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A Review on Relay Selection Techniques in Cooperative Communication

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Abstract –**Interest for high data rates is expanding quickly for the future wireless generations, because of the prerequisite of universal coverage for wireless broadband services. More base stations are expected to convey these services, keeping in mind the end goal to adapt to the expanded limit request and intrinsic unreliable nature of remote medium. Moreover, this would straightforwardly compare to very high basis expense and energy utilization in cellular systems. Recently, high power utilization in the network is turning into a matter of sympathy toward the administrators, both from financial and ecological perception. Cooperative communication, which is viewed as a virtual Multiple-Input-Multiple-Output (MIMO) channel, can be extremely proficient in contending with fading multipath channels and enhance scope with complexity and cost. With its spread structure, cooperative communication can likewise add to the energy productivity of wireless systems without any restrictions. Utilizing network coding at the highest point of cooperative communication, uses the network resources more effectively. A lot of research has concentrated on highlighting the additions accomplished by utilizing network coding as a part of cooperative communication. Relay selection is a method that can significantly increase the performance of cooperative communication. This paper provides a review on relay selection techniques in cooperative communication**

Keywords – **Cooperative communication, MIMO, Relay selection.**

I. INTRODUCTION

Diversity obtained through multihop transmissions is usually referred to as cooperative diversity [1]. Diversity is a very powerful technique to increase robustness against channel fading. Cooperative diversity is a kind of spatial diversity that can be obtained without multiple transmit or receive antennas. It is especially useful when time, frequency, and spatial diversity through multiple antennas are not feasible. The first examples of practical cooperative diversity protocols were studied by Laneman et al. [2]. It was shown that diversity relaying has the potential to improve end-to-end (e2e) performance in slow fading environments despite the penalty of relaying in terms of bandwidth expansion.

Since the source node in the cooperative communication scheme depends on the relay nodes to forward the transmission, relay selection and resource allocation for the relay nodes become important in order to obtain optimal performance of the cooperative communication system. By choosing the right nodes to relay the transmission, the system can achieve higher capacity by using lower resources.

The overall concept behind cooperation in wireless communications is to make the independent, and by nature non-cooperative, users of the network share their limited resources. Cooperation can be classified as implicit or explicit. Implicit cooperation is a primitive form of cooperation and does not require any pre-established cooperative framework. A wireless communication protocol can be considered an implicit cooperation protocol if it applies rules for medium sharing among users (for example ALOHA).

On the other hand, explicit cooperation obliges advanced cooperative protocols to be pre-inveterate. In this type of cooperation, the components of the framework are coordinated to collaborate by these protocols. Cooperation is also extended to the relaying procedures, which are targeted to extend the coverage range of the communication systems. The simplest topology where cooperative procedures occur in is a network which consists of three independent terminals/devices (Figure 1). Out of these three terminals one acts as the source terminal (S) of the signal, the other acts as a relaying terminal (R), which conveys the signal, and the last is the destination terminal (D).

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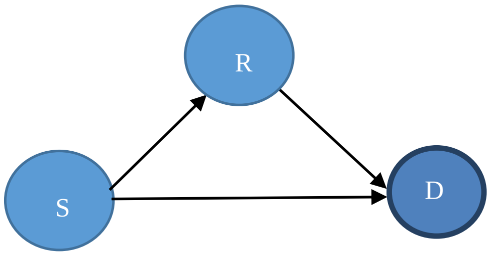

Figure 1: Cooperative Communication

This paper gives brief overview of relay selection techniques which can be applied in cooperative communication. It also presents a detailed literature review of recent papers in third section.

II. Relay Selection Techniques in Cooperative Communication

In cooperative communication, to choose the relay or partner or set of them, is the challenging task. The proper selection of the relay can effectively improve the overall performance of the network in terms of higher data rate/through put, lower power consumption and better bit error rate performance. The relay is based on the performance indices like Channel state information (CSI), Signal to noise ratio (SNR), Bit error rate (BER) etc. The relay is not to be selected by only considering the source to destination performance but it must be done by keeping the overall system performance in view. The relay selection can be classified as follows:

Group Selection: In this method, relay selection occurs before transmission. The purpose of selection is to achieve certain pre-defined performance level.

Proactive Selection: In this method relay selection is performed by the source, the destination, or the relay itself during the transmission time.

On-Demand Selection: Here relay selection is performed when needed i.e. when direct channel conditions decrease below a pre-defined threshold.

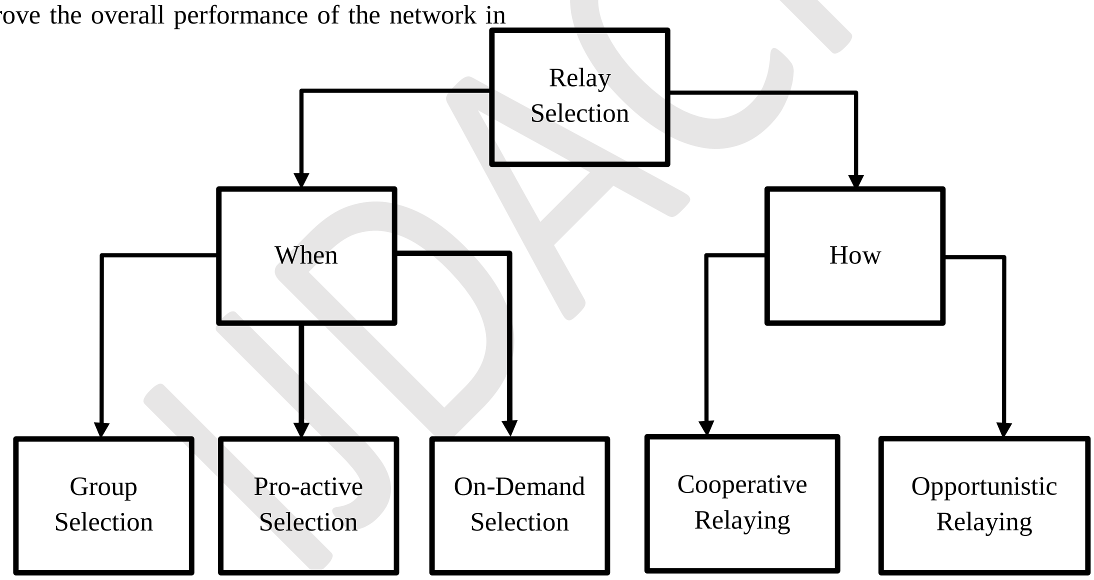

Figure 2: Classification of Relay Selection

Depending on the relation between the network entities, relay selection mechanisms can be divided into two categories:

- Opportunistic Relay Selection.
- Cooperative Relay Selection.

The basic opportunistic relay selection scheme is based on local measurements. They can be further classified as:

- Measurement-based relay selection.
- Performance-based relay selection.
- Threshold-based relay selection.

All these three approaches are opportunistic and follow a proactive selection approach. The on-demand selection category (e.g. Adaptive relay selection) follows a different approach, in which the relay selection procedure is only triggered if needed. Contrary to opportunistic relay selection, cooperative relay selection procedures require the exchange of information among the involved communication nodes. In this case there are two categories:

- Table-based relay selection that leads to the selection of a controlled number of relays

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(one or two) based on information kept by the source.

- Contention-based relay selection that leads to the selection of a set of a variable number of relays.

Measurement-based Relay Selection

Measurement-based relay selection approaches are characterized by requiring no topology information, being based only on local measurements of instantaneous channel conditions. This technique is proposed by H. Shan [3]. Measurement-based approaches are able to select the best relay among N devices, but for this they may require 2N channel state estimations. In measurement-based selection, each potential relay estimates channel conditions of source-relay and relay destination channels by using RTS/CTS signalling. CSI estimation is based on fading amplitudes between source-relay and relay- destination and on the expected performance of the source-relay-destination channel. After CSI estimation, each relay sets a transmission timer to a value inverse to the estimated CSI value. The timer with the best suitable CSI expires earlier, qualifying that device as relay. Devices in listening mode will back off as soon as they overhear a short duration packet sent by the qualified relay. To avoid the case of "hidden" relays, the qualified relay may request the destination to notify all the other potential relays about its transmission.

Performance-based Relay Selection

Performance-based selection approaches rely on performance criteria like delay and energy efficiency to select the most suitable relay [4]. The operation of performance- based selection approaches is as follows: In a first phase, sources transmit their required performance level, and in a second phase all potential relays estimates their channel conditions as well as performance level. However, estimation overhead may bring some limitations to performance-based approaches, and the transmission may still occur over the direct link if the performance conditions are not met.

Threshold-based Relay Selection

Threshold-based approaches rely on a certain threshold to reduce the number of competing relays, and thus reducing the overhead of channel estimations. This class of relay selection can be opportunistic or cooperative. The relay selection involves two phases. In a first phase, each neighbour compares the quality of signal it received from the source with a threshold such as SNR [5] or BER [6]. In a second phase, only relays that satisfied the threshold requirements will enter into relay selection according to the algorithm. For instance, the node with the maximum lower value of the SNR in the source-relay and relay-destination links is selected as relay. This category of schemes may lead to some complexity, for instance, when all M relays satisfy the threshold, there will be 2M channel estimations. Another problem is the choice of the threshold value; if it is fix then relay selection mechanism is unable to react to variations on channel conditions.

Adaptive Relay Selection

Due to variations on channel conditions the PER of the link from source to destination may decrease in a way that relaying over a helping node is not needed. Adaptive relay selection approaches propose to perform relay selection only if relaying is needed with high probability. An example of adaptive relay selection is Adam et al. [7]. The operation of adaptive relay selection approaches is as follows: in a first phase the destination compares the quality of received signal with a pre-defined threshold. If the quality of received signal is below that threshold, then the relay selection process is triggered. Adaptive schemes should address the transmission collision problem and should take more advantage of spatial diversity. Moreover, thresholds at destination need to be optimal to guarantee fast reaction to channel variations.

Table-based Relay Selection

Table-based approaches [8] follow a cooperative relay selection process aiming to decrease the impact of relay selection on transmission time. Here sources keep CSI information about the links between themselves and potential relays as well as about the links from potential relays and each potential destination. The CSI information is gathered using RTS/CTS frames as well as information collected from overhead transmissions. Relays are selected by the source by looking up in a table. A node may be selected as relay if the transmission time over the direct link to a destination is higher than the sum of the transmission time over the source-relay and relay-destination links. The usage of RTS-CTS frames is also different. In [8], the cooperative-RTS which is sent by the source to the relays and by the latter to the destination to show their willingness to cooperate. If the destination finds that such cooperation is beneficial via both relays, it sends cooperative-CTS to the source. Table-based approaches present degradation problems in the presence of moving nodes. Another problem with

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this class is the periodic broadcast and extra handshaking signals which can limit the efficiency.

Multi-Hop Relay Selection

The most common relaying approach in the literature is to select a relay (or a set of relays) to help a transmission from a sender to a destination over a direct poor wireless link. When applied to multi-hop networks, this method requires the repetition of the relay selection procedure for each hop from sender to destination. However, such hop-wise cooperation can reduce network capacity. The operation of multi-hop relay selection approaches is as follows: Potential relays access routing information (from the local network layer) creating a limited image of the network beyond the adjacent wireless links (typical two hops). By overhearing transmissions over the identified network, potential relays may decide to relay overheard information to potential destinations, even in the absence of a direct link between the source and destination of the packet. This means that relays may have received the information to be relayed directly from the source or from other relays or intermediary nodes (routers) In multi-hop relay selection, the destination node may receive more than two independent signals of the same packet e.g. directly via the source, via the intermediary node identified by the routing protocol and via the selected relay node. This extra spatial diversity increases robustness and performance. However, the price to pay is the extra network overhead to transmit redundant information, and the cross layering needed to collect routing information, which may not be updated with the frequency require to react in environments with mobile devices.

III. LITERATURE REVIEW

Table 1: Comparison table of different researches

Authors	Research Name	Description
J. N. Laneman, G. W. Wornell	Energy-efficient antenna sharing and relaying for wireless network	This paper develop energy-efficient transmission protocols for wireless networks that exploit spatial diversity created by antenna sharing: coordinated transmission and/or processing by several distributed radios. This research paper is focused on single-user transmission and examine several possibilities for the strategy employed by the assisting radio, or relay, including decoding and forwarding as well as amplifying and forwarding. In each case, authors develop receivers based upon maximum-likelihood and/or maximum signal-to-noise ratio criteria, relate their structures, and compare their bit-error probability performance by means of analysis and simulations. The paper cast single-hop and multihop routing into the proposed framework for comparison purposes. All of antenna sharing protocols offer diversity gains over single-hop and multihop transmission, and results suggest that low-complexity amplifying and forwarding is energy-efficient in spite of noise amplification at the relay [9].
A. K. Sadek, Z. Han, and K. J. R. Liu	A distributed relay-assignment algorithm for cooperative communications in wireless networks	A crucial challenge in the implementation of a cooperative diversity protocol is how to assign source-relay pairs. This paper address this problem under the knowledge of the users' spatial distribution and proposed a distributed relay-assignment algorithm for cooperative communications. In the proposed algorithm, the relay is chosen to be the nearest neighbour to the user towards the base-station (access-point). An outage analysis for the proposed scheme is provided under a random spatial distribution for the users, and an approximate expression for the outage probability is derived. Simulation results for indoor wireless local area networks (WLAN) are provided. By utilizing this protocol, simulation results indicate a significant gain in coverage area over the direct transmission scheme under fairly the same bandwidth efficiency and fixed average transmitted power. A 350% increase in the coverage area can be achieved by the distributed Nearest-neighbour protocols. This coverage increase can also be translated to energy efficiency over direct transmission when fixing the total coverage area [10].
A. Bletsas, A. Khisti, D. P. Reed, and A. Lippman,	A simple cooperative diversity method based on network path selection	Cooperative diversity has been recently proposed as a way to form virtual antenna arrays that provide dramatic gains in slow fading wireless environments. However, most of the proposed solutions require distributed space-time coding algorithms, the careful design of which is left for future investigation if there is more than one cooperative relay. This paper proposed a scheme that alleviates these problems and provides diversity gains on the order of the number of relays in the network. This scheme first selects the

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		best relay from a set of M available relays and then uses this "best" relay for cooperation between the source and the destination. This paper develop and analyze a distributed method to select the best relay that requires no topology information and is based on local measurements of the instantaneous channel conditions. This method also requires no explicit communication among the relays. The success (or failure) to select the best available path depends on the statistics of the wireless channel, and a methodology to evaluate performance for any kind of wireless channel statistics, is provided [11].
D. S. Michalopoulos, G. K. Karagiannidis, T. A. Tsiftsis, and R. K. Mallik	An optimized user selection method for cooperative diversity systems	Multi-user cooperative diversity is a recent technique promising great improvement of the performance of wireless communication systems operating in fading environments. Based on combinatorial optimization theory and specifically on the so-called knapsack problem, this paper presents a method of optimizing the selection among the potential cooperating users, when amplify-and-forward relays are used. In particular, two optimization problems are studied: the error probability minimization subject to total energy consumption constraints, and the dual one, the energy consumption minimization under error performance constraints. Depending on the frequency of repeating this selection, the above problems are categorized into short-term and long-term node selection. Numerical examples verify the expected knapsack scheme's advantage of adapting the number of cooperating users, depending on the desired performance-consumption tradeoff. Moreover, long-term node selection seems to lead to similar error or consumption performance compared to the short-term one, despite its simplicity [12].
W. P. Siriwongpairat, T. Himsoon, W. Su and K. J. R. Liu	Optimum Threshold-Selection Relaying for Decode-and-Forward Cooperation Protocol	This paper proposes a threshold-selection relaying scheme, in which each relay decides whether to forward the source information by comparing the received signal power with a decision threshold. The challenging problem is to design the threshold such that the relay is able to forward only correctly decoded information. In this work, Bit-Error-Rate (BER) performance analysis is provided for the proposed scheme with BPSK signals. This paper develop a BER upper bound which is tight over the entire range of signal-to-noise ratio values. Based on the established BER formulation, it jointly determine optimum decision threshold and power allocation. An interesting result is that the effect of optimum threshold dominates that of optimum power allocation, especially when the relay is close to the destination. For example, in case of equal power allocation, the proposed scheme with optimum threshold yields 10 dB performance improvement over the fixed relaying scheme without Q threshold at a BER of 10^{-2}. If both the power allocation and the threshold are jointly optimized, then the performance of the proposed scheme can be further improved by 2 dB [13].
K.-S. Hwang and Y.-C. Ko	An Efficient Relay Selection Algorithm for Cooperative Networks	Recently, the cooperative diversity systems, based on the distributed space-time coding (DSTC), have been presented to provide the spatial diversity gain in the wireless networks. Although the performance of DSTC cooperative diversity systems is quite attractive in terms of the link performance, the complexity and the power consumption at each node are the main practical issues for the deployment of the systems, in particular, when the number of nodes is large. This paper proposes the suboptimal relay selection algorithm where a predetermined threshold is set both at the relay node and the destination node, and the node selection is performed only when the signal quality of either relay node or destination node is below a predetermined threshold, which has less complexity than the opportunistic relaying in while satisfying the required performance. This paper provide the closed-form expression of statistics of the output SNR and study the complexity of the proposed scheme. Based on analytical results this paper shows several selected numerical examples to show the efficiency of proposed schemes [14].
O. S. Shin, A. Chan, H. T. Kung, and V. Tarokh	Design of an OFDM co-operative diversity system	This paper proposed a wireless system that realizes theoretical benefits of space-time cooperation. Specifically, it designs a space-time cooperative system based on orthogonal frequency division multiplexing (OFDM), which refer to as a cooperative (CO)-OFDM system. This design includes a two-phase space-time cooperation protocol, as well as a transmitter and receiver architecture that facilitates cooperation. Furthermore, it develop a frame structure, on which it build practical timing and frequency synchronization algorithms and a channel estimation algorithm. In particular, the proposed

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		frequency synchronization algorithm utilizes the underlying structure of the cooperation protocol, and the proposed channel estimation algorithm is based on a pairwise orthogonal construction of two sequences. This paper validate the performance of the proposed synchronization and channel estimation algorithms through simulations. Then present simulation results that demonstrate the overall performance advantage of the CO-OFDM system over an OFDM system without cooperation, not only under idealistic assumptions but also under realistic situations where the proposed algorithms are employed [3].
Adam, H., Bettstetter C., Senouci S. M.,	Adaptive relay selection in cooperative wireless networks	The concept of cooperative relaying promises gains in robustness and energy-efficiency in wireless networks. Although protocols for cooperative relay selection were proposed recently, their analysis was made without consideration of the energy required for receiving. Such an analysis is unfair, as relaying requires more receptions than direct source-destination transmission. This paper consider this lack of analysis and propose two refinements of cooperative relaying. Using ldquorelay selection on demand, rdquo relays are only selected if required by the destination. Using ldquoearly retreat, rdquo each potential relay assesses the channel state and decides whether to participate in the relay selection process or not. Simulation results show that these enhancements reduce the overall energy consumption significantly [7].
Y. Jing, H. Jafarkhani,	Single and Multiple Relay Selection Schemes and their Achievable Diversity Orders	This paper is on relay selection schemes for wireless relay networks. First, it derive the diversity of many single-relay selection schemes in the literature. Then, it generalize the idea of relay selection by allowing more than one relay to cooperate. The SNR-optimal multiple relay selection scheme can be achieved by exhaustive search, whose complexity increases exponentially in the network size. To reduce the complexity, several SNR-suboptimal multiple relay selection schemes are proposed, whose complexity is linear in the number of relays. They are proved to achieve full diversity. Simulation shows that they perform much better than the corresponding single relay selection methods and very close to the SNR-optimal multiple relay selection scheme. In addition, for large networks, these multiple relay selection schemes require the same amount of feedback bits from the receiver as single relay selection schemes [4].
S. S. Ikki and M. H. Ahmed	Performance analysis of generalized selection combining for amplify-and-forward cooperative-diversity networks	This paper consider an amplify-and-forward (AF) cooperative-diversity system where a source node communicates with a destination node directly and indirectly (through multiple relays). This paper analyze the system where N multiple relays that have the strongest signal strength at the destination are selected out of M relays and forward their received data from the source node to the destination node. It derive closed-form expressions for the average symbol error probability, the outage probability, the average channel capacity, the average signal-to-noise ratio (SNR), the amount of fading, and the SNR moments. In particular, closed-form expression for the moment generating function of the SNR at the destination node is determined. Then, the paper find a closed-form expression for the probability density function (PDF) of the total SNR at the destination. This PDF is used to derive the closed-form expressions of the performance metrics. Simulation results are also given to verify the analytical results. Results show that increasing N will slightly improves the error performance and degrade the outage probability and average channel capacity. In particular, N = M gives the best performance in terms of error performance and N = 1 (the best relay) gives the best performance in terms of outage probability and average channel capacity [5].
Y. Ding and M. Uysal	Amplify-and-forward cooperative OFDM with multiple-relays: performance analysis and relay selection methods	This paper investigate a cooperative system with multiple relays and amplify-and-forward relaying over frequency-selective channels. To extract the available multipath diversity, this paper employ orthogonal frequency division multiplexing (OFDM) with precoding. Through the derivation of pairwise error probability (PEP), this work demonstrate that PEP is not a simple exponential function of the signal-to-noise ratio (SNR), but it includes a term that involves some power of logarithm of the SNR. If that term is ignored, the diversity order is given by the summation of the channel length in the direct link and the minimum of channel lengths in each relaying link confirmed by simulation results. Based on the PEP expression, this paper also propose two relay selection strategies; one is on a per-subcarrier basis and

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		the other is on an all-subcarrier basis. Simulation results indicate that both strategies result in performance improvements although the per-subcarrier method performs better [6].
Zhi-Yong Liu, Weihai	Single and Multiple Relay Selection for Cooperative Communication under Frequency Selective Channels	In this paper, a relay selection scheme for cooperative communication with amplify-and-forward (AF) under frequency selective channels is proposed. In the scheme, to tackle with the difficulty caused by frequency selective channel, the output SNR of equalization detector is used as the end-to-end SNR to order the relays. According to relay ordering, one or multiple relay can be sequentially selected out from N relays. The numerical results verify the method of relay ordering and show that the multiple relay selection scheme outperforms conventional optimal single relay selection scheme [15].
Glauber Brante, Guilherme de Santi Peron, Richard Demo Souza, and Taufik Abrão	Distributed Fuzzy Logic-Based Relay Selection Algorithm for Cooperative Wireless Sensor Networks	Relay selection is a technique that can considerably increase the performance of cooperative communications. This paper proposes new relay selection algorithm using fuzzy logic aiming at both network lifetime and end-to-end throughput. This algorithm operates in a distributed way, running independently at each node, not requiring a central entity for complex coordination. The method considers the channel state of the relay-destination link and the residual energy of its battery. It is shown that the proposed scheme can transmit a larger amount of information during the network lifetime with respect to both the opportunistic (which focuses on throughput) and random (which focuses on lifetime) selection algorithms, increasing the network utility [16].
El-Mahdy, Ahmed, and Ahmed Waleed	Log-likelihood ratio-based relay selection algorithm for cooperative communications	In this paper, a relay selection algorithm is proposed in a slow flat fading channel. The algorithm is based on evaluating the log-likelihood ratio of all relays and the relay which has the largest magnitude of log-likelihood ratio (LLR) is selected to help the source to transmit the data to the destination. The performance of the algorithm is evaluated by simulation and compared with other relay selection algorithms. The performance is measured in terms of bit error rate (BER) and outage probability. Both decode and forward and amplify and forward protocols were investigated. The performance is evaluated for known and estimated channel. The channel is estimated using least square algorithm. The performance of channel estimation algorithm is measured in terms of the mean square error. The results show that BER provided by LLR-based selection combining algorithm is lower than BER provided by the conventional SNR-based selection combining schemes [17].

IV. CONCLUSION

Carrying out literature review is very significant in any research project. It clearly establishes the need of the work and the background development. It generates related queries regarding improvements in the study already done and allows unsolved problems to emerge and thus clearly define all boundaries regarding the development of the research project. This paper discuss the previous work done against the relay selection for cooperative communication.

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