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Organizing Wireless Sensor Network Coverage Region for Improving Network Lifetime

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Abstract

Wireless sensor networks (WSNs) offer a model to gather and monitor distributed data and transmitting these data to sink nodes this work anticipates WSN based multi-hopping network based infrastructure to enhance network lifetime (NLT) by modelling routing strategies. Initially, a network model has to be determined with operational control strategy for modelling and nodes' energy consumption has to be determined. Subsequently, effectual coverage has to be anticipated to acquire unique path that considers preserving energy of nodes chosen for communication and to determine total energy consumed while transmitting data. However, energy consumption of every individual node and entire network has to be computed. A criterion model is determined to examining nodes performance and to compute competency of data transmission. At last, route establishing criteria are anticipated to enhance NLT by modifying transmission route in securing weaker node (node competency for lesser transmission). Comparison and simulation were done with MATLAB simulation environment to determine superior performance of anticipated model to enhance network lifetime.

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1. Introduction

Wireless Sensor Networks (WSNs) have been measured as an investigational focus in last few decades owing to its diverse applications like environmental observation, health care, building automation, industrial monitoring, smart home and battlefield [1]. Moreover, large scale WSN has been deployed as in needs application constraints to huge amount of technical confronts. These confronts are constraint in computational energy, technical constraint, diminished communicational bandwidth, memory capability and lesser storage [2]. Moreover, sensor nodes (SNs) are powered typically with batteries of restricted capability which may not fulfil an impressive NLT until appropriate power saving strategies is determined [3]. In sensing network, sensors are cast off to offer observation towards certain targets/regions for longest probable time with restricted batter capacity [4]. Coverage crisis are categorized based on target and area coverage crisis. In this investigation, area coverage constraint is measured where the ultimate target is to observe constant coverage region for certain time [5]. To offer a coverage area, a sensor inside a coverage region (CR) is sensing coverage that can have two states: sleep and active. In former state, generally sensors may remain idle and can be measured as zero energy consumption [6]. While in latter, it may cover certain region by consuming considerable amount of batter lifetime.

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Then sensed data may perform certain processing tasks with limited smaller memory size and power processor. Processing data is transmitted to a centralized point termed as sink nodes (SNs) with built in wireless transmitter based communication [7].Communication path among sink and sensor node may have direct connection (one hop) or multi-hope communication paths with one amongst routing protocols. Battery is determined to be an essential power source in SNs [8]. For example, limitation in power source, constraint processing ability and least data rate of SNs may not fulfil higher performance in certain environment specifically for real time circumstances.

Owing to SNs lack in energy, potential WSN utilization have to be restricted, as SNs in numerous applications are needed to work for numerous months or may be years devoid of human interference nor maintenance (for instance, recharging or battery changing), therefore rise in energy conservation approaches are being generated for improving WSNs energy efficient [9]. SNs network lifetime is depicted by huge amount of energy accessible and energy consumption rate. Target of being long lifetime is complex to attain by raising amount of energy, henceforth, energy efficient layers protocol design, operating systems, communication strategy and saving energy based routing methods to offer effectual ways to extend nodes lifetime.

One amongst the saving energy strategy is duty cycle strategy may depict co-ordinated wakeup/sleep schedules between nodes network. The relevant wakeup/sleep scheduling measures assumption of sensors group at similar time. In this investigation, every cluster is termed as coverage and fulfils limitations over coverage with targeted sub-regions [10]. Owing to cheap and lesser cost of wireless sensors, random sensors may be deployed is simpler specifically than that of deterministic deployment for superior sensors density. However, high sensors density enhances with probability of coverage region, it offers more sensors to coverage region more than one time [11]. Placing these sensors into clusters is an extensively appropriate method to improve NLT and they may functions in sequential way.

This work concentrates on maximizing network lifetime crisis in WSN which is formulated as set of coverage region problem [12]. This crisis determines maximal amount of coverage area where these may be depicted as sensors subset that may manage all these targeted regions. It is equal to dividing sensors cluster to maximal amount of regions [13]. To enhance network lifetime, groping of coverage region with maximization of coverage region has also to be done. Thereby, lifetime has been improved. NLT is managed by all sensors that possess maximal lifetime in certain regions. When coverage region is eliminated, other sensor regions may still possess remaining energy. Sensor based residual energy is diminished with disjoint WSN cover, as every sensor may functions only inside these region [14]. The ultimate objective of improving network lifetime during disjoint coverage networks is by maximizing total coverage during sensor based residual energy minimization of terminated covers [15]. Pushing minimal residual energy with active time of sensor has to be higher and subsequently NTL is maximized as in Fig 1.

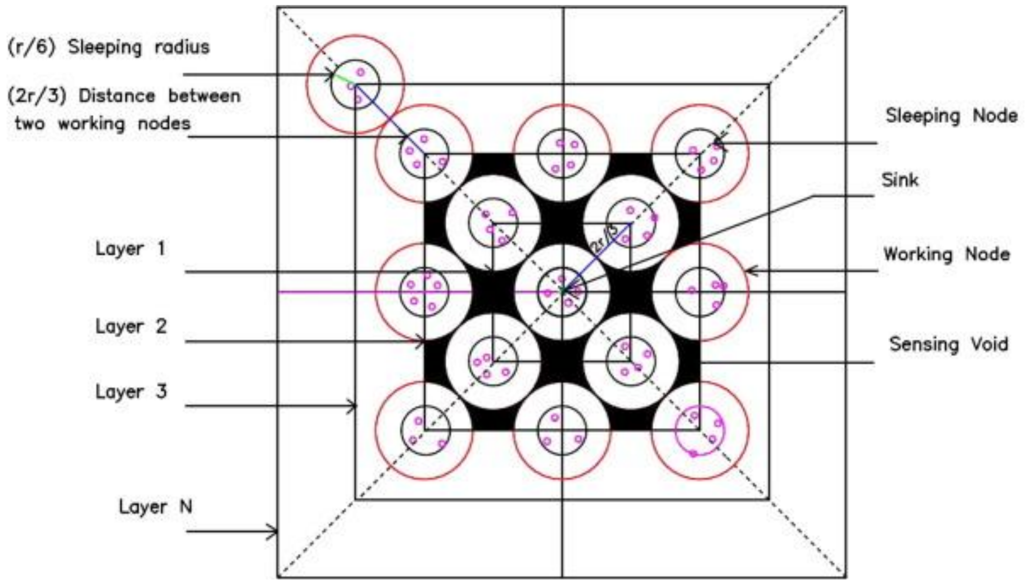

Figure 1: WSN Coverage Region

In this work, maximizing WSN NLT is examined with two objective problems. One objective is to enhance maximal probably amount of coverage region. Subsequent objective is to take considerable amount of residual energy. This can be resolved by reducing difference factor may compute difference among critical sensor NLT and coverage lifetime. This is not analyzed previously in managing WSN lifetime crisis. Consideration of difference factor is compared with two other prevailing approaches that are anticipated in literature; overlap among variance and sensors' coverage region is done among number of coverage region that omens under similar complete region. To resolve this crisis, ordered sensors are anticipated for collection of data and routes with multi-objective crisis with probability computation.

The remainder of this investigation is structured as: In section II, background studies are analyzed. Section III explains about anticipated model for handling maximization in network lifetime. Section IV illustrates numerical results and discussion that corresponds to anticipated model. Section V is conclusion of anticipated model with direction for future extension is provided.

2. Related Works

Author in [16], anticipated a novel greedy deterministic model which is measured as a most restricted minimal constraint covering t resolve this crisis, this model may not fulfil maximal amount of covers. In [17], author depicted that these problems are transformed from maximal flow crisis with heuristic model termed as maximal covers with mixed integer program. The outcomes depict that this models execution time rises from number of sensors exponentially. In [18], author offered a genetic approach for resolving crisis with integer coded procedure termed as GAMDSC. Outcomes depicts that anticipated model can enhance NLT by rising huge of covers by 16%, with probable computational time in contrary to MCMIP specifically over larger scale network.

By expanding WSN network lifetime via ordered based genetic model is anticipated in [19]. Order based method may not require knowledge regarding maximal pre-specified disjoint coverage region accessible at WSN alike of integer dependent methods. It may attain huge covers drastically than MC-MCC and is extremely lesser than MCMIP time. Ordered based genetic model offers a solution to trade off among effectual and quality for resolving K-cover set algorithm, Author in [], depicted targeted coverage crisis in maximal set cover approach that may retrieves maximal probable amount of sensor subsets. Author in [20] anticipated with a crisis that may extend connectivity constraint along with it. Connected set covers crisis possess an objective in determining maximal amount of set covers as it every sensors are activated and get connected with base station (BS). In [21], author depicted about disjoint cover set crisis as it may resolved with hybrid particle swarm optimization approach termed as PSO. Owing to controversial characteristics of WSN design factors, Multi-objective optimization has attained numerous investigations when designing multi-objective problems. In MOO, set of alternative crisis termed as non-dominated solutions may be attained simultaneously which is offered as decision making to chose an appropriate outcome with nominal trade off among conflicting objectives.

In [22], investigator anticipated a de-centralized density controlling factor termed as optimal geography density control. This approach maintains connectivity and coverage by maintaining minimal amount of SNs. Author in [23], anticipated an effectual energy efficient approach termed as Maximal life time scheduling approach in residual energy of SNs and target coverage overlapping which is measured as coverage construction. In [12], author concentrates on local approaches for superior k-barrier coverage dependent on detection based coverage approach. Investigator examines certain influencing crisis based on barrier coverage lifetime and transforms it to Multi-objective optimization crisis. Multi-objective optimization approaches are utilized to improve WSN performance with diverse objectives as in [8], where NSG II is cast off for optimizing two objectives that are load balancing and number of covers inside sensors coverage. Author defines two objectives for optimization approach for two diverse approaches of sensors collection.

Author in [24], offered a Multi-objective optimization dependent on scheduling approach for controlling density to attain maximal NLT and coverage in WSN. In [25], author concentrated on energy efficiency constraint and maximal NLT and author depicts an energy aware sleep scheduling procedure for lifetime maximization in WSN. Certain approach utilizes probabilistic approach that facilitates cover fault tolerance and distributed and dynamic sleep timer computation. In [25], author depicts coverage crisis as multi-objective optimization crisis for maximizing network lifetime and reduction in energy consumption while maintaining coverage as QoS measures. NSG II is an evolutionary multi-objective crisis is utilized to resolve this crisis resourcefully.

In [25], author illustrates the objective of anticipated work to deal with maximal targeted region by at least k-sensor nodes to produce fault tolerance in network and to enlarge NLT in WSN by partitioning sensors set into maximal cover sets amount.

3. Proposed Methodology

WSN sensors models are depicted as set of $S = \{s_1, s_2, \dots, s_n\}$. Nodes are randomly deployed with certain coverage region based on boundary regions that are partitioned into lesser regions $R = \{r_1, \dots r_j, \dots, r_m\}$ of size inside sensing range. When area size is compared with sensing region, superior problem computation and appropriate solution are given in Fig 2. Region R_j is termed as sensor coverage s_i, if s_i is in sensing range.

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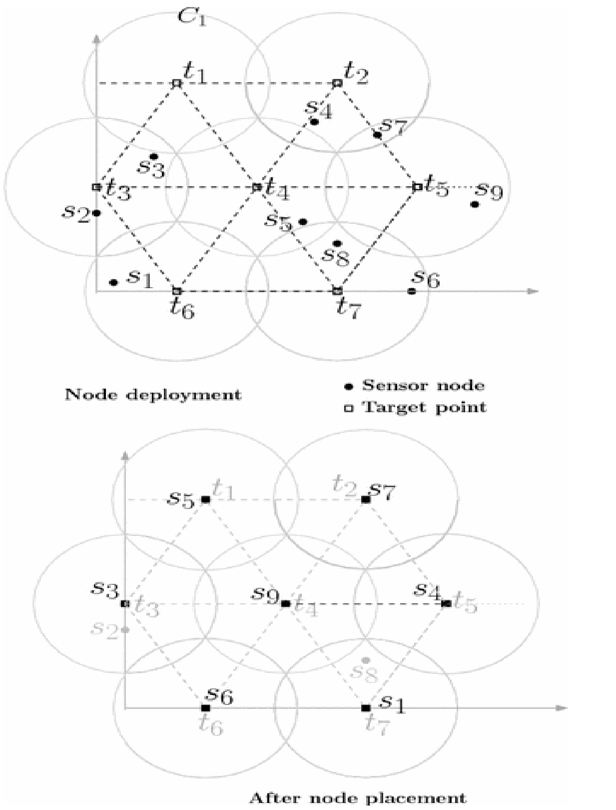

Figure 2: Generic WSN node placement based coverage for NLT validation

WSN are specified by coverage matrix with size $a * b$. matrix element value $(m * n)$ iff entire sub region $'j'$ is positioned inside sensor region and zero if not. WSN are specified using bipartite graph $G = (V, E)$ where $V = S \cup A$ and $(s_j, a_j) \in E$ when s_i is under a_j. Maximal lifetime problem of WSN is formulated with analysis of weaker coverage region. This is specifically to determine maximal amount of node coverage when all these regions are subset of sensors regions. These regions may be partitioned into number of subsets under coverage constraint. A general formulation of this weaker coverage region is provided as: Assume a WSN with set of sensors modelled to examine targeted region, this is to determine maximal amount of $'k'$ coverage $c_1, \dots, c_k$ *belongs to* $c_i \cap c_j = \emptyset$ *for* $i \neq j$. These nodes may belong to any of those clusters. Fig 2 depicts sample WSN connection within region partitioned into sub-regions. Bi-partite graph of WSN instance is provided here.

a. WSN-NLT computation

Nodes may consume higher amount of energy to carry out three essential tasks termed as processing, sensing and communication. Here, consider sum of nodes initial value is equivalent to power accessible by sensors. Here, nodes are considered to be homogeneous with similar node holding capacity. Energy consumed during idle position may be eliminated, whereas energy consumed during above mentioned tasks may be based on coverage region. When higher the energy consumed, then lower the sensors lifetime.

Based on these assumptions, NLT is computed with $T_i = \frac{\tau}{|s_i|}$, sensor lifetime for one unit is $t_i = (\tau - |s_i|)$, where $'i'$ is sensor count, $|s_i|$ is sensed regions by s_i and τ is constantly higher than maximal amount of sensing regions to eliminate unrealistic sensor LT (negatively). Consider that entire NLT is depicted as aggregation of nodes coverage. Coverage lifetime is sensor activity is still in coverage constraint which is violated in observing region,

Every targeted node has imaginary lifetime which is depicted as complete period of lifetime of sensors inside these regions. Owing to fact that entire network restrictions complete NLT is restricted with minimal targeted region network lifetime. With Fig 2, maximal amount of observing regions of network is considered to be four, τ value is higher than 4.For instance, $\tau = 10$, then acquire $T_1 = \frac{10}{3} = 3.3$; $T_2 = \frac{10}{1} = 10$. Outcomes are considered based on computational regions of lifetime as in Table I.

WSN lifetime is measured as sum of coverage region based nodes lifetime. Region lifetime is higher when sensor lifetime is also higher. Consider two diverse scenarios, $C_1 = \{s_2, s_3\}., C_2 = \{s_4, s_5\}, TC = \min(T_2, T_3 = 2.5$ *and* $TC = 3.3$. Entire lifetime is provided by $TC_1 + TC_2$. Thus, overall NLT is evaluated as 7.8 UT.

Table I: NLT computation

	a_1	a_2	a_3	a_4	a_5	$\|s_i\|$	T_i	t_i
s_1	1	0	1	1	0	3	3	7
s_2	0	1	0	0	0	1	9	9
s_3	1	0	1	1	1	4	2.6	6
s_4	1	0	0	1	0	2	5	8
s_5	0	1	1	0	1	3	3	7
s_6	0	0	1	0	1	2	5	7
Sensor	3	2	4	3	3			
INL	10	13	14	10	10			

b. Backbone sensors (BK-S)

Here, define the targeted network region as minimal sensing region in network as crucial targeted region and corresponding nodes are depicted as backbone sensors. The essential network is termed as BK-S as it manages all WSN lifetime functionalities.

Every entire region comprises of BK-S and maximal amount of these regions are restricted by number of backbone sensors that possess superior influence towards complete NLT. Upper case of NLT can be attuned with every nodes lifetime that is connected with BK-S. If BK-S nodes are seems to be running out of energy then coverage region may be terminated from its region. This is for computing optimality of sensor coverage region when total amount of residual energy at BK-S is zero. Subsequently, NLT lifetime is maximal LT attained during complete coverage constraint. From Table I BK-S is considered as a_2 owing to its minimal amount of sensors, subsequently BK-S regions are s_2 and s_5. Upper case is equivalent to number of crucial sensors. NLT of upper case is equivalent to minimal amount of imaginary NLT of targeted coverage region.

From all these, two solutions are attained, solution $A\ and\ B$. here, solution $'B'$ provides higher NLT than that of $'A'$. Network region overlapping is demonstrated as similar coverage region with duplication in communication and sensing energy utilized by overlapped region. These outcomes are energy wastage. Organization of nodes should be effectual by reducing total amount of overlapping nodes. Here, overlapping is provided as in Eq. (1):

$$O = \frac{1}{K}\sum_{k=1}^{K}\left[\sum\nolimits_{i}|s_{k_i}| - observing\ region\right] \quad (1)$$

c. Variance in node placement

When sensors are observing huge targeted region, they hauls higher amount of energy. Owing to this, load balancing among those sensors may be specifically influence able over NLT. In[], author depicts that placement variance. It is defined as measurement of sensing region based variation with sensors that belongs to entire coverage region. If variance is equal to zero, sensors are at dying state. Subsequently, residual energy of sensors may be reduced and complete NLT is maximized with energy usage and NLT is higher. Node placement variance is depicted as in Eq (2):

$$Variance = \frac{1}{K}\sum_{k=1}^{K}\left[\sqrt{\frac{\sum_i\left(|s_{k_i}| - A_k\right)^2}{|C_k|}}\right] \quad (2)$$

Where A_k is mean of sensing region. The success of variance is based on higher network lifetime. Algorithm 1 depicts about NLT in WSN:

Algorithm 1:

Input: Set of senor nodes, cluster of coverage region, NLT, coverage matrix, overlapping factors, variance.

1. Initialize parameters
2. Compute NLT = 0;
3. Compute sensor lifetime with $\frac{\tau}{|s_i|}$
4. Backbone sensor = crucial sensing region
5. Upper case of coverage region = minimal imaginary lifetime
6. While $k < upper\ case)$
7. While $(all\ regions\ are\ not\ covered)$
8. $r = r + 1$
9. $C_k = C_k \cup O(r)$
10. Region $(c_k) = area\ (c_k) U\ area\ (O(r))$
11. End while
12. If (all regions are covered)
13. $k = k + 1;$
14. $lifetime = minimal\ sensor\ life$
15. Compute overlap with placement variance
16. End if
17. End while
18. Compute idle sensor rate = $O - \sum_k C_k$
19. Output NLT, idle sensor and coverage region

d. Idle sensor computation

In the clusters of coverage region, some sensors are not used and remain to be idle for longer period of time. Based on overlapping constraint some nodes may be eliminated from these regions and some may perform certain functionality. This process will be repeated as analysis will be commences from starting to final sensor region. This process will be vice verse, after completion this will be terminated. With this simple constrained, unnecessary nodes will be eliminated from coverage region and these nodes may not affect the significant objective of NLT computation.

4. Numerical Results and Discussions

Here, simulation is carried out in MALTLAB simulator. Simulation instances of sensors are produced randomly. Deployment regions are with dimensions $50m * 50m, \tau$ value is 1000 initially with $15m$ sensing region. Termination will be chosen in 2000 generations. Computation is done with 100 diverse networks with diverse coverage region and outcomes are normalized as in Table II. Computational complexity is done with region overlapping, placement variance and normalization. Initial step is aggregating of sensing regions, next is subtraction of observation region based on constant number. MSE of sensing region is computed with $O(s)$. It is lesser complex for all coverage region. Subtraction is performed between backbone sensing region and coverage region is minimal sensing lifetime.

Table II: Parameter Setup

Properties	**Values**
Total nodes	200
Initial node energy	0.5 J
Idle energy	50nJ/round
Aggregation energy (CH to BS)	5nJ/bit
Amplification energy (Node to CH)	$E_{amp}/10$
Packet size	400 bits

Total number of nodes deployed in sensor environment is provided in Fig 3. As network transmission commences, number of active nodes reduces as huge nodes deplete energy. For further analysis, remaining energy of every sensor nodes with diverse cases i.e. $100m * 100m$ and $200\, m * 200\, m$. In every iterations, period among network utilizes target that are uncovered was utilized as network lifetime. Every experiment was functions 10 times higher than prevailing approaches.

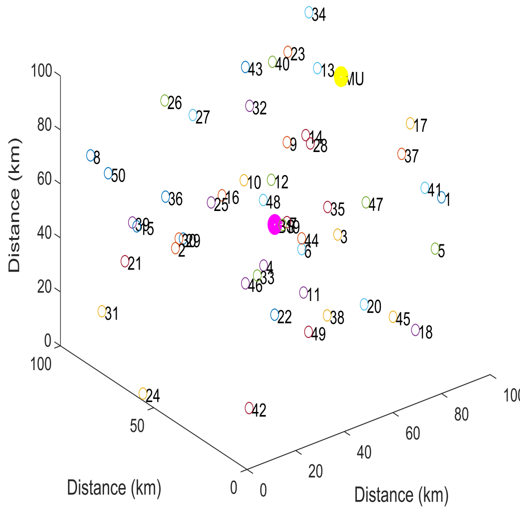

Figure 3: Node deployment

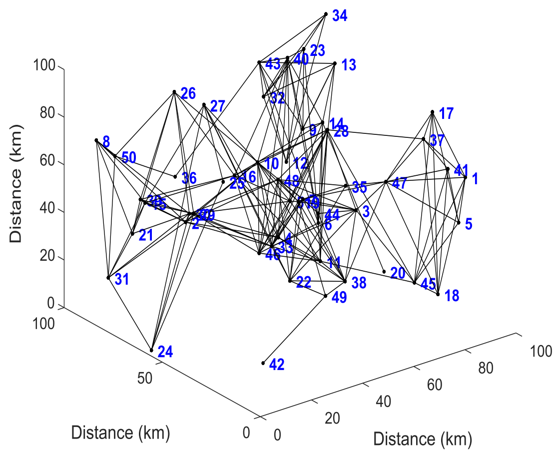

Figure 4: Node connectivity

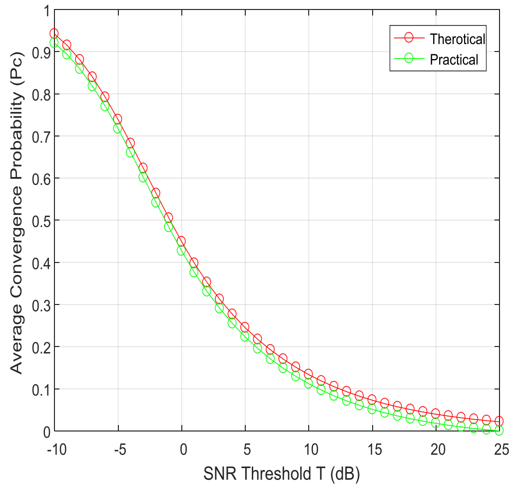

Figure 5: Average convergence probability

From the above results, some experimentation has been carried out to compute performance of anticipated model with various coverage regions as in Fig 4. With this, amount of energy consumed at every node level have been computed with Average coverage probability as in Fig.5. Network parameters utilized in these experimentations are provided in Table II. Here, energy, free space, mobility of sensing region is identified. The ultimate objective of anticipated approach is balancing energy and to improve NLT among sensors by computing remaining energy amount maintained by sensors at similar energy level.

5. Conclusion

WSN have been utilized in diverse tracking and monitoring environment. In these kinds of application, target coverage is achieved only by determining NLT and constant coverage with computed time. This work anticipates effectual coverage to acquire unique path that considers preserving energy of nodes chosen for communication and to determine total energy consumed while transmitting data. The energy consumed by expected region is measured to be at active coverage for subsequent rounds. In contrary to prevailing approaches, this method provides an enhanced WSN performance based on total energy consumed, NLT, time needed for switching among diverse CR. This framework can be adopted both in mobile and static environments that are utilized to enhance NLT. Functionality of this work can be validated in real time environment as future direction.

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