International Journal of Emerging Engineering Research and Technology
Volume 2, Issue 5, August 2014, PP 209-216
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

Subcarrier Based Resource Allocation in I/Q Imbalance Using Water Filling Algorithm

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Abstract: *To suggestively improve the performance with assured Quality of Service (QoS) for multiple users with adaptive resource allocation, a promising technique namely, Multiple Antenna Orthogonal Frequency Division Multiple Access (OFDMA) can be proposed with high downlink capacity in the next generation wireless systems under realistic conditions. A transceiver structure is proposed to reduce the interference among transmitting subcarriers and receiving subcarriers, in terms of Signal Interference and Noise Ratio (SINR), which is evaluated by both analysis and simulation methods. And is incorporated into a recently proposed cooperation strategy to examine its performance under the realistic structure for OFDMA systems. It is shown that although the cooperation strategy suffers from performance degradation due to the residual interference between the transmitting and receiving subcarriers, it still outperforms the conventional cooperation schemes. Moreover, most of the current source allocation algorithms are limited to the unicast system. For multiple antennas OFDMA based systems, the dynamic resource allocation is focused to provide multicast service, whose performance is simulated and evaluated by comparing with unicast system.*

Keywords: *Orthogonal Frequency Division Multiple Access (OFDMA), Multiple Input Multiple Output (MIMO), Water Filling Algorithm*

1. Introduction

To provide broadband multimedia services namely voice, web browsing, videoconference, etc., the next-generation wireless networks are suggested with diverse Quality of Service (QoS) requirements. The two key traffics in wireless multimedia communication are unicast traffics and multicast traffics. Currently, main focus is on unicast traffics with dynamic resource allocation as it is one of the most efficient techniques to achieve better QoS and higher system spectral efficiency [1]. Orthogonal Frequency Division Multiplexing (OFDM) is suggested to provide high data rates in multipath fading environment. Orthogonal Frequency Division Multiple Access (OFDMA) is a multiuser version of the popular OFDM scheme and also known as multiuser OFDM. Many broadband wireless networks have now included Multiple input multiple output (MIMO) [2],[3],[5] technology in their protocols including the multicast system. ComparativelyMIMO offers the higher diversity,over Single Input Single Output (SISO) system, which can potentially lead to a multiplicative capacity enhancement. To improve the system performance in MIMO-OFDM systems, dynamic resource allocation always misuses multiuser diversity gain and is classified into 2 types of problems for optimization: 1) to increase the throughput of the system with the power constraint of the total transmission; 2) With constraints over the data rates or Bit Error Rates (BER) - to decrease the complete transmit power. The dynamic resource allocation algorithms consider unicast multiuser OFDM systems. In wireless networks, many multimedia applications modify to the multicast transmission, from the Base Station (BS) to a group of users. These targeted users of a multicast group will be receiving the data packets of the same traffic flow. The user transmission rate is investigated. For OFDM based multicast systems, the dynamic resource allocation was enlightened, however it is focused on SISO system and cannot be applied to MIMO system directly. For MIMO OFDMA-based wireless multicast systems, a dynamic subcarrier and power allocation algorithmsis proposed. In the suggested algorithms, the subcarriers and powers are dynamically distributed to the multiuser groups. Our objective is to maximize the system throughput, for given total power. Multiusers and each multicast group may have different number of users. The included users in the same multicast group are called co- group users and these can be located in different places in the cell.

1.1 Co-operative MIMO OFDM

In MIMO terminology, the "Input" and "Output" are referenced to the wireless channel, which includes the antennas. Performance gains are achieved as multiple transmitters simultaneously input their signal into the wireless channel and then combinations of these signals simultaneously output from the wireless channel into multiple receivers [5].

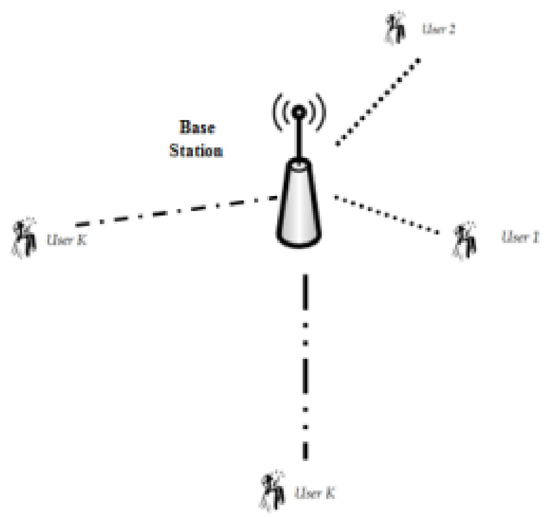

Fig 1. *Co-Operative Multi Users in MIMO-OFDM [5]*

For downlink communication, a single Base Station (BS) would contain multiple transmitters connected to multiple antennas and a single Mobile Station (MS) would contain multiple antennas connected to multiple receivers.Like the relationship between OFDM and OFDMA, MU-MIMO (and, similarly, Space Division Multiple Access (SDMA))can be assumed of as an escalation of MIMO applied as a multiple access strategy [6] in various ways. Prominent difference is that the functioning of MU-MIMO relies on pre-coding capability than OFDMA, otherwise MU-MIMO is not [6]. Multiple accesses MIMO, technologies leverage multiple users as a degree of freedom in achieving successful radio transmission [5,6].

1.2 Subcarrier Resource Allocation

Since the cooperative scheme require that subcarrier-based duplexing can be achieved, we will focus on the feasibility of subcarrier-based duplexing in this section to understand the tradeoffs and limitations that would occur in the cooperative OFDMA systems considered. The orthogonality between subcarriers is partially lost in OFDM systems due to the non-ideal characteristics of different subsystems (e.g., nonlinearity of power amplifier, frequency offset of local oscillator etc.), resulting in signal leakage between subcarriers or inter-carrier interference (ICI). When a user is operating in subcarrier-based duplexing mode, due to the enormous difference in the power of the transmitting signal and desired signal, the effect of ICI on the receiving subcarriers could be significant, which should be taken into account in the cooperative OFDMA system [7], We will consider a user operating in subcarrier-based duplexing mode and look into the effects of the non-ideal subsystem characteristics on its performance. Then we will propose a transceiver structure that uses baseband echo cancellation to suppress the interference between transmitting and receiving subcarriers caused by these subsystem imperfections. For ease of notation, we will use “far end signal” and “near-end signal" to denote the desired signal (transmitted from other user(s)) and the signal transmitted by the user itself, respectively [8].

1.3 Echo Cancellation Process

When we transmit full-duplex data, the primary problem is undesired feed-through of the transmitted data signal into the receiver through the hybrid [10]. This extraneous signal is called *echo*. Where the mechanism for echo was stated to be a mismatch between the impedance of the two-wire cable and the hybrid balancing impedance [10]. The echo cancellation method of full-duplex transmission is illustrated. There is a transmitter (TR) and receiver (REC) on each end of the connection, and a hybrid is used to provide a virtual four-wire connection between the transmitter on each end and the receiver on the opposite end.

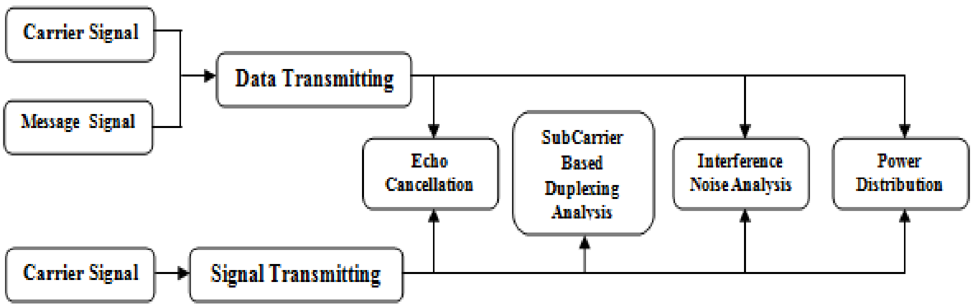

Fig 2. *Echo Cancellation Using Duplexing in MIMO OFDM [11]*

As shown in the fig:2 The echo canceller is an adaptive transversal filter that adaptively learns the response of the hybrid, and generates a replica of that response which is subtracted from the hybrid output to yield an echo-free received signal [11].

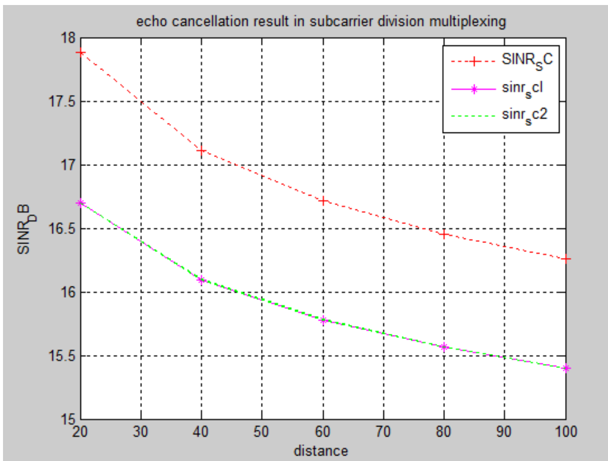

Fig 3(a). *Performance of the proposed transceiver with localized subcarrier allocation*

1.4 Interleaved Sub Carrier Analysis

In this paper our interest lies in the performance of cooperative OFDMA systems under subcarrier-based duplexing and in particular the tradeoffs and limitations in realistic configurations [12]. To perform this we make use of a transceiver structure that utilizes baseband echo cancellation to suppress the interference among the subcarriers of transmitter and receiver. The performance of this transceiver is verified by analysis and computer simulation, and it is shown that it is possible to achieve subcarrier-based duplexing in short-range low-transmit-power communication systems (e.g., 802.11a/g systems) with careful design. This scheme is then incorporated into the cooperation strategy of [10] to investigate its performance under realistic conditions. It is revealed that although the performance of the cooperative network is degraded due to the residual interference imposed on the receiving subcarriers by the transmitting subcarriers, it still performs better compared with conventional cooperation schemes [11].

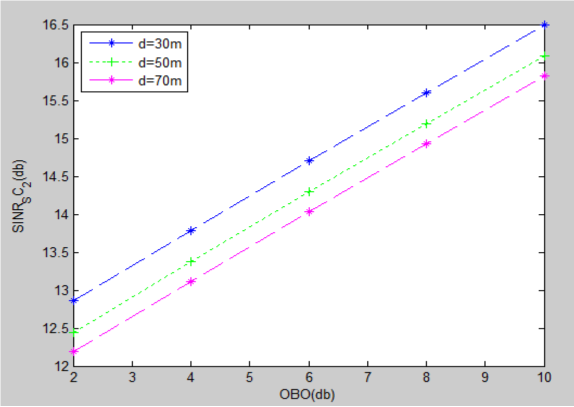

Fig 3(b). *Performance of the proposed transceiver for different levels of phase noise (interleaved subcarrier assignment)*

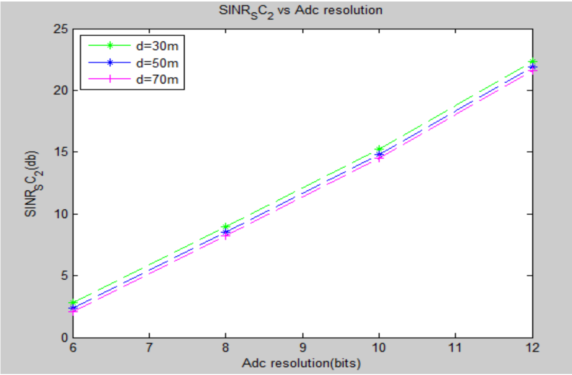

Fig:3(c). *Performance of the proposed transceiver for different degrees of PA nonlinearity (interleaved subcarrier assignment)*

Power Distribution Process

When the data rate of user 1 and user 2 varies while *d*10 is fixed to be 50m. It can be seen that the difference between the power consumption of DF cooperation in the ideal case and that in the realistic case increases with the data rate [8-10]. The reason is that the transmit power of user 1 increases with the data rate, therefore more interference is generated to the data streams from user 2 to user 1, and user 2 needs to scale up its transmit power in order to compensate for the SINR loss. As the data rate increases, the extra transmit power required by user 2 also increases, thus the total power consumption of optimal DF cooperation will finally exceed that of AF&DF cooperation and that of no cooperation.

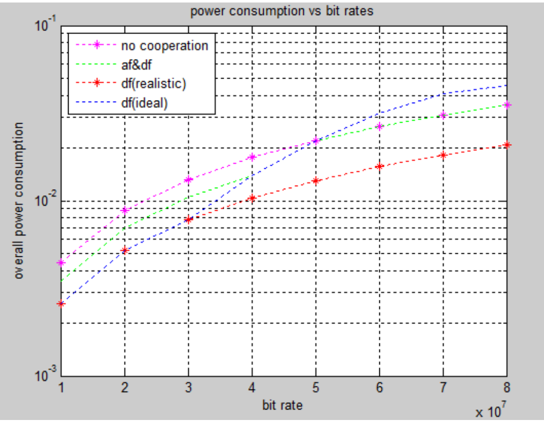

Fig 3 (d). *Total power consumption of 2-user cooperative OFDMA system for different data rates*

We also consider a 4 user system, where the Base Station is located at the origin of a 2-D plane, while the co-ordinations of user 1,2,3 and 4 are (50m, 50m), (50m,-50m), (100m,50m) and (100m,-50m) respectively. User 1 and 2 help relay the messages of user 3 and 4. The data rate of user 1,2,4 are 20Mbps, and the data rate of user 3 changes between 0 and 40Mbps. It is shown in Fig. 6(a) that optimal DF cooperation is better than AF&DF cooperation. The overall power consumption of optimal DF cooperation under realistic condition is at-least 25% less than that of the AF&DF cooperation scheme, which again demonstrates the advantage of the optimal DF cooperation scheme over the conventional schemes.

1.5 Power Allocation in MIMO-OFDM

The concept of water filling can be adapted over multiple users, where one resource can be allocated to one user [13]. However, the ideal solution's computational complexity is overthrown, because of the 2 problems.One is assigning users to resources and the other is to distribute user's transmitting power budget. The important constraint for real world application for the ideal solutionis maximizing the sum of throughput, which often interprets to - cell-edge users with a bad channel get practically no throughput at all [15].

This opposes typical radio system design, in which most important design challenges is to reliably serve cell-edge users. Shannon's equation is not applicable to extremes SNR range [14]. That is, an SNR below -2 dB cannot be achieved with modulation and coding. Water filling manages to spread the available power over the broadest possible bandwidth, operating at very low SNR's

2. WATER FILLING ALGORITHM

As shown in the fig:4 users are assigned in anfashion of Round-Robin and the best available channel is temporarily allocated to the current user. Since the best resource is picked first, for each additional resource [15] SNR is reduced. Below a defined threshold SNR drops.Resources can be limited to improve the performance and each cell edge users, takes the power budget as an parameter at the expense of sum throughput [14].The mode parameter switches between fixed-power allocations. Optimizing power allocation by replacing iterative "Water Fill (WF)" subroutine with, one that splits power equallyamong resources allocated to the user.

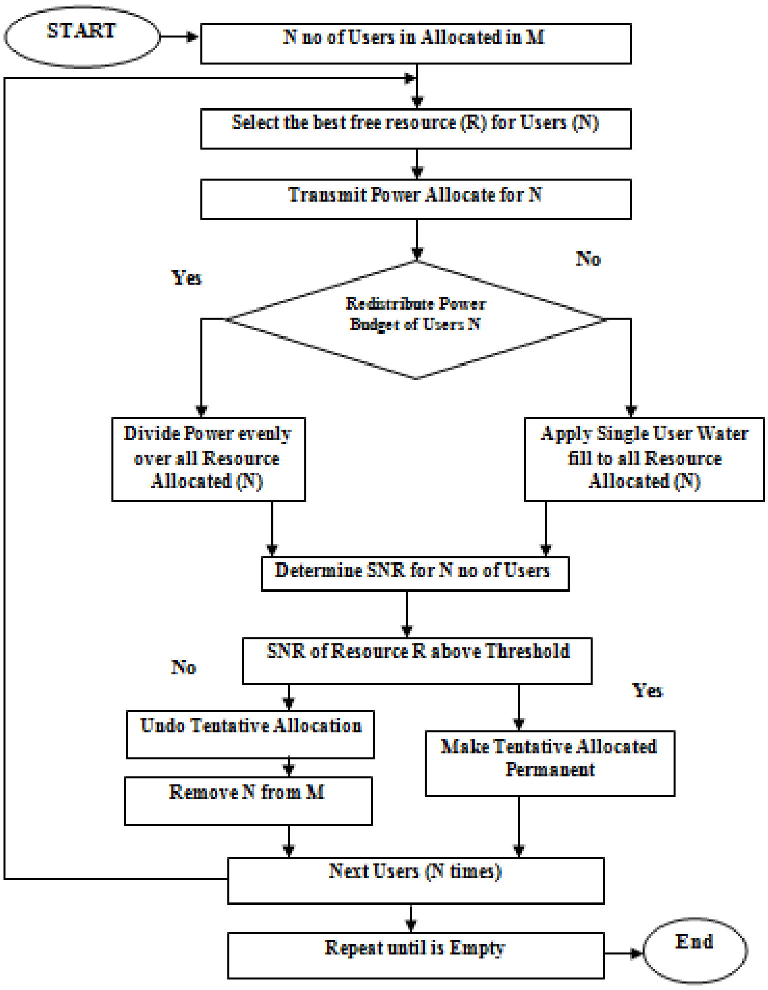

Fig 4. *Water filling Process Flow Chart on MIMO OFDM System [14]*

Water-filling Algorithm

- Round-Robin fashion is used to handle and the best free channel is assigned to the current user. Since the most free channel is considered first, the SNR reduces for each additional resource. If threshold drops below a user defined value the process halts
- To improve the performance at cell-edge users number of channels or bandwidth available for any number of users can be limited at the expense of sum throughput
- Power budget of each user is considered as a parameter in the algorithm.
- The mode parameter switches between fixed-power allocations. Further optimization of code for fixed power distribution by replacing the iterative "water fill (WF)" subroutine with any otherwhich splits power evenly channel allocated users.

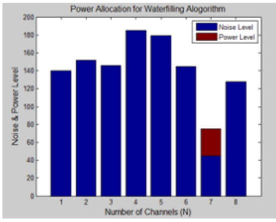

Fig:5(a):N=8 in Power Allocation

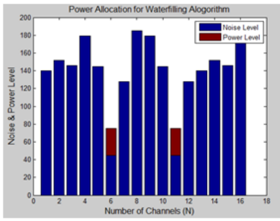

Fig:5(b):N=16 in Power Allocation

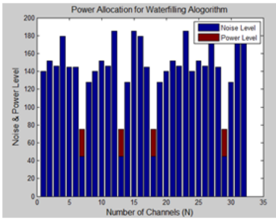

Fig:5(c):N=32 in Power Allocation

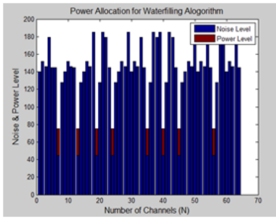

Fig:5(d):N=64 in Power Allocation

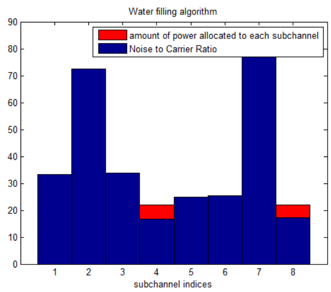

Fig 5(e). *Power Allocation Process in MIMO OFDM*

3. Result Analysis

We incorporate the subcarrier-based duplexing scheme investigated in the previous section into the cooperation strategy to investigate its performance.To make the comparisons more meaningful we use the sameconfiguration as. In particular we consider an OFDMAsystem with 20MHz bandwidth and 512 subcarriers, i.e.,N= 512. The Cyclic Prefix(CP) length is chosen to be 64. A raised cosinefilter with roll off factor of 0.2 is used for pulse shaping. Theother parameters including those of the subsystem imperfections used in the simulation are the same as those used inthe previous section. For each channel realization, we firstlyassume perfect isolation between different subcarriers andobtain the optimal power and subcarrier allocation strategy asin (the ideal case). The power and subcarrier assignmentis then incorporated into the simulation of the previous sectionto obtain the SINR values of the data streams from the sourcenodes to the relay nodes in the realistic model [5-8]. Since theseSINR values are lower than the ideal SNR values, we scale upthe transmit power of the source nodes on the correspondingsubcarriers by a factor of SNR/SINR to compensate for this loss [12, 13]. The overall power consumption of cooperative OFDMA systems under realistic conditions can be obtained. In the MIMO-OFDM system with water filling algorithm of resource Power allocation needs lesserpower compared to the existing system of the capacity for the existing system and the proposed system. From the figure 6, it is clear that there is an improvement in channel capacity of MIMO-OFDM, by implementing the water filling solution to achieve capacity maximization, which is also used to allocate different powers to the sub channels. Fig 5(a,b,c,d,e) demonstrates the channel capacity versus SNR for different MIMO-OFDM systems [15]. The graphgives capacity of the MIMO-OFDM channel increases as the antennas number used at both the transmitter and the receiver increases. 4x4 MIMO systems provide better channel capacity, stating that the higher order MIMO increases the system performance and it almost remains same for the lower order (2x3 MIMO and 3x2 MIMO) systems.It compares MIMO with water fillingwith better performance and SISO systems.

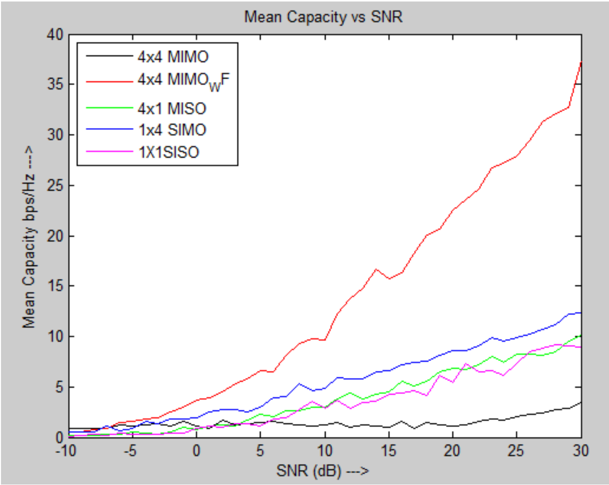

Fig 6(a). *Capacity Ananlysis of SISO,SIMO.MISO,MIMO,MIMO-Waterfilling Process in Signal to Noise Ratio*

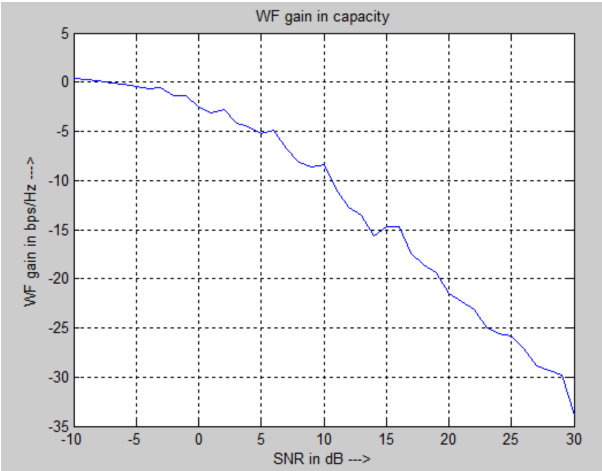

Fig 6(b). *Waterfilling Gain Process in Signal to Noise Ratio*

4. Conclusions

A particular subcarrier resource allocation approach investigated in this paper is a method based on nodes that transmit and receive on adjacent OFDM subcarriers simultaneously. To perform the investigation we proposed a transceiver structure that allows OFDM users to transmit and receive simultaneously on adjacent subcarriers so that the system tradeoffs and limitations of this approach could be understood. The performance of the transceiver was evaluated by both analysis and computer simulation and it was shown that the non-ideal characteristics of subsystems will limit the achievable SINR. In particular our investigation shows that the effects of quantization error and LO phase noise are more significant than other subsystem imperfections such as PA nonlinearity and Tx I/Q imbalance.Some of the capacities of multicast and unicastschemes are shown for multiple antenna OFDMsystems. Among the users, it is believed that there is no channel power. If 4 users receive the same contents, in the multicast systems, unicast system users contentsare different from each other. M by N multicast and unicast system means that M users receive the same contents as one group and the left Nusers receive different content (i.e., 2x2 multicast and unicast systems means 2 users has same content while the other 2 users are grouped into unicast).Higher capacities are observed in multicast systems than unicast scheme or the other mixed cases. Lesser number of users in a system can achieve higher system capacities.

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