Comparative Analysis of different Interference Cancellation Schemes for OFDMA Systems

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Abstract: **Each user in the uplink of an Orthogonal Frequency Division Multiple Access (OFDMA) system may experience a different carrier frequency offset (CFO). These uncorrected CFOs destroy the orthogonality among subcarriers, causing inter-carrier interference and multi-user interference, which degrades the system performance severely. In this paper, novel time domain multi-user interference cancellation schemes for OFDMA uplink are proposed. They employ architecture with multiple OFDMA-demodulators to compensate for the impacts of multiuser CFOs at the base station's side. Analytical and numerical evaluations show that the SA-MUIC and CA-MUIC schemes achieve a significant performance gain compared to the conventional receiver and a reference frequency-domain multi-user interference cancellation scheme. In a particular scenario, a maximum CFO of up to 40% of the subcarrier spacing can be tolerated, and the CFO-free performance is maintained in the OFDMA uplink. In the cancellation schemes used till now the multiple access interference are not removed. The proposed work of this project would be a scheme called Selective Parallel Interference that reduces multiple access interference and reduces the data loss. This paper provides a comparative analysis of different interference cancellation schemes.**

Keywords –OFDMA, Uplink, Multi-user Interference, Self-Interference, CFO

1.INTRODUCTION

A.Overview of OFDMA

In recent years, Orthogonal Frequency Division Multiple Access (OFDMA) has emerged as the primary transmission and multiple access schemes for broadband wireless networks. Being a multi-user version of the famous Orthogonal Frequency Division Multiplexing Division Multiplexing (OFDM) technique, OFDMA operates by separating data into multiple lower-rate streams and transmitting them in parallel over orthogonal carrier frequencies, or subcarriers. Due to the orthogonality, those subcarriers are allowed to overlap in the frequency-domain; therefore high spectral efficiency can be achieved. The low-rate parallel subcarriers transmission turns multi-path fading channels into flat fading ones, thus simplifying the equalization task at the receiver. In OFDMA, available subcarriers are grouped into sub-channels, which are assigned to different users operating simultaneously. This allows a finer granularity for multiple accesses, compared to Orthogonal Frequency Division Multiplexing- Time Division Multiple Access (OFDM-TDMA) scheme, in which all subcarriers are given to only one user at any given time.In OFDMA systems, the multiple user signals are separated in the time/frequency domains. Typically, a burst in an OFDMA system consists of several OFDM symbols. The subcarriers and the OFDM symbol are the finest allocation units in the frequency and time domain, respectively. Hence, multiple users are allocated to different slots in the time and frequency domain, i.e. different of subcarriers and/or OFDM symbols are used for transmitting the signals to/from multiple users.

B.Subchannels in OFDMA

Sub-channels are the smallest granular units in the allocation of frequency domain and are created by grouping subcarriers in an OFDM symbols in various ways. The formation of these sub-channels from subcarriers is an important concept in OFDMA systems. The formation can be classified into 2 types; one is the mapping of a contiguous group of subcarriers into a sub channel called as adjacent subcarrier method (ASM) and the other is the diversity/permutation based grouping called as diversity subcarrier method (DSM) wherein the sub-channel typically contains noncontiguous subcarriers. In ASM method, a sub-channel typically contains a group of contiguous subcarriers and it is expected that the channel frequency responses on the subcarriers in a sub-channel will be strongest correlated. This is based on the fact that subcarriers which fall within the coherence bandwidth have similar responses. In DSM, subcarriers from seemingly random positions in the frequency domain are grouped into a sub-channel. Thus a sub-channel has a potential frequency diversity which can be leveraged when the data to be sent on this sub-channel is suitably coded and interleaved.

II. ANALYSIS OF INTERFERENCE CANCELLATION SCHEMES

A.SI-MUIC Scheme

SI-MUIC stands for Simple Time Domain Multi-User Interference Cancellation Scheme. This scheme is based on multi-FFT receiver. In this each active user is assigned one OFDM demodulator block so that the CFOs can be compensated independently in time domain. The Frequency-Domain Multi-User interference Cancellation scheme that was employed before the SI-MUIC scheme had the disadvantage of power loss. This could be corrected by the SI-MUIC scheme. Assume that the users are sorted in order of their Received Signal Strength (RSS) and the BS processes from the user with the strongest received power to the one with lowest power, thus increases the chances of correct estimation and decoding.

The block diagram of the SI-MUIC Scheme consists of a frequency offset block followed by an IFFT block at the transmitter side. The transmitted signal of serial bits is converted to parallel bits and given to IFFT. Data symbols modulate the spectrum and time domain symbols are obtained using the IFFT. Cyclic Prefix is added to the start of each bit. The main advantage of using the cyclic prefix is to maintain the orthogonality. We know that each user my experience a CFO and in order to eliminate it we employ a method by which certain CFO is added with the transmitted signals and the receiver determines the strongest received signal and the weakest signal is eliminated with the strongest signal. Receiver demodulates the signal with strongest RSS first. Fast Fourier Transform is used in the receiver side where the time domain symbols are converted to frequency domain symbols and data is obtained. Cyclic Prefix is removed here. The output is sent to the decoder section.Successive Interference Cancellation (SIC) algorithm is used here where the feedback from every iteration till the u^{th}user is taken. On each iteration the CFO gets cancelled giving the reduced rate of estimation errors. SIC algorithm in the SI-MUIC scheme is superior to that of the Parallel interference Cancellation (PIC) algorithm that was used in the FD-MUIC scheme.

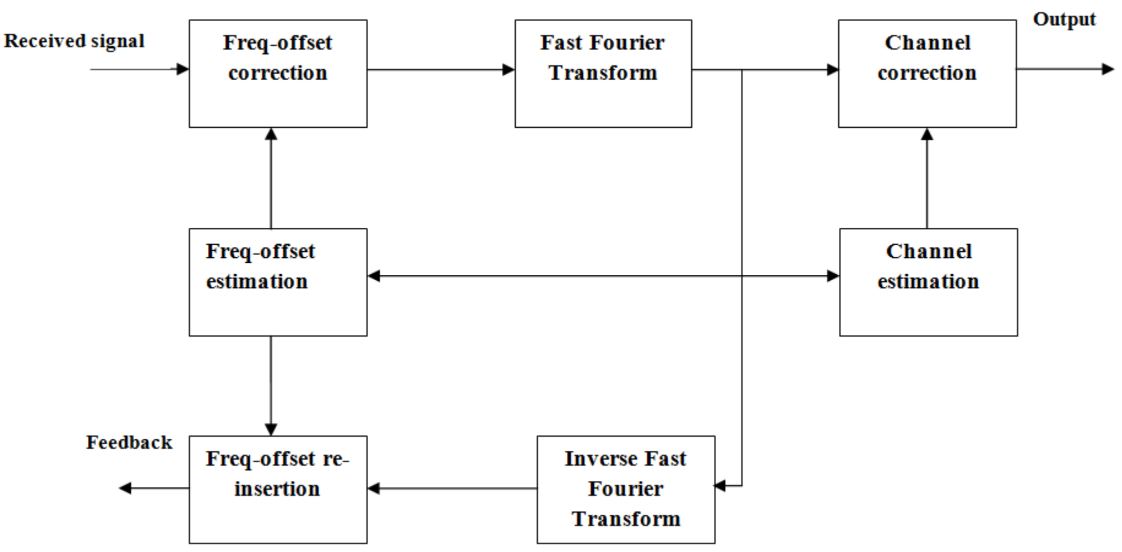

Fig.1 Demodulator block of SI-MUIC Scheme

B.CA-MUIC Scheme

CA-MUIC scheme stands for Code Aided Time Domain Multi-User Interference Cancellation Scheme. It is similar to the SI-MUIC scheme, however differs in the fact that the feedback is added in the scheme at the receiver in order to avoid the residual noise that is appeared in the SI-MUIC Scheme. The main difference between the two schemes is that, instead of output of the OFDMA demodulator, the received signal itself is used to calculate the feedback. For estimating the correct estimate of the received signal and output of the demodulator the carrier transfer function and the transmitted data symbols has to be perfectly estimated.

This method removes all the cross interference terms thus enabling a CFO free performance at the output of the demodulator. In order to achieve the correct estimate of the data symbols, channel coding is applied in the CA-MUIC scheme, thus it is named as code aided TD-MUIC scheme.The main difference in the SI-MUIC scheme with the latter is that the symbol mapping is applied to the CA-MUIC scheme. This provides the reduction in provision for multiple symbols for modulation and increased performance with the reduced CFO.

Channel Estimation in both the above schemes is based on the pilot signal that is sent along with the transmitted signal. The delay subspace is estimated and delay subspace using the Least Mean Square Estimates. Pilot signals are multiplexed along with the data streams to estimate the channels. When the channel is slow fading the channel estimation inside the block can be updated using the decision feedback equalizer at the each subcarrier. The main idea behind such equalization is the use of channel estimate of the previous symbol for the data detection of current estimation and thereafter using the newly detected data for the estimation of current channel.

C. Channel Estimation

Channels are fading both in time and in frequency. Channel estimator has to estimate time-varying amplitudes and phases of all subcarriers. One way to do this is to use a two-dimensional channel estimator that estimates the reference values based on a few known pilot values. In this case, the signal has 4 subcarriers containing known pilot values to allow the estimation.

To be able to interpolate the channel estimates both in time and frequency from the available pilots, the pilot spacing has to fulfil the Nyquist sampling theorem, which states that the sampling interval must be smaller than the inverse of the double-sided bandwidth of the sampled signal. For the case of OFDM, this means that there exist both minimum subcarrier spacing and minimum symbol spacing between pilots.

By choosing the pilot spacing much smaller than these minimum requirements, a good channel estimation can be made with a relatively easy algorithm. The more pilots are used, however, the smaller the effective SNR, becomes that is available for data symbols. Hence, the pilot density is a trade-off between channel estimation performance and SNR loss.

D. Channel Correction

The receiver estimates the channel using the mean square estimate. The user with the strongest RSS is demodulated first and given as input. The channel correction is done as the next section where the estimated CFO (wrong channel) is corrected. This is done by subtracting the feedback from all the users except itself. The result of the channel correction would be the compensation of the CFO of the particular user.

E. Symbol Mapping

During symbol mapping the input data is converted into complex value constellation points, according to a given constellation. Typical constellations for wireless applications are, BPSK, QAM, and 16 QAM. The amount of data transmitted on each subcarrier depends on the constellation. Channel condition is the deciding factor for the type of constellation to be used. In a channel with high interference a small constellation like BPSK is favourable as the required signal-to-noise-ratio (SNR) in the receiver is low. For interference free channel a larger constellation is more beneficial due to the higher bit rate. Known pilot symbols mapped with known mapping schemes can be inserted at this moment.

F. Symbol De-Mapping

When channel estimation is done the complex received data is obtained which are de-mapped according to the transmission constellation diagram. At this moment, FEC decoding and de-interleaving are used to recover the originally transmitted bit stream.

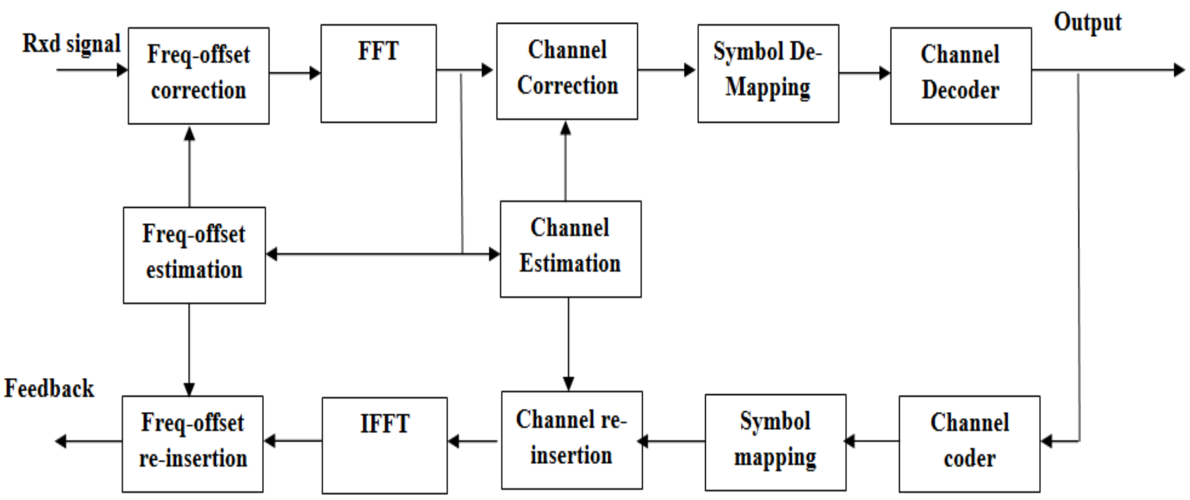

Fig.2 Demodulator block of CA-MUIC Scheme

III. PROPOSED SYSTEM-SPIC

SPIC stands for Selective Parallel Interference Cancellation. In this technique we explain a method to counteract the effect of different frequency offsets of the users in a OFDMA uplink system with frequency selective Rayleigh fading channel. The multiple access interference is reduced by reconstructing and removing the interfering signals. This is done by accomplish Successive or Selective Cancellation. We analyze the performance of these cancellation schemes assuming either ideal or estimated frequency offsets. SPIC, the cancellation is performed on a reliability classification basis. The received signals are divided between reliable and unreliable after a threshold comparison. If the carrier has been evaluated as reliable, it is directly detected, reconstructed and removed from the received signal. For the unreliable carriers, instead, the decision is taken after the cancellation of the reliable ones. The multiple access interference due to the frequency misalignment of the users was removed by using Interference Cancellation. The advantage of this scheme is mainly the reduction of BER followed by the better performance in SNR. Reduction in data loss would be the most notable improvement.

A. SPIC as an effective algorithm

Before the SPIC stages all the signals of the users are ranked according to the signal power. Without the loss of generality we assume that the first user has the strongest received power followed by the second user. The SPIC performs the cancellation of interfering users from the whole received signal based on their relative reliability that is determined by the ranks. In each Interference Cancellation stage all the active users are divided into two groups: one is regarded as the reliable group, the users with the strongest power and the other is the unreliable group with the users of weaker power. Since the users in the reliable group have higher probability to be correctly demodulated, their BER performance will reach to be satisfied with fewer stages than those in the unreliable group. The estimated MUI due to those users is then subtracted from the received signal and the resulting residual signal is used for the detection of the left users in the reliable group, within which the parallel detection is performed to estimate the user's transmitted signal and MUI. Meanwhile, the estimated MAI due to the whole reliable group is also subtracted from the received signal and its residual signal is processed for the detection of the unreliable group. The signals in the unreliable group won't contribute to the cancellation part in the same stage due to its relative lower reliability. The S-PIC combines the advantages of SIC and PIC together. Similar to PIC, its parallel process in each stage reduced the detection delay greatly compared with SIC. With the selective cancellation based on the power rank which is a key feature of the SIC, the "Ping-Pong" behaviour of PIC may be overcome. The computational complexity and processing delay depend on the number of SPIC stages, the size of the reliable group and the necessary cancellation operations at each stage.

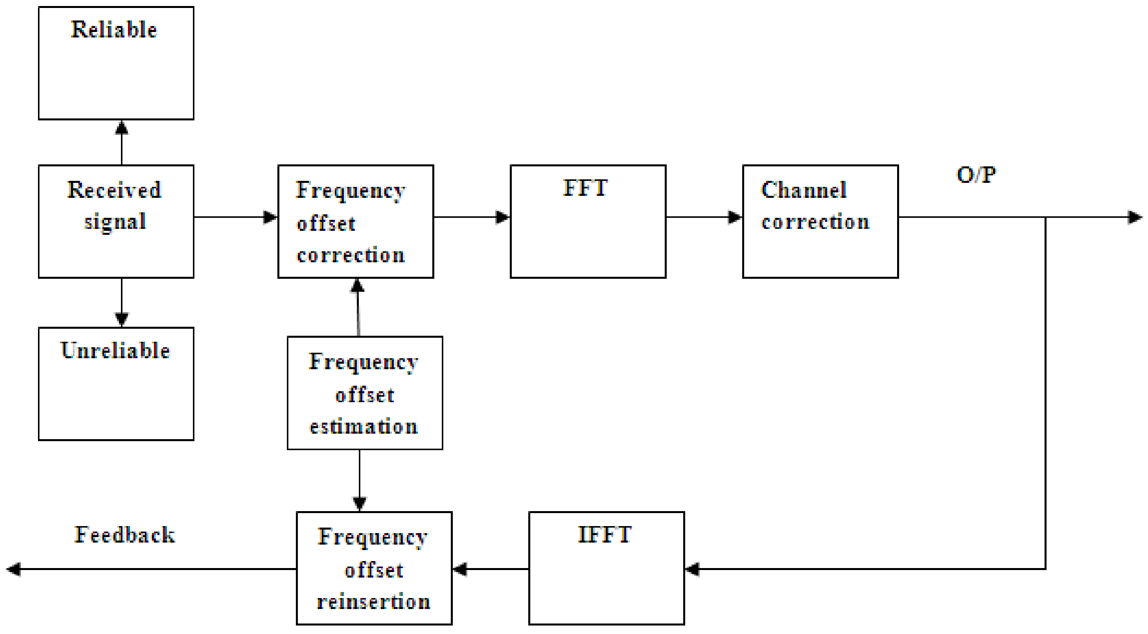

Fig.3. Demodulator Block of SPIC Scheme

4. ANALYTICAL RESULTS

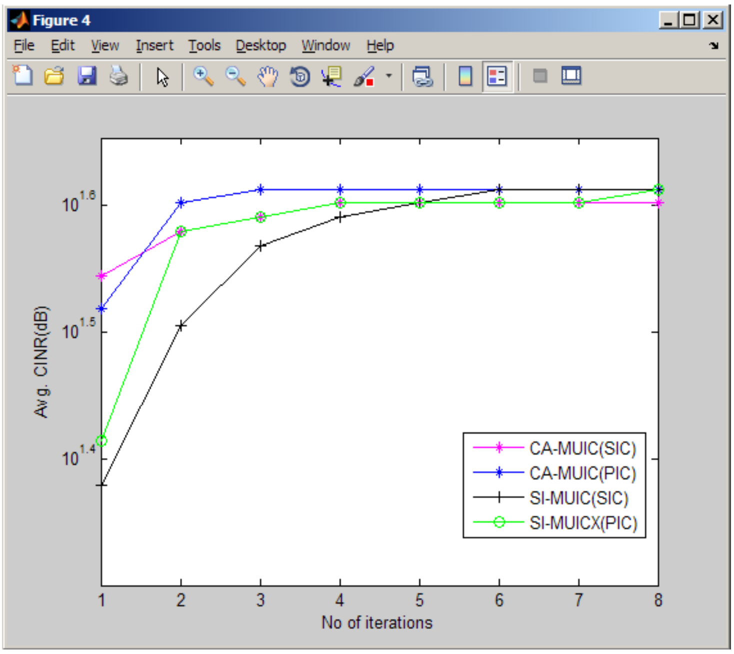

Fig.4. Average CINR v/s No. of iterations

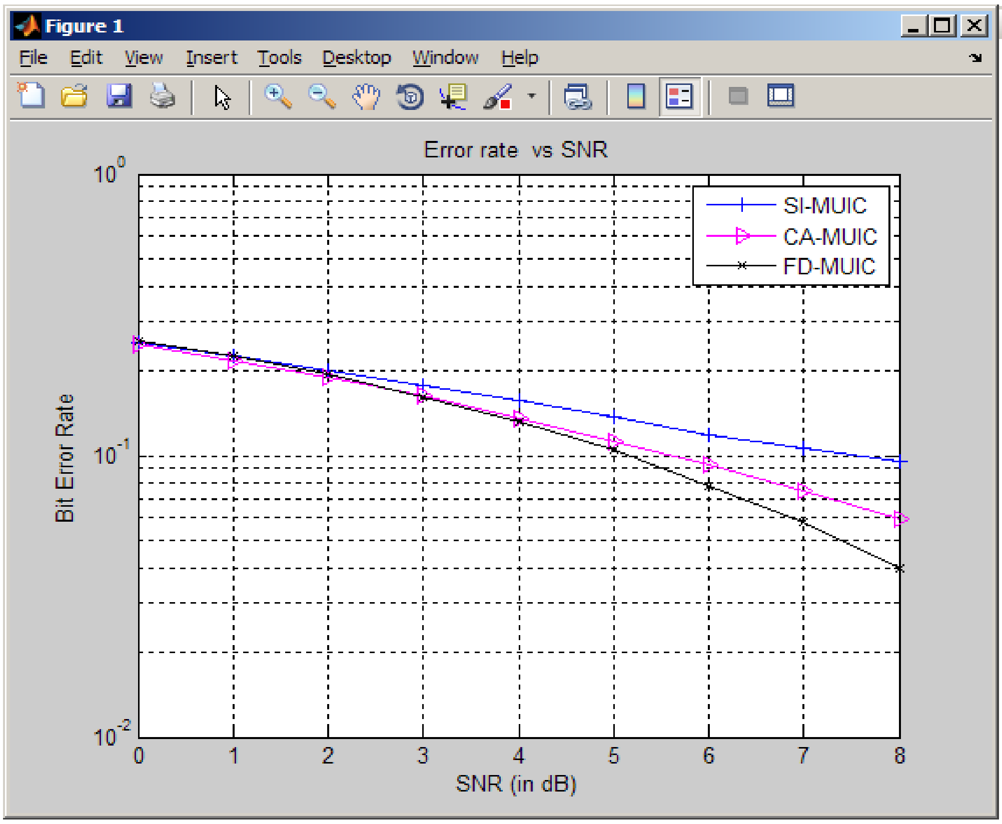

Fig.5. BER v/s SNR of existing system

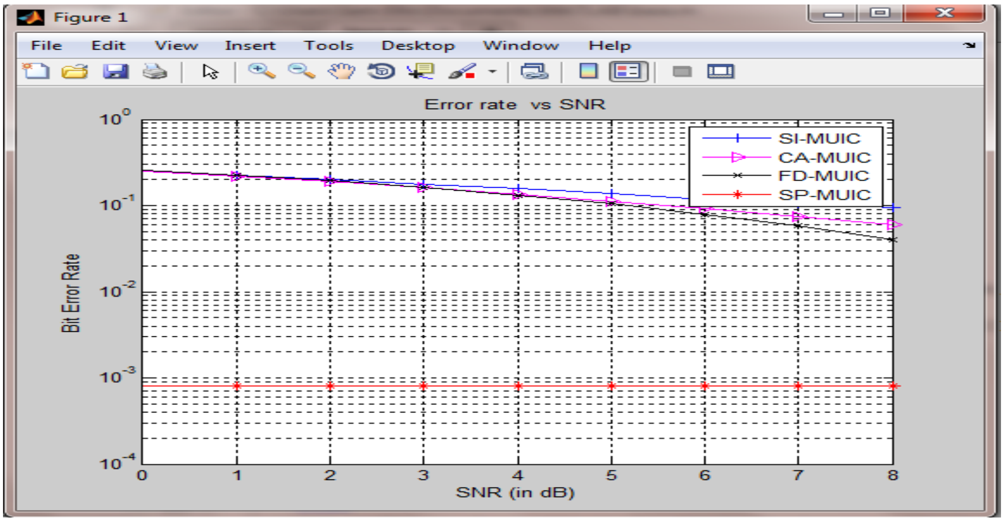

Fig.6. BER v/s SNR of existing and proposed system

V. DISCUSSION

From the results it is evident that the proposed system has a better performance than the existing system. The BER performance of the system is low in the proposed system than the existing interference cancellation scheme. The CINR performance is also improved in the proposed system.

VI. CONCLUSION

This paper has proposed novel MUI cancellation schemes, which are very effective against the effects of multiple CFOs scenario in the uplink of the OFDMA-based system. Analytical and numerical evaluation has shown that the schemes outperform the performance of the conventional OFDMA receiver and the FD-MUIC scheme, for both block and interleaved subcarrier allocations. The proposed schemes are especially useful in scenarios where BS cannot instruct users to adjust their CFO or implementation of such instruction is expensive (e.g. there is no feedback channel or low cost terminal does not have ability to adjust its frequency base accurately). They are compatible with current standard for MS using OFDMA technique, for example the IEEE 802.16, since all changes are transparent for MS. The proposed schemes introduce additional complexity, which can be justified by the fact that the complexity is added only to BS and the lower cost and faster operation of FFT processing chip. The schemes show good performance under practical CFO estimator, and the performance converge after several iterations. However the self-interference problem that could not be corrected is expected to be corrected in the proposed system. The extension of the work is expected to reduce the data loss with improved SNR value and decreased BER. Number of users and the corresponding BER would be calculated.

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