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Energy Consumption Minimization in WSN using BFO

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Abstract — The popularity of Wireless Sensor Networks (WSN) have increased rapidly and tremendously due to the vast potential of the sensor networks to connect the physical world with the virtual world. Since sensor devices rely on battery power and node energy and may be placed in hostile environments, so replacing them becomes a difficult task. Thus, improving the energy of these networks i.e. network lifetime becomes important. The thesis provides methods for clustering and cluster head selection to WSN to improve energy efficiency using fuzzy logic controller. It presents a comparison between the different methods on the basis of the network lifetime. It compares existing ABC optimization method with BFO algorithm for different size of networks and different scenario. It provides cluster head selection method with good performance and reduced computational complexity. In addition it also proposes BFO as an algorithm for clustering of WSN which would result in improved performance with faster convergence.

Keywords — *Wireless sensor network, ABC, BFO Algorithm.*

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I. INTRODUCTION

A. Wireless Sensor Networks

Sensor nodes offer a powerful mixture of distributed sensing, computing and verbal exchange. The ever-increasing skills of those tiny sensor nodes, which include sensing, statistics processing, and speaking, allow the belief of WSNs primarily based at the collaborative attempt of a number of other sensor nodes. They allow an extensive range of programs and, at the equal time, provide numerous challenges because of their peculiarities, basically the stringent electricity constraints to which sensing nodes are generally subjected. WSNs comprise knowledge and technologies from 3 unique fields; Wireless communications, networking and Systems and Control theory. In order to understand the existing and potential applications for WSNs, state-of-the-art and extraordinarily green communication protocols are required. This chapter offers a first advent to the WSNs, consisting of structure, specific traits and packages.Much more important to detector network operation is electricity-performance, that dictates community period of time, and also the high level QoS, or fidelity, that's met over the direction of the network period of time. This QoS is application-precise and will be measured variety of various strategies. For instance, in a normal police investigation utility, it should be needed that one detector stays active inside every sub location of the network, so as that any entrant is also detected with High chance. During this scenario, QoS may be delineated by means that of the share of the environment that's genuinely blanketed by spirited sensors. in a very normal trailing application, this QoS may be the anticipated accuracy of the goal space estimation provided by means that of the community.

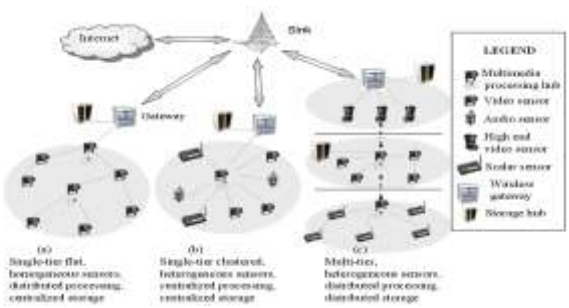

Figure 1.1 Wireless Sensor Networking

B. Network Protocols

When we style the network protocols for a Wi-Fi detector networks, then numerous sorts of key parts area unit to be thought about. Initial and main, thanks to the scarce power assets, routing choices ought to

be guided through a number of awareness of the ability resources within the network. Moreover, detector networks area unit explicit from fashionable advert hoc networks therein contact channels oft exist between activities and sinks, in situ of between man or girl supply nodes and sinks. The sink node(s) area unit ordinarily larger interested in associate degree traditional description of the environment, as hostile specific readings from the individual detector devices. Thus, communication in detector networks is usually referred to as statistics-centric, rather than cope with-centric, and records could also be aggregate regionally as hostile having all raw records sent to the sink(s). These specific functions of detector networks have implications within the community layer and so need a re-taking under consideration protocols for statistics routing. In addition, sensors typically have understanding in their personal space as how to meaningfully investigate their facts. These neighborhood facts could also be applied among the network layer for routing functions. Finally, if a detector

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network is correctly connected (i.e., above is required to produce communication paths), topology management services need to be used at the aspect of the everyday routing protocols.

1) Clustering for knowledge Aggregation

As detector networks area unit foretold to scale to massive numbers of nodes, protocol measurability could be a crucial style criterion. If the sensors area unit managed directly by victimization the bottom station, communication overhead, management delay, and management complexness end up to be limiting parts in community performance. Clump has been planned with the help of researchers to establishment a number of sensors, ordinarily within a geographic neighborhood, to form a cluster that's controlled by approach of a cluster head. A hard and fast or adaptive technique could also be used for cluster maintenance. Support many critical network features inside a cluster, which includes channel access for cluster contributors and energy control, in addition to among clusters, consisting of routing and code separation to avoid inter-cluster interference. Moreover, clustering distributes the control duty from the bottom station to the cluster heads, and gives a handy framework for records fusion, local selection making and local control, and strength savings.

The important purpose of WSNs protection is to protect the wireless sensing element networks from any sorts of attack. Completely different the various} application eventualities provided within the sooner phase denote those WSNs may additionally have terribly different residences. Thus, considering the accepted protection necessities and application state of affairs the algorithmic program is developed to relaxed a WSN. The foremost homes that created the security mechanism exhausting in WSNs are aid constraints, operational surroundings and unreliable spoken communication, which might be mentioned at a lower place. Resource constraint Resource constraints: it is commonly assumed that sensing element nodes are very resource restricted. For associate degree example, the Berkeley MICA2motes and TMotemini are offered in Table 1.3 [36] [37]. Thus, protection protocols for WSNs need to be possible supported to be had hardware and notably ought to be terribly economical in phrases of strength consumption and execution time.

II. PROPOSED WORK

Wireless sensor network (WSN) is a very fast evolving technological platform having tremendous applications scopes in several domains for examplehealth monitoring, agriculture, military, structural monitoring, homenetworks and many more.A WSN contains substantial number ofsmall-size sensor nodes with low power consumption and must be capable of detecting physical phenomena for example constrained in energy supply, bandwidth and processing power. In our work, we implemented Bacterial Foraging Optimization (BFO) algorithm in a cluster-based routing protocol based on Sugeno fuzzy inference system.As in a given populations of nodes clustering can be done by different techniques such as FCM, Kmeans, Cmeans etc. We have used Kmeans for clustering as it is efficient and fast. After clustering centroid of clusters chosen. In the cluster-based protocols Cluster Heads (CHs) are generally selected among all sensor nodes from pool of nodes who is reliable to maintain cluster work, and then, clusters are made byassigning each node to the nearest CH. The major limitation is to generate an inappropriate distribution of CHs over WSN. The main steps of our work can be summarized as follows:

• An optimized Sugeno fuzzy inference system (FIS) is proposed as an efficient and fast, application specific routing protocol in Wireless Sensor Network environment. We have designed three membershipfunctions with 27 set of rules in Sugeno

• K-means algorithm is utilized to form balanced clusters over the network.

• An objective function is made to calculate residual energy (RE), distance of node from sink (DNS), distance of node from centroid (DNC). Position of centroid is calculated by Kmeans algorithm. Objective function also finds position of Cluster Head on the basis of fuzzy inference system.

• Bacterial Foraging Optimization (BFO) algorithm is implemented to optimize the fuzzy rules of FIS file in order to prolong the network lifetime, based on the different applicationspecifications.Flow chart of our work is given below for easy understanding.

A. FUZZY LOGIC INFERENCE SYSTEM

As the fuzzy inference system FIS can achieve a better combination of the all input parameters to obtain the optimal output. So a Sugeno FIS is constructed in MATLAB. The fuzzy controller consists of three parts: first is fuzzification in which real environment variables are converted to fuzzy variables, second is inference model which inherits the rule sets or decision variables and third is defuzzifications which reverse the fuzzy variables to environment variables. These are:

1. Residual energy of node (RE)
2. Distance of node from sink of cluster (DNS)
3. Distance of node from centroid of cluster (DNC)

The three input signals are fuzzified and represented in fuzzy set notations by membership functions. The defined ‘if … then …’ rules produce the linguistic variables and these variables are defuzzified into control signals for comparison. Fuzzy logic control involves three steps: fuzzification, decision-making using FIS and defuzzification. Fuzzification transforms the non-fuzzy (numeric) input variable measurements into the fuzzy set (linguistic) variable that is a clearly defined boundary. In the proposed controller, the RE, DNS and DNC are defined by linguistic variables such as LOW, MED, HIGH characterized by memberships. The memberships are curves that define how each point in the input space is mapped to a membership value between 0 to 1 for RE and -1 to 1 for DNC and DNS. The membership functions belonging to the other phases are trapezoidal Membership functions for the inputs are shown in Fig.2.1.

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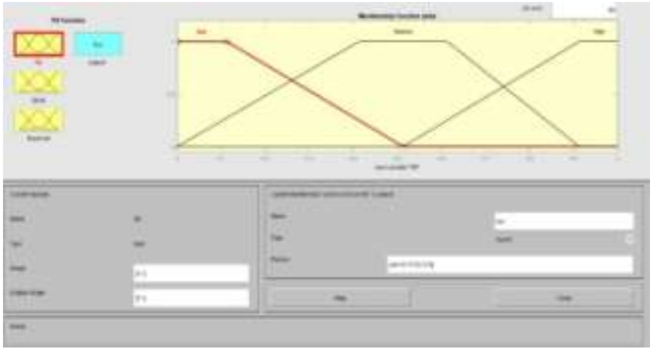

Figure 2.1: Membership function of input RE

1) Calculation of Residual Energy of each node

In every round, the nodes sense the WSN environment and send the obtained information to the sink. The sink is responsible for receiving the data from nodes, and sending this information to the user end. All nodes have the same capabilities of sensing, processing and communicating. Each node can communicate directly with the sink and with other nodes. All nodes are equipped with GPS devices, so they are aware of their own location as well as the location of the sink. The first order radio communication is used to model the dissipated energy. In this model, a radio dissipates $E_{elec} \times l$ to run either the transmitter or the receiver circuitry. The energy consumption for transmitter and l bit data packet with distance d can be formulated as equation 15.

$$E_{TD}(l \times d) = \begin{cases} l \times E_{elec} + l \times \varepsilon_{fs} \times d^2 & if\ d \le d_0 \\ l \times E_{elec} + l \times \varepsilon_{amp} \times d^4 & if\ d > d_0 \end{cases} \quad (15)$$

$$E_{RX}(l) = l \times E_{elec}$$

Where E_{elec} is the dissipated energy (per bit) in every transmitter and receiver circuit, and depends on such electronics factors as digital coding, modulation, filtering and spreading of the signal. The amplifier parameter used for free space and multipath environment ε_{fs} and ε_{amp} respectively. The distance threshold d_0 is defined as $d_0 = \sqrt{\varepsilon_{fs}/\varepsilon_{amp}}$

2) Performance evaluation:

An overall clustering is firstly performed via Kmeans and then a CH is selected within the each cluster. In order to demonstrate the effectiveness of the proposed, the maximum and standard deviation of intra-cluster distance are used to compare by BFO and ABC algorithms.The standard deviation of intra-cluster distance can be expressed as

$$STD_{cl} = \sqrt{\frac{1}{N}\sum_{J=1}^{M}\sum_{i=1}^{N}(x_i\, a_{ij} - c_j)^2}$$

Where, a_{ij} is binary parameter determining whether node i belongs to cluster j or not. In order to demonstrate the effectiveness of the BFO, simulation results of the both algorithm are compared for 50mx50m , 100mx100m and 200x200m geographical area. The base station located at the centre of the network. All sensors have the same initial energy. Table 1.1 presents the network details.

Table 1.1Network details

Parameter	Value
Initial energy	1 J
E_{elec}	50 nJ/bit
E_{fs}	100 pJ/bit/m^2
E_{amp}	0.013pJ/bit/m^2
Data packet size	4000 bit
Control packet size	50 bit

B. FUZZY LOGIC TUNED WITH BFO

1) Description

In previous section we discuss the fuzzy logic decided output on the basis of three inputs RE, DNS, DNC membership functions. In figures 2.2-2.4 membership range of three inputs are defined. In the given fuzzy system, the number of fuzzy memberships for the each input is 3 (Low, Medium, and High). So, the number of fuzzy rules is 3×3×3=27.We tuned the membership function range based on the input conditions and bacterial foraging optimization (BFO algorithm. In BFO Bacteria move in random direction in search of its food which takes time into convergence of BFO.

2) Algorithm Steps

A step by step algorithm for the proposed work is given as:

STEP1. Initialize the node population random positions and directions of bacteria.

STEP2. Apply Kmeans clustering technique to make clusters of nodes and their centroids.

STEP3. Create an objective function which can calculate RE, DNS. DNC and also choose CH on the basis of RE and calculates mean RE of clusters and total node population.

STEP4. Create a Fuzzy Inference System FIS using Sugeno function for three inputs RE,DNS,DNC and make their membership function and rule set to decide output.

STEP5. Initialize random positions and directions of bacteria in BFO

STEP6. Consider the searching space dimension as number of membership function values to be tuned which is 15 in our case.

STEP7. Initialize the chemotactic, swarming, reproduction and dispersion steps. The initial step size of bacteria is taken as 0.005.

STEP8. In each chemotactic step, for every bacteria fitness function is and position of bacteria is updated by position updating formula. It is

$$new\ pos = old\ pos + step\ size \times \frac{direction}{\sqrt{direction * direction'}}$$

STEP9. In swarming step the previous fitness function output is compared with the next position output of same bacteria. If found less then position of bacteria is updated again by formula given in step 5.

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STEP10. The present position of bacteria is termed as current values of membership functions.

STEP11. The chemo tactic and swarming loop continues till all initialized steps are completed. In each loop BFO updates the direction of bacteria and move the bacteria into the direction of fast convergence.

STEP12. Reproduction steps take place for bacteria with high fitness function values.

STEP13. To disperse or kill the weak bacteria, a probability of 0.25 is defined as the deciding probability. If random probability is higher than it, bacteria is dispersed or vice versa.

STEP14. Result will be positions of bacteria with minimum fitness function output. These positions are membership function's tuned variables for fuzzy logic controller.

Following these steps in optimization of BFO, optimal values of fuzzy controller membership function is achieved in our work.

III. RESULTS & DISCUSSION

In our work we have proposed a technique for increasing the lifetime of a wireless sensor network (WSN) using fuzzy logic controller and BFO optimisation algorithm the proposed work is implemented in MATLAB R 2016a. The basic description of MATLAB is given in appendix. We have developed our code in modules and are named as per their functions.

Table 1.2: input variables set in GSA optimization

Input	Value
Total number of nodes	100
Total no. of clusters	3
Range for RE	[0,1]
Range for DNS	[-1,0]
Range for DNC	[-1,0]

1. Create X no of nodes in wireless sensor network to make WSN environment. Divide in 3 clusters using Kmeans clustering technique.
2. Create Fuzzy inference system (FIS) file using three inputs and three membership functions of each inputs with a set of 27 rules to choose output.
3. Apply BFO algorithm to tune input parameters of FIS.
4. Apply ABC algorithm to tune input parameters of FIS.
5. Comparison of results of both BFO and ABC.

Case-1 When Geographical area is 50mx50m

When geographical area is 50 m^2 then we calculated and observed imapct of BFO and ABC algorithm on increasing the lifetime of WSN.

Here are results of this case:

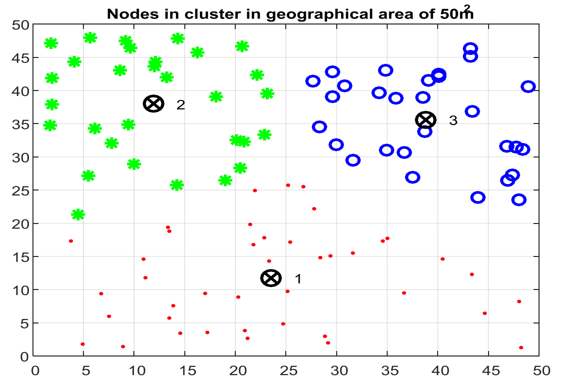

Figure 3.1 Nodes in cluster in geographical area of 50 m^2

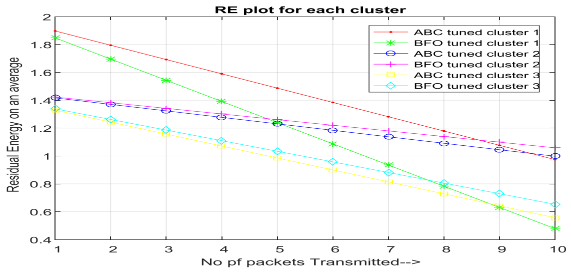

Figure 3.2 RE plot of BFO and ABC

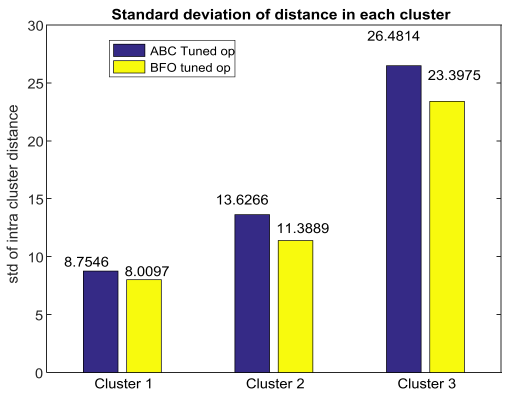

Figure 3.3 Standard deviation of cluster distance

Table1.3 Cluster-wise comparsion for BFO and ABC for case-1

Case-1 $50m^2$	**Cluster 1**	**Cluster 2**	**Cluster 3**
BFO	8.75456456141063	13.6266384294770	26.4814014635824
ABC	8.00970696477768	11.3888740950478	23.3974753421539

Case-2 When Geographical area is 100mx100m

When geographical area is 100 m^2 then we calculated and observed imapct of BFO and ABC algorithm on increasing the lifetime of WSN.

Here are results of this case:

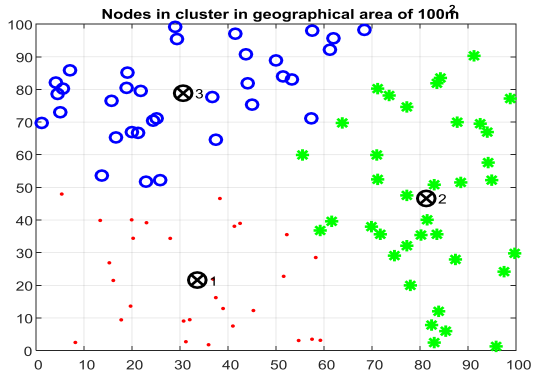

Figure 3.6 Nodes in cluster in geographical area of 100 m^2

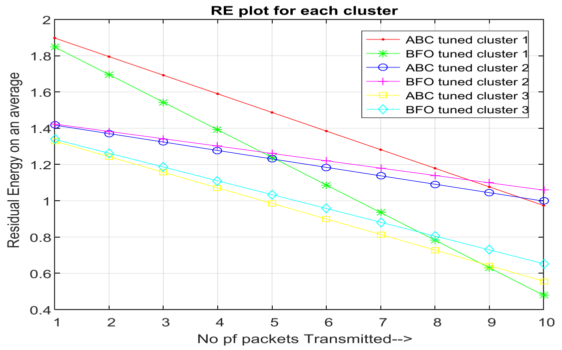

Figure 3.7 RE plot of BFO and ABC

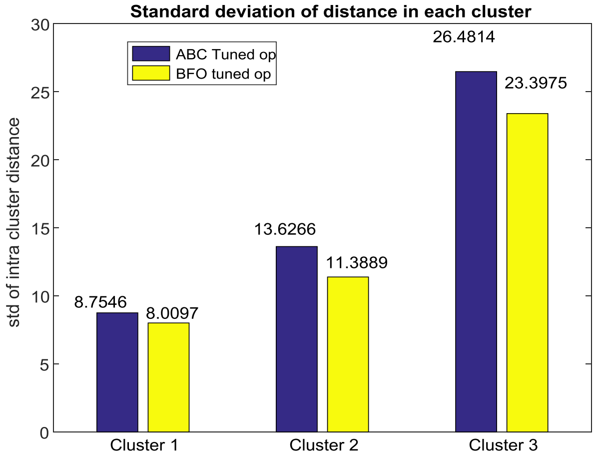

Figure 3.8 Standard deviation of cluster distance

Table1.4 Cluster-wise comparsion for BFO and ABC for case-2

Case-2 100m^2	Cluster 1	Cluster 2	Cluster 3
BFO	8.75456456141063	13.6266384294770	26.4814014635824
ABC	8.00970696477768	11.3888740950478	23.3974753421539

Case-3 When Geographical area is 200mx200m

When geographical area is 200 m^2 then we calculated and observed imapct of BFO and ABC algorithm on increasing the lifetime of WSN.

Here are results of this case:

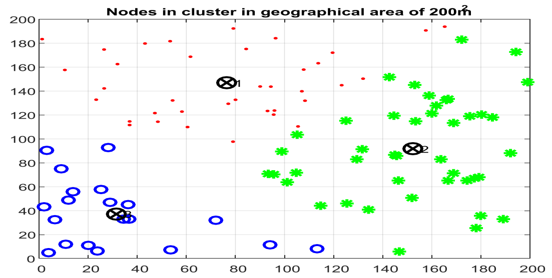

Figure 3.9 Nodes in cluster in geographical area of 200 m^2

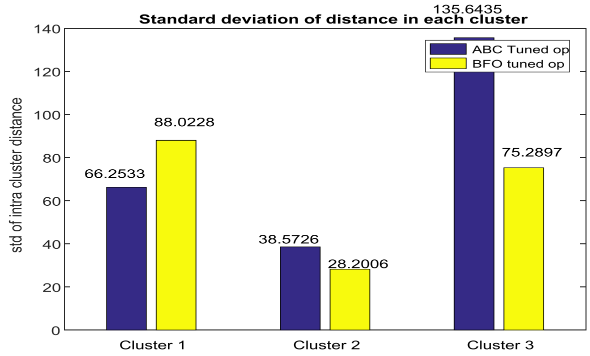

Figure 3.10 Standard deviation of cluster distance

Table 1.5 Cluster-wise comparsion for BFO and ABC for case-3

Case-3 200m^2	Cluster 1	Cluster 2	Cluster 3
BFO	66.2532605617461	38.5725720516026	135.643533028712
ABC	88.0227760388700	28.2006211404531	75.2897030161919

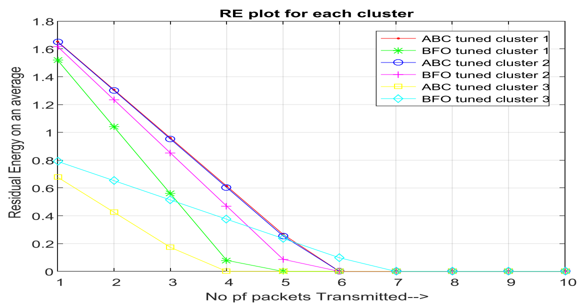

Figure 3.11 RE plot of BFO and ABC

It can be observed that BFO is giving better performance in comparison to ABC for same set of rules and WSN environment. Further observation is that when geographical area is large then results of BFO and ABC are comparable, but for small geographical area BFO over perform the ABC for same set of rules, WSN environment and conditions.

IV. RESULTS & DISCUSSION

A. Conclusion

Our thesis work includes the study of clustering, cluster head (CH) selection and other energy efficient communication protocols such as ABC and BFO optimization algorithms for WSN, since it was proposed earlier that clustering improves the network lifetime. We used Fuzzy logic controller based approach for cluster head choosing and compared performance of BFO and ABC for cluster head selection and improvement of network lifetime. It was also found that the BFO tuned Fuzzy controller gives better results than ABC tuned parameters. We used ABC as a reference to compare the performance of each of the clustering methods It is concluded that for three different geographical sizes BFO tuned fuzzy logic controller gives improved result in respect of network lifetime in comparison to ABC algorithm. As geographical size increases impact of BFO becomes comparable to that of ABC but for smaller areas BFO should be preferred over ABC for longer network lifetime.

B. Future Scope

In this work we focused on longer network life time which is very important parameter of a WSN network. But for a better and secure WSN environment, security from external attacks is also main concern. These types of attacks can be overcome by end to end encryption. Second is a malicious attack where attacker node attracts packet by inserting false routing protocol. Secondly Guard node can also be used when transmitted data from high security level to low security level of transmission. Similarly, Multi-Level Security algorithm can be analyzed and modified for better performance along with our proposed technique of increasing network lifetime.

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