International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

An Efficient design of Point and Area Sweep-Coverage founded Systems for Wireless Sensor Networks

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Submitted: 21/04/2023 **Revised**: 15/06/2023 **Accepted**: 25/06/2023

Abstract: The mobility of WSNs creates a number of challenges, some of which include planning for mobile data collectors and charging trucks. Other challenges include providing coverage. Communication in WSNs often takes place on a hop-by-hop basis between nodes and base stations. Managing connections that involve multiple hops between the sink node and the sensor nodes might be challenging. This is a significant challenge because it evaluates the degree to which WSN sensor nodes cover a given target. The process of continually monitoring a particular point of interest (PoI) over the course of time is referred to as sweep coverage. However, using static SNs for continuous coverage results in an increase in the amount of energy required. In place of continuous monitoring, periodic monitoring may at times be sufficient for determining content, and it also requires significantly less energy. T-sweep coverage refers to the process by which SNs cover a target's points or sub-area after a certain length of time t has passed. It is NP-hard to select the best possible combination of mobile SNs in order to maintain a constant sweep speed while ensuring coverage. The purpose of this study is to address the issue of sweep coverage for a particular point of interest by presenting a new method that uses an approximation of 1.5. There are two different ways to approximate the best possible solution to the point sweep-coverage difficulty found in the research. The A-SCA model's objective is to cover the AoI with a limited number of mobile SNs as much as possible. When most people think about the problem of area sweep coverage, they immediately think of the method known as the 22 approximation. The suggested techniques have been demonstrated, via extensive simulation and analysis, to dramatically minimize the amount of mobile SNs when compared to the state-of-the-art methodologies.

Keywords: *WSN, PoI, SN, Sweep Coverage.*

1. Introduction

The attention delinquent, which emphases on how effectively the deployed sensors view the physical space, is a significant issue in WSN [1]. There have been many different coverage formulations put forth. Area coverage, point coverage, and barrier coverage are the three categories into which the coverage issues in WSN can be divided. Either of these coverage kinds uses a large number of stationary sensor nodes that continuously monitor the surrounding environment [2]. Certain applications, such as patrol inspection, need periodic monitoring of specific points of interest (POI) rather than continuous surveillance of the entire region. Assuming that all sensors in this scenario are mobile, a mobile node must periodically visit each POI, a process known as a sweep coverage [3].

Due to the peculiarities of sweep coverage, it is not possible to employ the conventional static coverage methodologies in a sweep coverage scenario, which could result in subpar efficiency and needless additional costs [4-5]. This problem is also known as the min-sensor sweep-coverage problem. Using sweep attention to simplify and lower the charge of the WSN has a lot of potential benefits, but it also has a lot of challenges. Essentially, this issue is a combination optimization issue, and it consists of two closely related components. Periodic POI coverage (data collection) is the first part, and data transfer from POIs to sink is the second. Owing to these

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challenges, the only approach currently being used to address this issue is data collection [6].

Wireless sensor networks (WSNs) are one of the most promising and rapidly expanding technologies, and their applications span the majority of real-world domains, including environmental monitoring, defence, the automation industry, the healthcare system, vehicular communications, wildlife tracking, and agricultural practices. WSNs are appealing to all of these applications for a number of different reasons, including their compact size, ease of deployment, and low cost [7]. The primary purpose of these deployments is to capture data about the region or site of interest and transmit it to the base station in order to carry out monitoring of the area. Each SN is equipped with the necessary components to carry out this operation. These components include a sensing unit that is used for observing the phenomenon, a transceiver that is used to connect the network and transmit data, a small processing unit that is used for processing data, a power unit that is used to supply power, and a buffer that is used for storing the data in a spatially organized manner [8]. The battery's availability determines how long the SN is operational. Long coverage times and network longevity are both increased by effective battery management. One of the difficult issues in WSNs is energy optimization, which is especially difficult for WSNs with mobility functions [9].

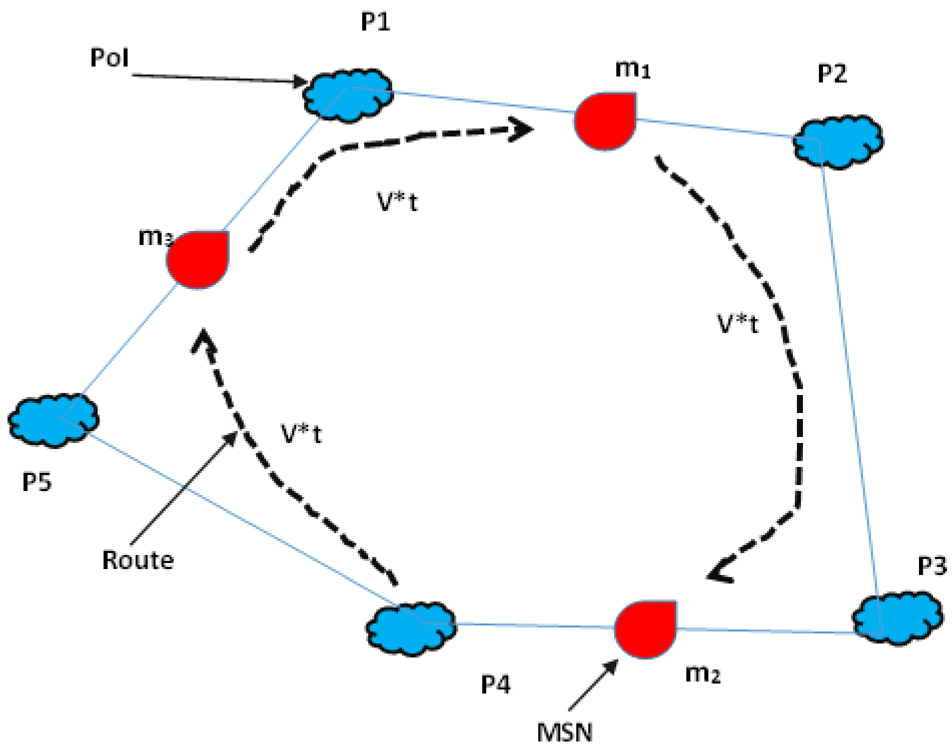

Fig I: An design for Mobile Sensor Node and PoIs.

Coverage is very difficult when the SNs are movable. The literature describes three methods for achieving target coverage when sensor nodes are mobile: determining the lowest number of nodes necessary to cover the available targets, managing node velocity, and determining the length of time needed to reach the target [10]. It takes more energy to continuously cover a target with static SNs. In certain situations, conducting content analysis on a more sporadic, rather than a constant, basis is appropriate and requires significantly less energy. Coverage problems can be broken down into three distinct categories according on the ways in which they are applied. The first one is known as area coverage, and it occurs when wireless SNs completely encircle every site inside a particular area of interest (AoI) [11]. The second type of coverage is called point coverage, and it requires the sensors to encompass the selected point within a particular area. The third approach is called barrier coverage, and it involves SNs keeping a constant check on the boundary of the chosen path or the AoI [12].

Once the SNs have completed their coverage of the targets, the data must be gathered and then sent to the base station so that they can be further processed. When the base station is in close proximity, they utilize a communication method called single-hop communication to send data. In all other circumstances, however, they use a communication method called multi-hop communication [13]. In situations like this, the SNs that are operating as relay nodes not only transmit the data packets they have obtained, but they also transmit the data packets that have been accumulated from other SNs. Because of this, in comparison to other SNs, these relay nodes have a significantly higher energy requirement and will eventually fail. Also, the SNs that are situated one hop distant from the sink node will suffer a significant amount of effect. The connection between the base station and a certain group of SNs is severed once one of these nodes passes away. This issue is also referred to as a sinkhole, energy hole, or hotspot issue [14].

What follows is the outline for the rest of the paper. The related work is briefly described in part 2, and the methodology and the theoretical foundations of the methods used are described in section 3. The simulation consequences and investigation are offered in section 4. For the paper’s final section, “key findings” we summarize the most important results.

2. Previously Done Related Work

It is important to keep an eye on whether all of the deployed SNs are connected and promptly transmitting data to the base station. Hence, some mobile SNs are assigned via point and area sweep coverage algorithms to monitor SN connectivity [15]. These algorithms, in general, characterize the surveillance quality in the sensing areas or targets in the mobile WSNs. The literature contains a number of algorithms that help mobile and static SNs in the network provide effective point and area sweep coverage. Most of these algorithms rely on linear programming, approximation algorithms, and heuristic methods [16].

The literature contains many strategies that address the coverage problems in a WSN. NP-complete problems are present in some of the papers introduced, and a few heuristics have been put forth in a few additional studies. Given the asymmetrical polygonal sensing ranges, the authors of another research have taken into consideration more practical scope conspire [17]. Another study by the same authors demonstrates an effective mechanism for WSNs by offering fully dispersed coverage via static SNs. By using the SNs in sleep-scheduling mode, the suggested technique lengthens the lifespan of WSNs. They have outlined the computing characteristics of the NP-hard problems and suggested a factor calculation strategy. Some studies have addressed the question of area coverage [18].

The authors of a few papers that addressed point-coverage issues considered an arrangement that included both stationary and mobile SNs as a possible solution. On a regular basis, the mobile sensors make their way to the static sensor in order to gather or combine the data they have obtained [19]. A mobile sensor is only able to obtain data from a static sensor when the two sensors are in the same area and within communication range of one another. Another group of researchers developed two distinct heuristics in order to address the many different mobile SN development requirements. In the first heuristic, which is known as MinExpand, mobile SNs travel along the same path each and every time [20]. In the second, dubbed OS-weep, mobile SNs travel a variety of paths over varying lengths of time. The authors have demonstrated that the issue is related to resolving the TSP issue. Researchers discussed the point and ASC difficulties in their study and demonstrated that the issues are NP-complete. For the point and ASC issues, they have suggested 2-approximation and $2\sqrt{2}$-approximation techniques, respectively [21].

The authors took into consideration a geometric subtype of the point coverage problem called the unit disc cover problem. This subtype is known as "the unit disc cover problem." Several distinct subfields of research each have their own approach to investigating point coverage issues. An approximation strategy that made use of constant factors was ultimately successful in solving the problem. In several of these research, questions pertaining to area coverage are investigated. The authors of this article propose a fully distributed coverage-preserving method for use in wireless sensor networks that make use of a collection of stationary sensors. The program extends the lifetime of the network by carefully calculating when the sensors will go to sleep and when they will awake. It guarantees that there will be no breaks in the network's coverage while the device is not actively being used. As three different strategies for movement-assisted area coverage, academics offered the vector-based process, the Voronoi-based process, and the minimax process [22]. The coverage gaps are localized with the help of a Voronoi diagram in this article. These mobility strategies contribute significantly to an increase in the coverage provided by mobile sensors. The second group of researchers came up with a distributed heuristic, which involves moving sensors in such a way that, with each iteration, the total topology gets closer and closer to an equilateral triangulation of the plane. This is the configuration that provides the most effective coverage for an area. The discipline of robotics is where the concept of covering in one continuous motion initially developed. A number of previously unknown studies in the topic of sweep coverage difficulties have come to light in recent times. Several writers have proposed two separate ways for dealing with a variety of mobility restrictions imposed on mobile sensors. Mobile sensors move along distinct paths during different time periods when using the second heuristic sweep as opposed to the first heuristic MinExpand, which uses the same path for all time periods [23]. This is in contrast to the first heuristic MinExpand, which moves along the same path throughout all time periods [24]. The authors noted that it is impossible to develop a distributed local algorithm that is capable of providing sweep coverage. This means that a mobile sensor is unable to determine locally if all PoIs are sweep-covered if there is no global information available. Some researchers have proposed using a two-approximation method to sweep across a group of points of interest (PoIs) in order to increase the amount of time that a coverage sweep will last when all mobile sensors travel to each PoI. The authors discussed a decentralized version of the suggested method that handles a group of stationary sensors as PoIs. This variant of the method uses a distributed system. Static sensors determine the number of mobile sensors, their movement pattern, and the initial deployment locations by communicating with one another and exchanging messages. The subject of area sweep coverage was discussed in this research, and a two-approximation method for calculating coverage in rectangular bounded zones was proposed [25].

3. Purpose of the Work

1) To develop Point and Area Sweep-Coverage based Algorithms for Wireless Sensor Networks.

4. The Projected Work:

In this paper, we propose a novel 1.5-approximation approach as a possible solution to the problem of inadequate sweep coverage at a particular area. For the point sweep-coverage challenge, the 2-approximation was found to be the most accurate one in the available research. A novel approach based on an estimate of 1.5 by 2 is also provided by us as a solution to the sweep-coverage problem. When it comes to approximation strategies for solving the area sweep-coverage problem, the 22-approximation method is by far the most well-known. The following is a brief summary of the outcomes of our efforts:

- We propose a new method that is an approximation of 1.5, and we term it the point sweep coverage algorithm. This will allow us to solve the problem of P-SCA (point sweep coverage). The total number of mobile SNs that are required to visit each PoI can hopefully be cut down with the help of this strategy. Among the various proposed approximation processes, the two-approximation, also known as point sweep coverage, is the one that has received the most attention.
- The unique technique known as the A-SCA (area sweep coverage algorithm), which uses a 1.5√2-approximation method, was presented for the purpose of performing area sweep coverage. The purpose of the algorithm is to cut down on the total number of mobile sensors needed to cover the Area of Interest as much as possible. The most well-known approximation for area sweep-coverage is known as the ASC, which stands for the 2√2-approximation. This approximation was also proposed.

Let's call the total number of PoIs in the search area n. The euclidean distance between the points is determined once a whole graph is built over the data (vertices). Prim's Algorithm is used to create the minimal spanning tree (MST) from the obtained linked edges. The minimal cost perfect matching is then computed and the result is shown after we have found the minimum spanning tree. Even if an edge is already there, we'll take it into account if adding it will result in a multigraph, as seen by the red line in the minimal spanning tree. In order to get the Hamiltonian tour, we now compute the graph's Eulerian tour and cut the circuit of the repeated vertices. P-SCA algorithm is as follows:

```
INPUT: Points of Interest (n), Area (a), Mobile SN Speed (v), and Sweep Time (t).
The output includes the path and approximated number of mobile SNs for a certain point sweep coverage
(L) (m)
1: graph (n,n), P(n,n);
2: M (n,n) st(n), G(n,n),
3: Perform
4: Pi0 = rand ()% ax;
5: Pi1 = rand ()% ay;
6: finish
7: for i=1 over and done with n, do
8: Set graphij = Euclidean expanse (Pi0, Pj0, Pi1, Pj1);
9: Do for j = 1 to n.
10: finish for
11; 12: Mst graph = prims mst(graph); /with the assistance of the prims process, regulate the MST of a
specified graph Process 2
13: M = seamless equivalent (Mst graph)
14: the novel graph G is attained by totaling the mass M to the graph Mst;
15: Eulerian trip (E) = Grassmannian (G); / retaining a Grassmannian-Eule
16: applying Euclidean expanse, define the stretch L of trip E;
17: for I = 1 to E finish do
18: if Ei stayed then
19: Ei.remove ();
20: finish if
21: Divided L into L / (vxt) and abode m = L/ (vxt) mobile SNs at apiece at all the panel themes;
22: Finish for.
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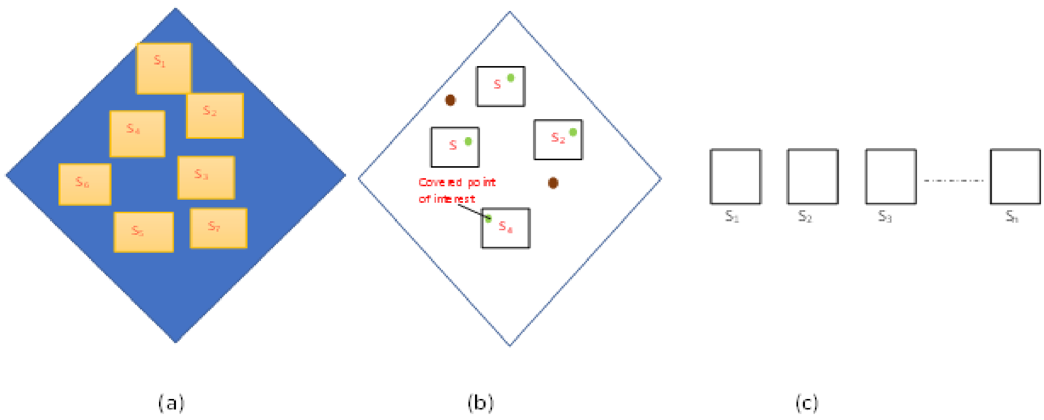

Fig III: Different categories of attention methods in WSNs (a) area attention (b) Point attention (c) Barrier attention

4.2. Below is a discussion of our suggested Area Sweep-Coverage Algorithm (A-SCA). Let's think about an AoI. In the algorithm, X and Y are taken to be the length and width, respectively, of the referred area. The sensing and transmitting distances of the mobile SNs will be denoted by Rs and Rc, respectively. The line represents a diagonal d bigger than the rc. After that, we create sub-areas with diagonals that are smaller than or equal to Rc. Let's pretend the Area of Interest (AoI) is subdivided into four sections, A1 through A4. Then, make a grid with a size of 2Rs in each individual section. Then, we apply our P-SCA algorithm over all the sub areas, which provides the route and location of mobile SNs for each sub area, guaranteeing complete coverage of the region of interest. Algorithm for A-SCA is as follows:

```
Input coordinates (X, Y, and R)
OUTPUT: route, convey node co-ordinate points
1. Make area = [] to start;
2: if checked area (X, Y) == Box then
3: mark area = X × Y;
4: otherwise
5: mark area = create box (X, Y);
6: Finish if
7: while make area is not equal to empty do
8: while diag Expanse (X, Y) > R do
9: X = X/2;
10: Y = Y/2;
11: mark area = X*Y;
12: finish while;
13: finish while;
14: for I = 1 to span (mark area) do step 15
15: Route[i] = P–SCA (mark area[i]);
16: finish for
```

5. Result and Discussion:

During the simulation, we evaluated the performance of our suggested A-SCA and P-SCA algorithm in comparison to the performance of the previously established approach for area sweep-coverage. The results of the area sweep coverage have been displayed for a variety of different areas. Python was used to create a simulation of this result, and the resulting output was displayed. In the figures, we have taken the area of the several ranges where we have illustrated the deployment of the mobile sensor nodes and represented it as a whole

Table I: The Projected System Assessment with Existing Method for PoIs Count.

S. No.	PoIs Count	Mobile Sensor Node Count	
		P-SCA	PSC
1	20	3	4
2	40	4	6
3	60	5	6
4	80	5	7
5	100	6	8

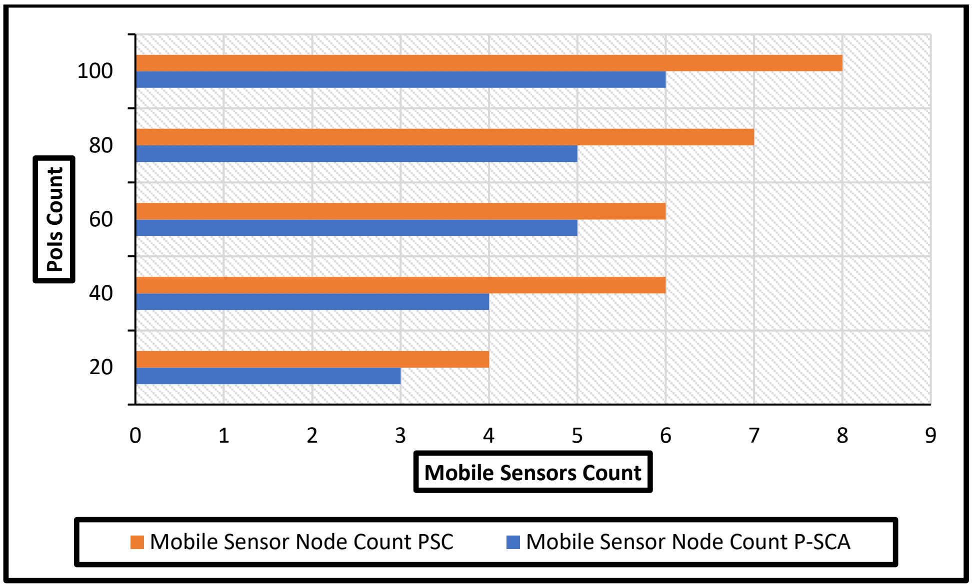

Fig III: The Projected System Assessment with Existing Method for PoIs Count.

Table II: The Projected System Assessment with Existing Method for Sweep Period (Sec).

S. No.	Sweep Period (Sec)	Mobile Sensor Node Count	
		P-SCA	PSC
1	80	20	20
2	130	8	7
3	180	6	7
4	230	2	3
5	280	2	2

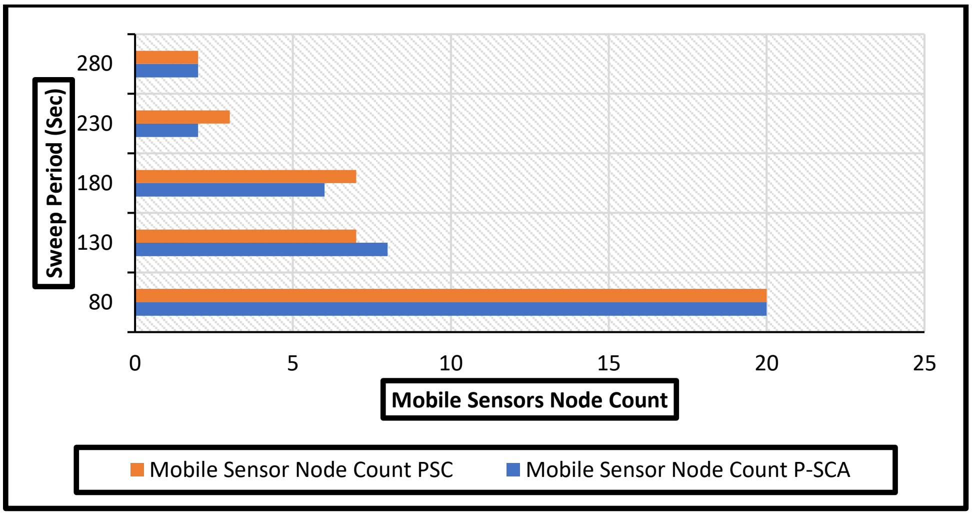

Fig IV: The Projected System Assessment with Existing Method for Sweep Period (Sec).

Figure III illustrates the number of SNs required to achieve sweep coverage for varying numbers of points of interest while maintaining the same amount of time during the sweep period. The bar plot shown in Figure IV illustrates the number of mobile sensors required to cover 50 PoIs over a range of possible sweep coverage times. In light of the data presented here, it is clear that the proposed mechanism requires a far lower number of mobile SNs than the approach that is currently in use.

During the simulation, we also compared the previously used approach for area sweep-coverage to the one that our newly developed A-SCA algorithm will replace. The results of the area sweep coverage have been displayed for a variety of different areas. With the help of this simulation's end result, we are attempting to demonstrate the multi-hopping notion in situations in which the communication range of the most recent relay node is shorter than the distance separating it from the sink.

6. Conclusion:

The deployment of SNs in WSNs is typically haphazard. The random nature of the deployment increases the possibility that certain nodes, or a subset of nodes, will be cut off from the rest of the network. Mobile SNs make the already difficult issue of managing connectivity much more so. Thus, the problems with connectivity must be fixed. After a reliable connection has been established, sending data back to the base station for analysis is a crucial step. The SNs closest to the BS deplete their energy rapidly during the transmitting because to the intensive data transmission. Mobile sink/s collect the data from the SNs in place of conventional routing schemes, helping to solve the energy fleapit problem. In this study, we present two different sweep coverage algorithms: P-SCA, an approximate 1.5-approach to the point-sweep coverage problem, and A-SCA, an approximate 1.5√2-approach mechanism for the ASC problem. P-goal SCA's is to send a small number of mobile SNs to each PoI. Two-approximation is the most well-known process for approximation that has been presented so far. Covering AoI with a minimum fleet of mobile SNs is the aim of the A-SCA model. For the area sweep-coverage problem, the most well-known approximation algorithm is the 2√2-approximation. We have proven, via extensive simulation and analysis, that the suggested algorithms achieve the lowest possible mobile SN count compared to the state-of-the-art methods.

Conflict of Interests:

The authors declare that there is no conflict of interests regarding the publication of this paper.

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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