spectrum safely. Otherwise, the CR users cannot allow using that spectrum band. Therefore, it is necessary to detect the nearby primary Rx's can directly identify the spectrum, which is called direct spectrum sensing. As we know that detecting, Rx is a difficult task, because the Rx usually does not transmit signals when it works. Therefore, most of the cases spectrum-sensing schemes are used for identify spectrum by detecting the primary Tx's. As shown in Fig 3,

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let *D* be the range for transmission of the primary Tx and *R* be the range for interfering of the CR Tx. Then, the CR Tx first needs to detect the presence of an primary Tx between a distance *D* + *R*. If the distance between the primary Tx and the CR Tx's is larger than *D* + *R*, then there is no active primary Rx inside the specified range of interfering the CR Tx, and then, the CR Tx can safely used that available spectrum. When distance between the primary and the CR Tx's is smaller than *D* + *R* then primary Rx may be inside the range of interfering of CR Tx and interfered by its transmission. Hence, detecting surrounding primary Tx's which can also identify the spectrum, but it is an indirect way, called as indirect spectrum sensing. When we compare direct spectrum sensing with indirect spectrum sensing, it is found that indirect spectrum sensing required a large range for detection i.e from *R* to *R* + *D*. Therefore, indirect spectrum sensing detects very weak primary signals, which makes spectrum sensing more challenging and difficult. Moreover, when we want to measured signal-to-noise ratio (SNR) of the primary signal and if it is found that the CR Tx is low enough, i.e below the SNR wall, it is difficult for the CR Tx to detect the primary Tx, even if there is infinite number of primary signals samples are used.

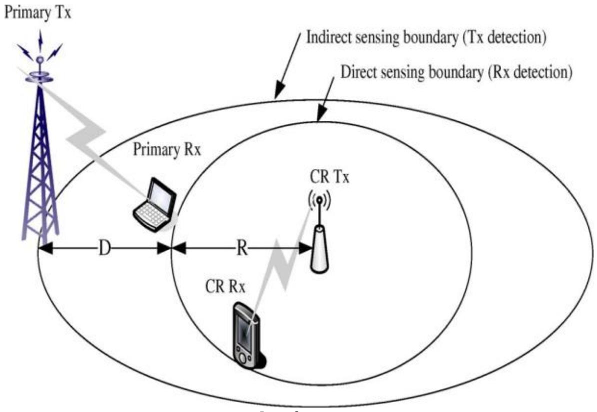


Fig. 3 Principle of spectrum sensing

There are Several spectrum sensing techniques have been proposed. Among these, the energy detector, which has a simple structure and widely used for spectrum sensing in cognitive radio networks. It has been demonstrated in, that the energy detector can be derived as the simplification of the optimal estimator-correlator (EC) detector for non-coherent spectrum sensing scenarios with isotropic signal and noise covariance matrices. Further, it is known from works such as, that the performance of the EC deteriorates with covariance uncertainty. However, due to the limited resources at the secondary users, estimation error and the fading nature of the wireless channel, it is often difficult to obtain an accurate estimate of the signal covariance matrix. Therefore, we propose robust detection schemes in order to reduce the effect of the uncertainty in the estimated signal covariance matrix on spectrum sensing in practical wireless scenarios. Employing perturbation theory, we derive results to bound the distortion in the estimated covariance matrix. Based on these results, we develop the generalized likelihood ratio test (GLRT) detectors for robust estimator-correlator based non-coherent spectrum sensing and demonstrate that these can be formulated as appropriate optimization paradigms. The GLRT test statistic can be employed to formulate the robust test statistic detector (RTSD), which although simplistic, can be solved efficiently since it is convex. Further, the robust estimator-correlator detector (RECD) is also derived. Simulation results demonstrate a significant improvement in the primary user detection performance of the proposed detection schemes in comparison to the nominal covariance matrix estimate based uncertainty agnostic EC detector.

## III. ROBUST DETECTION MODEL

Consider a multiple-input multiple-output (MIMO) cognitive radio system with *Nr* receives antennas at the secondary user and *Nt* transmit antennas at the primary user base-station. Random processes are also assumed stationary and argotic unless specified. The problem of signal detection in additive gaussian noise can be formulated as a binary hypothesis-testing problem with the following hypotheses

$$H0 : \mathbf{y}(k) = \boldsymbol{\eta}(k)$$
$$H1 : \mathbf{y}(k) = \mathbf{s}(k) + \boldsymbol{\eta}(k),$$

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Where, the null hypothesis H0 denotes the absence of the primary user and the alternative hypothesis H1 denotes the presence of the primary user. Gaussian signal covariance matrix $Rs \in CNr \times Nr$ defined as $Rs = E\{s(k)s^H(k)\} = HE\{x(k)x^H(k)\}H^H$. The respective distribution of vector y(k) is described as

$$H0 : y(k) \sim CN(0, R\eta)$$
$$H1 : y(k) \sim CN(0, R),$$

Where the covariance matrix R is defined as $R = Rs + R\eta$. The basic optimal decision rule for primary user decision is obtained by using likelihood ratio test (LRT). The component $T_{EC}(Y)$ of the test statistic $T(Y)$ constitutes the decision rule for the standard EC detector [7] with perfect knowledge of the covariance matrices $Rs, R\eta$ and can be equivalently given as $T_{EC}$ (Test for Estimator Correlator)

The performance of detector is totally dependent on the true covariance estimates. As we know that for primary user detection, covariance matrix is converted into eigenvalues of the estimated signal covariance matrix. The true signal covariance matrix $Rs = U\Gamma U^H$ and is converted into eigenvalues $\hat{\gamma_i}$ of the estimated signal covariance matrix $\hat{R_s}$ is given as

$$\gamma_i = \hat{\gamma_i} + \Delta\gamma_i, 1 \leq i \leq Nr$$

where $\Delta\gamma_i$ denotes the perturbation with respect to $\gamma_i$ the true eigenvalue of Rs. In this paper we formulate the RTSD and the RECD for primary user detection in cognitive radio scenarios that consider uncertainty in the signal covariance matrix in the signal covariance matrix

*A. Robust Test Statistic Detector (RTSD)*

It is based on the GLRT detector which is obtained by maximizing the EC test statistic for given uncertainty. This is equivalent to minimizing the term $\sum_{k=1}^{k} y^H(k)R^{-1}y(k)$. Now consider, decomposition of eigenvalues of covariance matrix R is $R = U\Lambda U^H$, eigenvalue $\lambda i$ of the diagonal matrix $\Lambda$ given as $\lambda_i = \gamma_i + \sigma^2\eta$. The minimizing problem is formulated as,

$$\sum_{k=1}^{k} y^H(k)R^{-1}y(k) = \sum_{k=1}^{k} y^H(k)\,(U\Lambda U^H)^{-1}y(k)$$
$$= \sum_{k=1}^{k} y^{\sim H}(k)\Lambda^{-1}y^{\sim}(k)$$
$$= \sum_{k=1}^{k}\left(\sum_{i=1}^{N_r} \frac{|y_i^{\sim}(k)|^2}{\lambda_i}\right)$$

where $\tilde{y}_i(k)$, i=1, ...,Nr are the elements of vector $\tilde{y}(k) = U^H y(k)$.

Hence, the test statistic corresponding to RTSD for spectrum sensing in MIMO cognitive radio scenarios can be equivalently given as $T_{RTSD}$ (Test for robust test static detector).

Now we formulate optimization framework to obtain the RECD for the primary user-sensing problem.

*B. Robust Estimator-Correlator Detector (RECD)*

RECD for uncertainty aware non-coherent MIMO spectrum sensing is based on the optimal GLRT method. It is the formulation of optimal detection rule for the primary user detection problem with uncertainty in the signal covariance matrix. The optimization problem is non-convex. The test statistic to RECD can be equivalently given as $T_{RECD}$ (Test for robust estimator correlator detector).

The above test statistic yields a robust decision rule for primary user detection in MIMO cognitive radio networks.

## IV. SIMULATION AND RESULTS

This section describes the simulation and results of this study. This paper provides reliability of the method, sensing time taken by a SU to detect a PU, security provided by the technique, reduce complexity of the technique. In this paper, MIMO modeling of cognitive radio and spectrum sensing is done and it is shown in fig 4. In fig 4(a) shows the multiple nodes for transmitting and receiving the data simultaneously. This node is placed at different position from each other with specified distance. These nodes are mobile in nature. Fig 4(b) shows the simulation of fig 4(a).The

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outer circle in this fig shows that it detect the availability of spectrum to detect the presence of primary user. In this fig, we consider 0 and 1 nodes are the primary user and remaining nodes represent the secondary user. If there is any transmission and reception between nodes, 0 &1 then secondary user sense that channel is busy. In fact, if there is no transmission and reception between nodes 0 &1 then secondary user sense that channel and cognitive radio allow to access that unutilized spectrum of primary user. Once cognitive radio is utilized spectrum it starts transmitting and receiving the data, which are shown by small dots in fig 4(b).

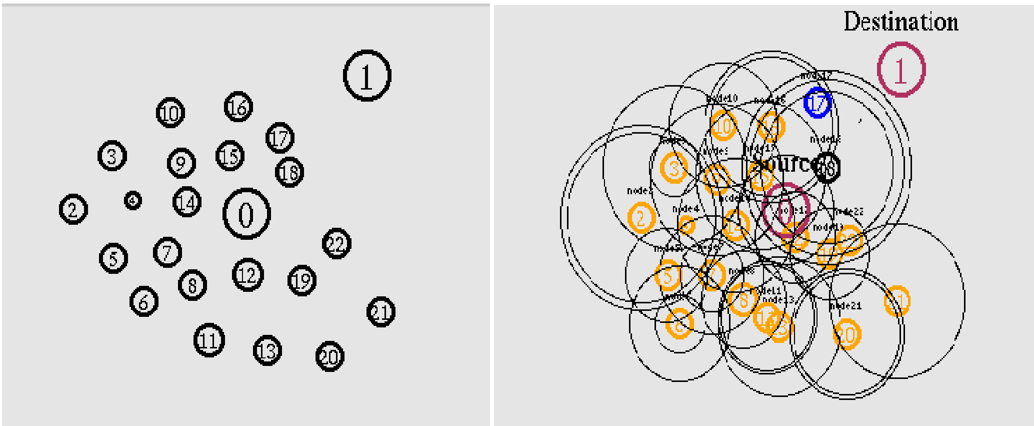


Fig. 4(a) Fig. 4(b)

Fig. 4 Model for cognitive radio and Spectrum sensing

Cognitive radio is automatically detect its parameter such as delay and packet delivery ratio (pdr). In fig. 5 we plot the delay graph in NS2 software by varying the simulation time. When we simulate the above model trace file is automatically created. Trace file contain the delay of transmitting and receiving of data. Data present in the trace file is represented by the delay graph.


Fig. 5 Delay graph for MIMO CR model

Fig. 6 shows the packet delivery ratio graph by varying the simulation time. Packet delivery ratio means how much packet is transmitted and received by the each nodes.

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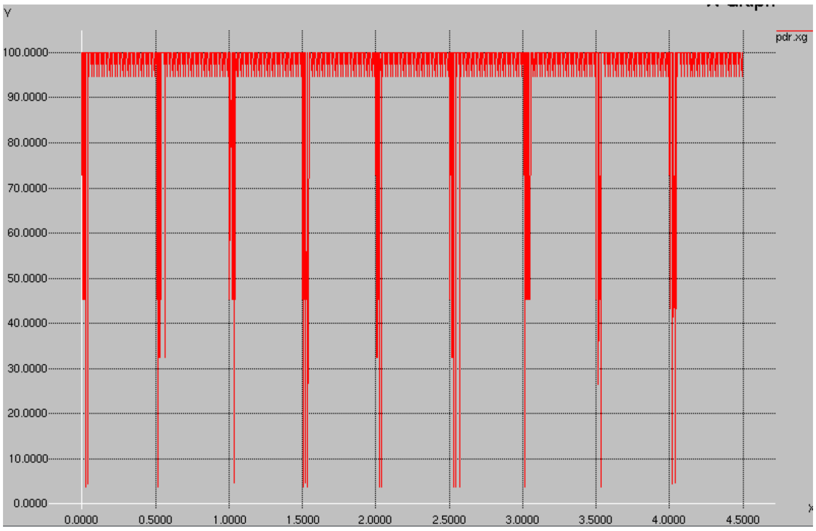


Fig. 6 pdr graph for MIMO CR Model

In fig 7. This graph we plotted in MATLAB software. On x-axis we take signal to noise ratio(SNR) of range 0-20 db and on y-axis we take prob of detection. This graph shows that when we increase SNR prob of detection also increase if we further increase SNR then prob of detection becomes constant. This is an extra version graph which gives an idea regarding the response of output.

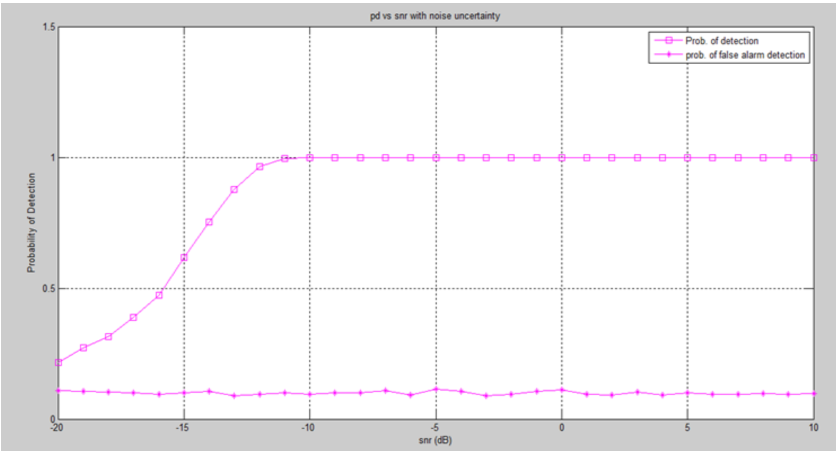


Fig 7 Probability of detection vs SNR graph

Fig. 8 is our final improved output. Generally, when prob of false alarm (pfa) is high then prob of detection (pd) is low. This graph is plotted between pd vs pfa this graph says that even if the pfa is high then also our pd is high. This graph shows that our pd response is constant for low pfa and high pfa.

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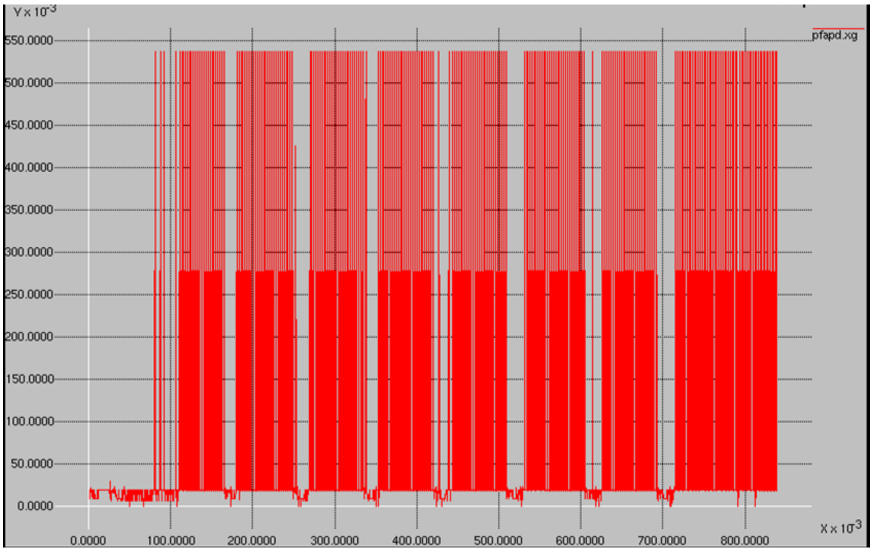


Fig. 8 Probability detection vs probability of false alarm graph

## V. CONCLUSION

In this work, we have proposed robust detection techniques for non-coherent spectrum sensing in MIMO cognitive radio scenarios. The proposed RTSD and RECD schemes improve the performance of primary user detection. Spectrum is very valuable resources in wireless communications system. Cognitive radio, is one of the most useful technique to utilize the available spectrum more efficiently. Simulation result demonstrates availability of spectrum and determines the cognitive radio parameter in the form of graph.

## REFERENCES

1. M. A. McHenry, P. A. Tenhula, D. McCloskey, D. A. Roberson, and C. S. Hood, “Chicago spectrum occupancy measurements & analysis and a long-term studies proposal,” in Proc. 2006 International Workshop on Technology and Policy for Accessing Spectrum, ser. TAPAS ’06. ACM, 2006.
2. J. Mitola and J. Maguire, G.Q., “Cognitive radio: making software radios more personal,” IEEE Personal Commun., vol. 6, no. 4, pp. 13–18, Aug. 1999.
3. S. Haykin, “Cognitive radio: brain-empowered wireless communications,” IEEE J. Sel. Areas Commun., vol. 23, no. 2, pp. 201–220, Feb. 2005.
4. T. Yucek and H. Arslan, “A survey of spectrum sensing algorithms for cognitive radio applications,” IEEE Commun. Surveys Tuts., vol. 11, no. 1, pp. 116–130, First Quarter, 2009.
5. Q. Zhao and B.M. Sadler, “A survey of dynamic spectrum access,” IEEE Signal Process. Mag., vol. 24, no. 3, pp. 79–89, May 2007
6. I. A. Akyildiz, W. Y. Lee, M. C. Vuran, and S. Mohanty, “NeXt generation/dynamic spectrum access/cognitive radio wireless networks: A survey,” Comput. Netw., vol. 50, no. 13, pp. 2127–2159, Sep. 2006
7. S. M. Kay, Fundamentals of Statistical Signal Processing, Volume 2: Detection Theory. Prentice Hall PTR, Jan. 1998.
8. “Spectrum Policy Task Force Report,” Federal Commun. Comm.,Washington, DC, ET Docket No. 02-135, Nov. 2002.

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