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Quantum Particle Swarm Optimization and Compressive Sensing-Based Clustering Protocol for Wireless Sensor Networks

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Abstract: ***Wireless sensor networks play important role to build various smart systems such as health, medical, military, etc. A wireless sensor network contains tiny sensor nodes to sense information of given environment. But these sensor networks are battery constrained. Therefore, become dead after certain period. Also, the batteries of these sensor nodes are not rechargeable and even not replaceable. Therefore, conserving the energy of these sensor nodes become more challenging. Many researchers have developed various protocols to reduce the energy consumption. But it is still defined as an open area of research. Therefore, in this paper, we have designed a novel quantum particle swarm optimization and compressive sensing-based clustering protocol. Extensive experiments show that the proposed protocol indicates better energy conservation as compared to the competitive protocols.***

Keywords: Data aggregation, Particle swarm optimization, Network lifetime.

I. INTRODUCTION

In the modern era, there is a need for a world of fully connected devices. Networking is the fastest growing field in the area of research. Remote correspondences have brought the colossal unrest as it amplifies the abilities of different sorts of altered systems which incorporates area autonomous data stockpiling, transport, recovery, preparing and to help the clients to move openly starting with one area then onto the next [1]. Recent scientific and technical advancements in the field of networking have enabled us to produce a very small size, minimum price and battery-operated sensor nodes. All these nodes can easily sense the earth and obtain the information and forward through numerous jumps [2]. Sensor hubs measure totally concealing situation inside the surrounding atmosphere which can be helpful to represent the actual qualities of your marvels happening for the area in which the sensor hubs are usually appropriated efficiently [3]. An extensive number of sensor hubs are than set discretionarily over a topographical locale and organized through remote connections to make a remote sensor arrange.

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Every sensor hub is than ready to collaborate with each other and base stations are than used to incorporate and telecast the information further [4]. Wireless networking is a significant structure which is used to aid the specifications of armed forces and industrial services. Many types of restraints including storage capacity or energy consumption are important issues [5]. Wireless sensor network (WSN) represents a small grouping of spatially dispersed and specific sensors for supervising as well as saving the actual physical situation of the environment and planning obtained information in single main location [6]. WSNs determine the environmentally situation such as range of temperature, noise, degree of air pollution, moisture, wind flow, and so on. This kinds of act like wireless ad hoc network meaning which they depend upon wireless connection as well as natural development of networks so that sensor information may be sent wirelessly [7]. In some cases, these are known as dust network; mention to moment sensors no more than dust. WSNs are spatially allocated autonomous sensors to monitor actual physically as well as environmentally situations, like temp, sound, pressure, so on as well as cooperatively move their own data throughout the actual network in order to a primary location [8]. This is most recent networks are generally bi-directional, as well enabling control with sensor activity. The actual growth of WSNs was inspired by military services purposes like battle ground monitoring; these days this type of networks tends to utilize in more industrial as well as customer purposes, like manufacturing process managing as well as managing overall health supervision, etc.

A WSN is created with "nodes" – by fewer to many hundred or more than hundred, where every single node is attached to a single (sometime more than one) sensor [9]. Every these kind of sensor network nodes have normally various types: a radio transceiver using the interior antenna as well as connection with exterior antenna, electronic digital circuit for interfacing with all sensors as well as an energy source, usually a battery power or an embedded type of energy harvesting [10].

The topology of WSNs is generally different from the star network in a modern multi-hop wireless mesh network (see Figure 1). This propagation method between the hops in network can easily to be routing or flooding.

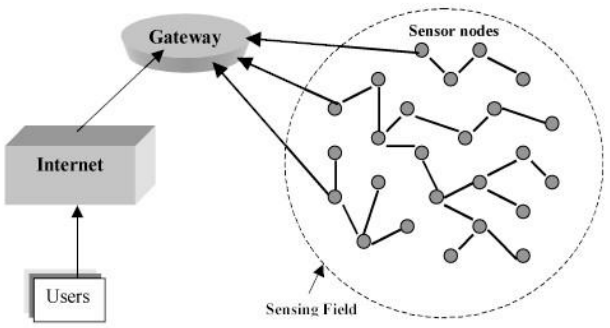

Figure 1. Multi-hop wireless sensor network architecture

WSNs has received immense challenges for researchers. The sensing technology when combined with wireless communication and processing power becomes more remunerative for being put upon in large number in future [11]. When the wireless technology is included it adds so many security threats. The most important work is to inquire the safety linked issues and to save the sensor network against threats [12].

Grouping of sensor nodes into clusters overcomes the drawbacks found in Multi-Hop transmission, thus helps to reduce consumption of energy and improves the network lifetime. In clustering, groups are formed, and each group has one leader called Cluster Heads (CHs). CHs performs the task of data fusion and aggregation, thus improves energy consumption. CHs node behaves as pathway between the sensor node and the BS. The cluster formation process consists of two-level hierarchy, where CHs nodes are at higher level and cluster members at lower level. Cluster member send their information to CHs. Then CHs removes the redundant data and sends that information either directly or through the intermediate communication with other CHs nodes to BS. Different algorithms were proposed to decrease energy consumption of sensor. LEACH is well known dynamic clustering algorithm proposed for WSNs that assumes all sensor nodes to be homogeneous.

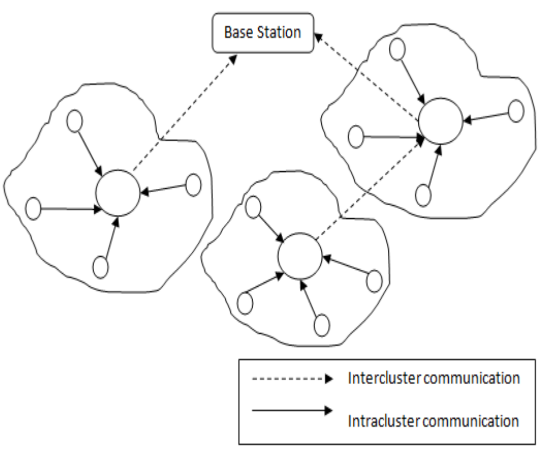

Figure 2 Data communication in a clustered network

It has been found that the development of an efficient energy efficient protocol for WSNs is still an open area of research. Therefore, a novel protocol is designed and implemented in this paper to conserve the energy in more efficient manner. Quantum based particle swarm optimization (QPSO)-based optimization is used for effective inter-cluster data aggregation. Compressive sensing is also used to reduce the packet size. Thereafter, a simulation environment is designed to implement the proposed technique. Finally, comparisons are performed between competitive and proposed protocols. The rest of paper is summarized as: Section 2 presents the literature review of the existing techniques. Proposed technique is discussed in the Section 3. Experimental set-up and results are discussed in Section 4. Concluding remarks are demonstrated in Section 5.

II. LITERATURE SURVEY

Xu et al. studied the dynamic topology control method to enhance the lifetime of WSNs. In this technique, the non-cooperative game aided topology is used for designing the energy balanced and energy-efficient network [15]. Biswas et al. proposed an analytical model to estimate the lifetime of WSN. In The various input factors such as link quality, remaining energy, and location of the sensor nodes are considered in this technique. The performance of any routing protocol can be evaluated through this model [16].

Chen et al. designed a sleep scheduling algorithm based on reinforcement learning for desired area coverage in WSNs. It also used node selection algorithm based on Q learning. In this, the precedence operator is used to form the groups [17]. Frezzetti and Manfredi et al. proposed an efficient technique based on two-layer controller that ensures improved network lifetime and signal reconstruction in WSNs [18]. Liu implemented a technique to maximize the lifetime of WSNs based on ant colony optimization (ACO). In this, optimal distance is evaluated using ACO to achieve high energy efficiency [19].

Yang et al. designed a protocol to increase the lifetime and energy efficiency in WSNs. In this protocol, the combination of time division and carrier sense multiple accesses are used. The results have been shown that the designed protocol decrease 6% to 15% energy consumption as compared to others [20]. Yildiz et al analysed the effect of limiting hop count on WSN's lifetime using integer programming. The study shows that network lifetime can be increased by reducing the hop routing [21]. Yildiz et al. given the studies that link level handshaking can be used over optimal transmission power in WSNs without effecting the lifetime [22].

Aslam et al. proposed a technique to optimize the charging of wireless portable charging device that present inside the WSN. The objective function is designed based on routing efficiency and energy consumption. The Nodal A* algorithm is also used in this technique to integrate the path [23]. Xu et al. proposed an algorithm to increase the lifetime with minimum service cost in WSNs for mobile charger. This technique considered the partial charging of sensor nodes so that maximum nodes can be charged. The optimization is also utilized to schedule the mobile charger [24]. Sun et al. implemented a routing algorithm based on ACO in WSNs. The optimal path is found based on transmission direction and transmission distance. Hence, it improves the lifetime time of WSNs [25].

III.PROPOSED METHODOLOGY

The cluster head (CH) selection is achieved using the following criteria i.e. existing CHs percentage which ranges from 5% to 10%, count of nodes previously selected as CH and energy level. Only those nodes will participate in CH selection whose energy value is either equal to or greater than average energy of all nodes. The sensor nodes that do not fulfil the required condition will have a delay of1/pr (where pr is the desired CH %) in rounds. Randomly a number is generated between 0 and 1 by nodes. The nodes having value <Th (nd), will become CH and CH label is attached to it. The threshold function can be computed as:

$$Th(nd) = \begin{cases} \frac{pr}{1-pr*\left(rou \bmod \frac{1}{pr}\right)} & nd \in Gr \\ 0 & otherwise \end{cases} \quad (1)$$

Here, 'pr' is the percentage of CH e.g. pr=5%, 'rou' is current round and 'Gr' denotes group of nodes that are not selected as CHs for the last 1/pr rounds.

In Cluster Setup, after CHs are selected, an advertisement message is broadcasted to Normal Nodes (NNs). During this phase, in order to listen the advertisement broadcasted by all CHs the receivers of NNs must be kept 'ON'. The Carrier Sense Multiple Access (CSMA) technique is used for broadcasting the message. Each node senses the signal strength and attach to nearest CH having greater signal strength (means NN have lesser distance from CH) [26].

In scheduling, a schedule is created for each CH using Time Division Multiple Access (TDMA) protocol. During this phase the schedule is broadcasted to each sensor nodes regarding when they will send data. Thereby decreases the consumption of energy of sensor nodes as each node knows when to transmit so that nodes turn off their radios. Only during its allotted slot of time, receivers of nodes are 'ON'. Steady Phase After clusters formation and establishment of schedule, Data Transmission stage starts. In this phase, NN transmit data to cluster head only during its allotted time slot and at that time the receiver of NN must kept 'ON' for transmission which leads to minimize energy consumption. While during data transmission phase the receivers of all CHs must kept 'ON'. Once the data has been collected by CH from its member nodes, CH starts performing aggregation of data i.e. removal of redundant data and transmits the aggregated data to the sink [27].

The step by step methodology is shown in Figure 3. Subsequent section discusses the mathematical flow of the proposed technique.

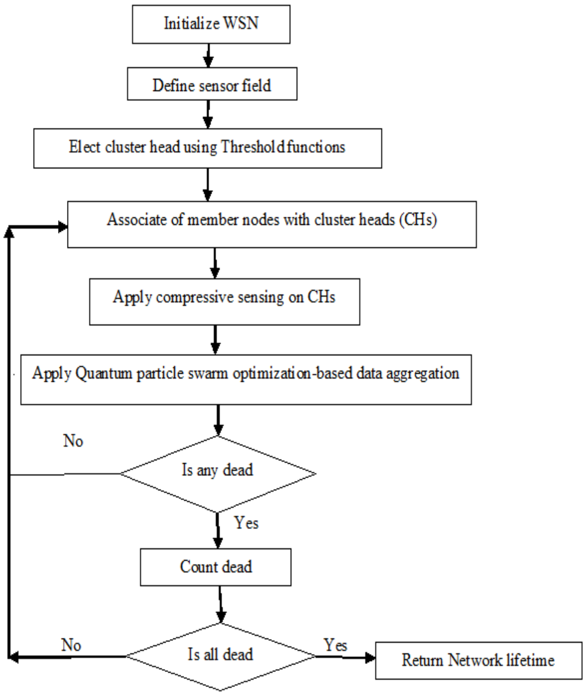

Figure 3 Flowchart of the Proposed Technique.

We consider only two types of nodes i.e. advanced and normal nodes. In proposed protocol, three kinds of nodes are defined depending upon its level of energy i.e. normal, moderate and advance nodes. It is designed for enhancing lifetime and stability period. Initially, a random number is generated and then its value is compared with threshold. Moderate or intermediate nodes can be selected either using the relative distance of advance nodes to normal nodes or using energy threshold level between advance nodes and normal nodes. The weighted election probabilities can be computed as below:

$$p_{nrm} = \frac{p_{opt}}{1+p.a+k.b} \quad (2)$$

$$p_{int} = \frac{p_{opt}}{1+p.a+k.b} * (1 + \mathrm{a}) \quad (3)$$

$$p_{adv} = \frac{p_{opt}}{1+p.a+k.b} * (1 + \mathrm{b}) \quad (4)$$

Total initial energy of heterogeneous network can be computed as:

$$E_t = n.(1-p-k).E_0 + n.p.E_o.(1+\alpha) + n.k.E_o(1+ b(5)$$

$$E_t = n.(1-p.a-k.b).E_0 \quad (6)$$

where 'a' is the additional energy factor between advance and normal nodes and b is the additional energy factor between advance, normal and moderate nodes.

After getting the probability for all the three types of nodes, threshold is computed for all the three cases i.e. normal, intermediate and advance nodes. For a normal node to become CH, the value of random number generated by a node should be less than the threshold for current round. For calculating the threshold, the formulae are:

$$T_{nrm} = \begin{cases} \frac{p_{nrm}}{1-p_{nrm}\left[r.mod\frac{1}{p_{nrm}}\right]} \; if \; n_{nrm} \in G^1 \\ 0 \; otherwise \end{cases} \quad (7)$$

$$T_{int} = \begin{cases} \frac{p_{int}}{1-p_{int}\left[r.mod\frac{1}{p_{int}}\right]} \; if \; n_{int} \in G^2 \\ 0 \; otherwise \end{cases} \quad (8)$$

$$T_{adv} = \begin{cases} \frac{p_{adv}}{1-p_{adv}[r.mod\frac{1}{p_{adv}}]} \, if \; n_{adv} \in G^3 \\ 0 \; otherwise \end{cases} \quad (9)$$

Here G^1, G^2 and G^3 are the subset of normal, intermediate and advance nodes, which are not selected as CH.

Algorithm 1 Proposed technique

Step 1: *Initialize network*

Step 2: *organize network at random within predefined sensor field.*

Step 3: *Be appropriate NEAHC toward estimate points When all nodes receive packet, will calculate their own energy – level (EL) by function:*

$$EL1'(i) = [Remaining\ energy(io)/\alpha] \quad (10)$$

Step 4: *Apply clustering toward develop cluster heads. Node develop into CH in favor of current rotation about but number with a reduction of subsequent threshold*

$$T(i) = \{Tn \begin{cases} \frac{F}{1-F\left[r \bmod \left(\frac{1}{p}\right)\right]} & ;J\ \varepsilon\ K \\ 0 & otherwise \end{cases} \quad (11)$$

Where p1 is best for percentage of CHs within each round r' is current node and i_0 stand used each node wants to become CH round. G1' is set nodes with the intention of comprise not PSO n selected as CHs in previous i/P rounds

Step 5: *Relate particle swarm optimization on clusters toward discover finest route with CHs to sink.*

Assigning in use PSO to the victuals source:

$$X'(i_0)=x_i'(i_0)\pm r(x'_i(i_0)-x'_k(i_0)) \quad (12)$$

Association of spectator ended via following equations:

Possibility of selecting nectar source:

$$P"_i = F'(\theta_i)/\sum_{k1'=1}^{s"} F'(\theta_{k1'}) \quad (13)$$

$p'_i(\theta_i)$ *:The possibility of select ith engaged PSO*

$p'_i(\theta_i)$ *:The number of employed fireflies*

$p'_i(\theta_i)$ *:The position of the ith in use PSO*

$p'_i(\theta_i)$ *:The strength rate*

Calculation the new site:

$$X_{i'j'}(t1'+1) = \theta_{ij}(t1') + \emptyset(\theta_{ij}(t1') - \theta_{kj}(t1')) \quad (14)$$

x_i' *= The position of spectator PSO*

T1: Iteration number

θ_k*: Randomly selected in use particles*

Evaluate the velocity of particles by

$$v = \frac{\partial \delta}{\partial t}$$

J1 : Dimension of explanation

$\emptyset\left(\theta_{i'j'}(t1) - \theta'_{k1'j}(t1)\right)$*: A series of random variable in the range .*

Association of the explore particles

Movement of explore particles follows equation

$$\theta_{i'j'} = \theta_{j'min} + r.(\theta_{j'max} - \theta_{j'min}) \quad (15)$$

r 1: Accidental quantity and r1 $\in [0,1]$

Step 6: *Evaluate and update energy consumption.*

$$d1'_{to\,CH=}\frac{M1}{\sqrt{2\pi k1}},\ d'_{toBS}=0.765\frac{M1}{2} \quad (16)$$

$$E_{tx1}(l", d1') = \begin{cases} l"E_{elec1} + l\varepsilon_{fs}\, d1"^2; d1" < d1"_0 \\ l"E_{elec1} + l\varepsilon_{fs} d1"^2; d1" \geq d1"_0 \end{cases} \quad (17)$$

Where

$$d1_0 = \sqrt{E_{fs1}/E_{mp1}} \quad (18)$$

M is area of WSN

E_{fs1} *is magnification power of liberated space*

E_{mp1} *is augmentation power while region is extra.*

Step 7: *Confirm whether every nodes turn into dead, condition yes subsequently illustrate network life span with come again as well maintain to step 3.*

$$Dead = \begin{cases} 1 & if s(i).Energy \leq 0 \\ 0 & otherwise \end{cases}$$

Step 8: *confirm whether every nodes turn into dead, condition yes subsequently illustrate network life span with come again as well maintain to step 3.*

$$\text{Termination}=\begin{cases} 1 & if\ count\ dead1 == n1 \\ 0 & otherwise \end{cases} \quad (19)$$

IV. PERFORMANCE ANALYSIS

The section discusses the comparative analysis of QPSO based PASCCC protocol. The experimental results demonstrate the proposed solution provides improvement over existing approaches. Table 1 shows the parameters setting of WSNs. All simulations are performed on MATLAB 2018a.

Table 1 Parameter Setting of Wireless Sensor Networks

PARAMETER	VALUE
Area	100*100 m
Base station	50,150
Nodes	200
Probability	0.1
Initial energy	0.01(in joule)
Transmitter energy	50 (in joule)
Receiver energy	50 (in joule)
Message size	4000 (in bits)
Fraction of Advance node	0.3 (in fraction)
Data aggregation energy	5 (no. of joule)
Amplification energy	0.0013 (in joule)
Maximum lifespan	4000 (sec/round)

Figure 2 shows packets sent to base station analysis between the proposed, PASCC and PSO based PASCCC protocols. It has been clearly shown that the number of packets sent to base station are significantly more in case of the proposed protocol.

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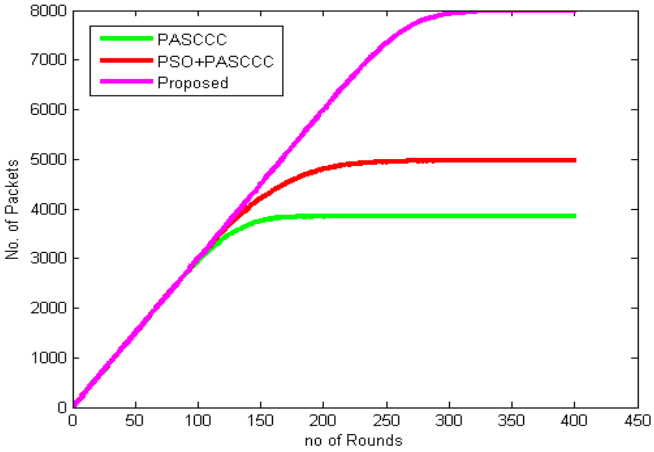

Figure 2 Packets Sent to Base Station

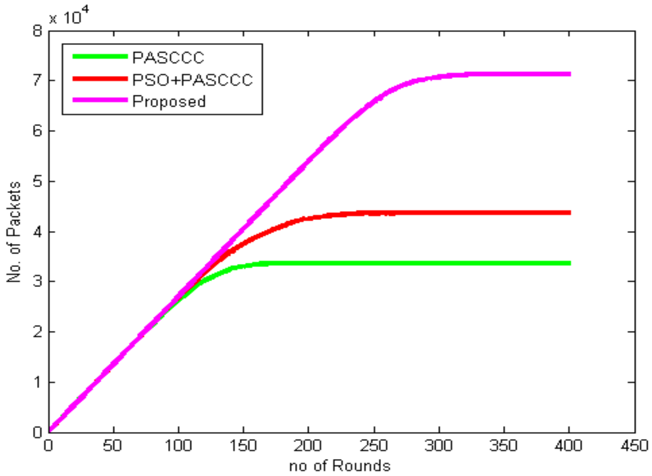

Figure 3 Packets Sent to Cluster Head

Figure 3 has shown the comparison among existing and theproposed protocols in terms of packets sent to cluster head. It has been clearly shown that the number of packets sent to cluster head are significantly more in case of the proposed protocol.

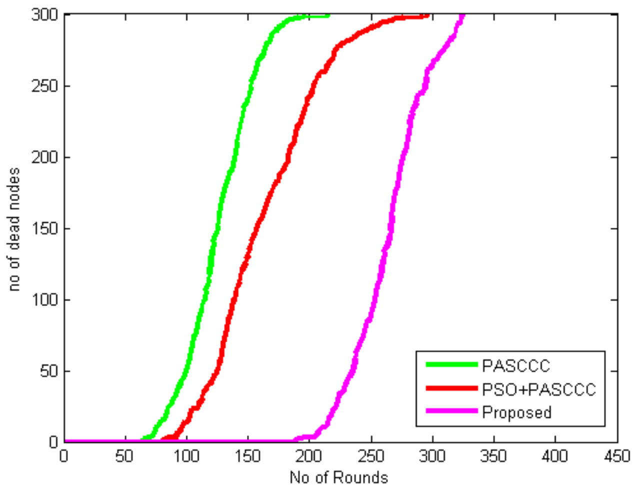

Figure 4 Lifetime Analysis

Figure 4 shows network lifetime analysis. It should be maximum. From Figure 4, it is found that the proposed protocol can achieve maximum network lifetime as compared to the existing protocols. It also shows it has better stability period as compared to PASCC and PSO based PASCCC.

Figure 5 shows the residual energy analysis. It has been found that the proposed technique conserve more energy in every round. Therefore, the proposed protocol is more efficiently conserve the energy as compared to the existing protocols.

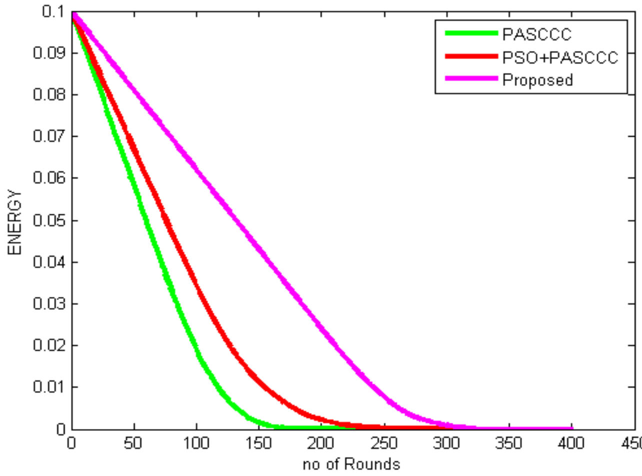

Figure 5 Remaining Energy Analysis

V. CONCLUSION

In WSNs, sensor nodes have the power constraint because the batteries of these sensor nodes cannot be replaced and recharged. Therefore, to improve the network's lifetime, many energy-efficient protocols have been implemented so far. The network's lifetime also suffers because of data flooding issues due to data aggregation at the sink. To overcome this issue, an efficient data aggregation technique has been implemented in this paper. A quantum particle swarm optimization and compressive sensing-based protocol has been designed. MATLAB 2018a tool has been utilized for experimental purpose. Various experiments have been carried out to assess the performance of the proposed protocol. From experimental results, it has been shown that the proposed protocol improved network lifetime as compared to the existing techniques.

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