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A geodesic deployment and radial shaped clustering (RSC) algorithm with statistical aggregation in sensor networks

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Abstract: Wireless sensor networks (WSN) comprise a large number of connected tiny or small sensor devices to sense physical phenomenon. In WSN, prolonging the network's lifetime is a biggest challenge due to absence of power harvesting facility and irreplaceable batteries of the sensor devices. Clustering is one of the widely accepted and standard technique to solve the energy issues faced in WSN. In addition to clustering, the shape of the deployment area also plays the major role especially for large scale sensor deployment. This paper proposes a radial shaped clustering (RSC) algorithm with angular inclination routing. The radial shaped deployed area is divided into virtual concentric layers and each layer is further divided into a set of sectors called clusters. Angular routing is applied to achieve multihop routing of packets towards the Sink node. In comparison to fan shaped clustering (FSC), RSC performs better in terms of residual energy and packet received ratio.

Key words: Wireless sensor networks, network lifetime, radial shaped clustering, node deployment, angular routing

1. Introduction to the area

In most of the legitimate applications, the sensor nodes are used in large-scale area and are applied preferably for better reliability and efficiency. WSN comprises of great quantities of sensors with the capability of sensing as well as communication, which means cooperatively collecting data and sending them to the coordinator called Sink. The main objective of sensor node deployment is to monitor the physical phenomenon, to process the sensed information, and to transfer the information to a center known as Sink. In general, the sensor nodes are powered by batteries, which are very limited in power and mostly irreplaceable [1–3]. Sensor nodes, depending on the nature of application, may have very minimum range of transmission. So, the parsimonious utilization of power is of utmost importance. So, a network of sensor nodes is essential to propagate their data to a longer distance.

One of the most widely accepted unique practices for data gathering is clustering where the sensor devices are grouped into a number of clusters that can be used for conserving the energy. Each cluster may have a group of nodes called cluster members and a reporting point to send the sensed data known as cluster head (CH). Each sensing node does its duty and the sensed data is transmitted to the CH located within that cluster. Then, the head collects the entire data, aggregate it by using any aggregation measure, makes them a single unique packet, and transmits data to the coordinator. Here, the capacity of network is balanced in addition

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to the minimized energy consumption which makes the set of connections to live longer by implementing the clustering technique.

Clustering and routing are some of the commonly adopted methods for collecting and transreceiving data, which would reduce energy consumption considerably [3, 4]. Energy optimization in sensor nodes turns out to be a significant challenge in WSN. Several clustering approaches were intended mainly to address the issue of optimizing the energy consumption in different scenarios in the last few years [5, 6]. Determining the suitable clustering method and to ensure all the nodes present in the network within the coverage area are the two eye openers for bringing out a stable WSN with nominal energy requirements.

2. Related works

Wireless sensor networks consist of large amounts of tiny devices called sensors used to sense the environment. The sensor nodes are very small in size, have very limited battery, and these nodes are deployed to gather the data from the specified location where the mankind cannot intervene. The major issue of WSN is energy limitations as the battery cannot be replaced after the node gets deployed. To address the energy issues, many clustering and routing protocols came into existence and this issue is even more critical when large scale deployment is considered. Clustering gains much attention in WSN for improving the scalability and energy conservation in WSN[6].

Many of the clustering protocols like low energy adaptive clustering hierarchy (LEACH)[7], power-efficient gathering in sensor information systems (PEGASIS) [8], threshold-sensitive energy efficient network (TEEN) and adaptive threshold-sensitive energy efficient network (APTEEN) [9] and hybrid energy efficient distributed (HEED) clustering [10] etc. came into effect to frame the deployed nodes as clusters and to collect data efficiently. The clusters were formed based on the transmission distance in LEACH, whereas virtual grid based clustering was implemented in HEED. The chain based clustering was established in PEGASIS which ensures the chain based routing, too. In most of the existing clustering algorithms like LEACH, PEGASIS, HEED, etc., the process of forming clusters was differentiated to decrease the energy consumption, but the shape of the deployment area was considered as a square invariably in all the algorithms. However, this square shape may not be the right choice for all the real time sensor based applications, because the surface of the deployment area may vary from one application to another as specified by Feng et al. [11].

For large scale deployment, the surface of the deployment area and the node coverage has to be considered to extend the lifetime of the network. To communicate effectively between all the nodes deployed, the provisions have been created with a number of algorithms [12]. The surface for deployment may be taken as a planar graph, and to measure the shape of the planar graph, Euclidean distance is applied for getting the landmarks. However, for translations, scaling, and rotations of the nodes, this metric has to be replaced by the shape space according to Huang et.al [13].

To measure the intercluster communication distances, standard hierarchical clustering techniques like LEACH and HEED maybe applied with zero similarity measures. In an environment based on certain different clustering structure, Chang et.al [14] have given a technologically advanced mixture model known as generic shape distributions. In the deployment shape measures calculation, normally the landmark coordinates are assumed to be isotropic covariance structure. Bivariate Gaussian densities are considered to be the optimal choice with model-based parameters for hierarchical structured algorithms [14].

Lin et al.[15, 16] separated the deployment area into a circular-shaped clusters. The circular or Fan Shaped Clustering (FSC) partitions the network into a number of concentric rings and each ring is further separated into different sectors known as clusters. FSC placed the Sink in the midpoint of the fan-shaped coverage and used multipath routing to transmit data from the outer layer towards the inner layer to reach to the Sink. But in many real-time applications such as natural protection of the environment, smart agriculture and so on, it might not be possible to locate the Sink inside the central area.

In FSC, the Sink is located in the middle of the deployment area. To reduce the hotspot issue in FSC, the inner layer is set as twice as that of the outer layer. If the Sink position changed based on the application, then the layering may not be suitable. The shape of the cluster may vary depending on the deployment shape, but it was considered as a grid in FSC. The intercluster communication was designed from outer ring to inner ring to reach to the Sink, yet this strategy also has to be addressed based on the Sink position. The following are the major contribution of radial shaped clustering (RSC):

(i) The radial shape of the deployment area, which can be adoptable to real world scenarios. (ii) A new clustering strategy with the distance and the angle to improve the network lifetime. (iii) An angular inclination based routing with geodesic distance to reduce the number of hops.

This paper is organized as follows: Section 3 describes geodesic deployment structure with probability distributions for geodesic distance , and Section 4 clearly depicts the network and energy model used for implementing the radial shaped clustering algorithm. The algorithm formulation of radial shaped geo clustering and angular routing is explained in Section 5, and Section 6 provides the performance comparison of RSC with the previous work FSC. Compared to the previous algorithms [17–21], RSC produces better results in energy conservation and minimizing the number of hops for data transmission. Section 7 concludes the work with future directions.

3. Geometrical deployment structure with probability distributions

Deployment area shape is of much interest in various sensing fields, which is normally considered as planar objects based on landmarks and phenomena of selforganizing nodes. The deployment region is manifold: the geometric structure considers local coordinates, which are measured by Euclidean, and pattern systems are essential in nature which depends on the quantifiable calculation of the vicinity of landmarks. For the assessment of different patterns, a similarity measure is required which are well-suited for a type of planar object.

A Riemannian metric given in [22] is adopted here with differential geometry since deployment area is manifold with probability distributions. Riemannian metric A with differential manifold would be brought by matrix f, which describes an internal product on each and every single tangent area of manifold for example. Consider $(x, y) = x^T f_{ij} y$ with norms associated as $||x|| = \sqrt{(x, x)}$. If so, the scale of length between the points M, N of the manifold to be assumed as the minimum distances of the complete piecewise plane object that routes β joining the two points. Specifically, the length of route is measured by applying the innermost product,

$$Length\ of\ \beta = \int \|\beta'(t)\|\, dt \quad (1)$$

,

and thus the distance

$$d\,(M, N) = min_\beta \,\{Length\ of\ \beta\} \quad (2)$$

The distance measured above in (2) is termed as geodesic distance and the shortest path framed through the curve structure is termed as a Riemannian geodesic metric. A geodesic measure is a suitable option only when the connections are defined solely based on the shortest path.

In the manifestation of nondeterministic phenomena, probability theory contributes the description of unprocessed data naturally. Every measurement c is identified as a trial from an essential probability distribution of the dimension which brings the categorical avenue by its probability density function $p\,(c/\theta)$. Generally distribution parameters describes the measurements, namely θ and it holds large information rather than expressing the measurement either as a value or an error text. So, pattern recognition methods are required and are applied as straight to fulfill the place of probability distributions. Let P represent the probability density function $p\,(c/\theta)$ parameterized by $\theta \in S^k$. Since statistical manifold structure is considered as the basis, the coordinates that remain local are endowed as the contour structure family parameters. If p variate Gaussian distance is considered as a measure, then

$$f(\frac{c}{\theta} = (\varphi, \Sigma)) = 2\pi^{\frac{-p}{2}}(\Sigma^{\frac{-1}{2}})\exp(\frac{-1}{2}(c-\varphi)^T\sigma^{-1}(c-\varphi)) \tag{3}$$

where mean vectors are represented as $c = (c_1, c_2, c_3 ... c_p)^T$ and $\varphi = \{(\varphi_1, \varphi_2, \varphi_3 ... \varphi_p)^T$ and the covariance matrix is denoted as Σ. The parameters of shape space has its own dimensions measured by $k = p + \frac{p((p+1)}{2)}$. Probability distributions manifold have two different geometrical structures which includes bivariate Gaussian densities, optimal transportation with Wasserstein distance if the structure of the random variables are known, reversible transformations is completed if random variables are applied with Fisher–Rao information metric etc.Riemannian metric with variate Gaussian distance is taken for implementation in this paper which induces Geodesic distances.

4. Network and energy model

The hybrid energy efficient distributed (HEED) clustering is one of the important works that focuses on minimizing the communication cost within the cluster. The network and energy model used in HEED is adopted for this work as the same random waypoint and multi path communication between nodes used in HEED is established here also. The power consumption model of HEED is used in RSC since the network and energy model is adopted from HEED. Subsequently, the nodes are fitted with quasi-stationary and distributed independently in a network area as like HEED. So, the energy model given in HEED is well-thought-out as the most preferable choice to be adopted for RSC. Each node is aware of its polar coordinates, and the devices are GPS (global positioning system) enabled. Initially, the network area is defined with circular shape using the following parameters:

- The radius of the deployment area (r)
- Angle (θ)
- Center position of the area (x_1, y_1)

Then, the network field is partitioned into virtual concentric rings by using the formulas

$$x := x_1 + tr * \cos(\theta) \tag{4}$$

and

$$y := y_1 + tr * \sin(\theta) \tag{5}$$

The equations 4 and 5 are used to divide the network field into concentric rings virtually. From the center position, the x and y values are calculated to structure the rings called layers. The transmission radius

tr is taken as 100m to measure each layer and it is assumed that the deployed sensor nodes have the fixed transmission radius. Each layer, further partitioned into a number of sectors and the entire network field is divided into number of quadrants to achieve optimized load balancing. The layer k is divided into $(2*k-1)*n$ sectors which are called clusters and the natural number n represents the quadrants. In Figure 1, the quadrants n considered as 4 and the Sink is positioned in the centre point of the network field.

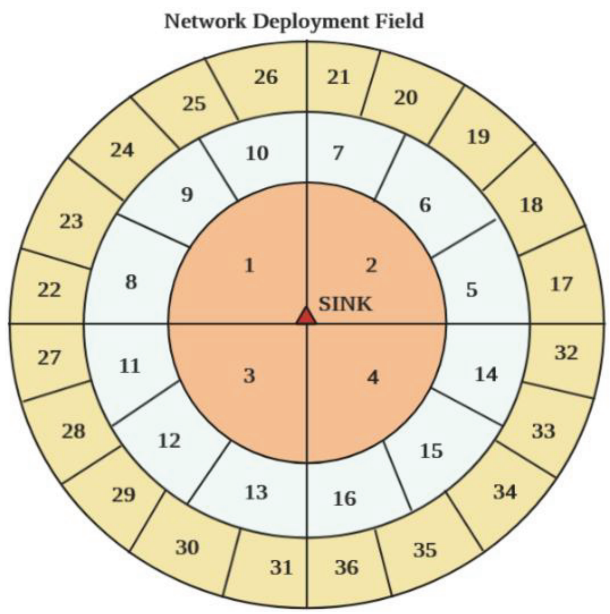

Figure 1. Deployment Structure

The deployment structure of RSC is given in Figure 1. In the previous work (FSC), the Sink located in the middle of the network field and the layer k, hich communicates with the layer $k-1$ to reach to the Sink. But, in a large scale deployment, this may not be the case. The Sink is always located in the middle of the network field. For measuring the distance between two clusters, the last cluster of the layer $k+1$ and the first cluster of the layer $k-1$ are used. But, the method to identify the last cluster and first cluster in a layer was not addressed in FSC. So, these issues were taken into account when the network field is defined in RSC. The Sink may be located anywhere in the field and the data is transmitted towards the Sink using the polar coordinates and location of the Sink. The geodesic distance is calculated for intercluster communication.

5. Radial shaped clustering and angular inclination routing

The nodes are deployed randomly. After deployment, the network area is separated into radial-shaped virtual a number of rings. Each ring has a set of sensing nodes with the transmission radius r. Each virtual ring in the network has m number of clusters. The number of sectors in each ring are calculated starting from the midpoint of the deployed area $plot(x_c, y_c)$ to the transmission radius of each layer. After framing the sectors, the nodes are deployed randomly in the deployment area. Each node identifies its location and polar coordinates. The sector number is updated to the nodes based on the coordinates of the sector. This process is clearly presented in Algorithm 1.

Algorithm 1: Radial shaped clustering.

Input: $-r$: Transmission radius
$-a$: Number of layers
x_c, y_c : Position of the Sink
Output: $-k$: The Number of Clusters
begin

$$k := (2 * k - 1) * a$$

/* **Find the number of sectors** */
for i ***from*** $1 to k$ **do**
  for j ***from*** $1 to i$ **do**

$$\theta = \frac{angle}{2} * i$$

$$x := x_1 + tr * \cos(\theta)$$

$$y := y_1 + tr * \sin(\theta)$$

$$plot(x, y)$$

  end

$$r := r + d$$

end
/* **Node deployment** */

$$r1 := rand(s.no, 1)$$

$$x := r1 * \cos(\theta) + x_1$$

$$y := r1 * \sin(\theta) + y_1$$

Node$_p lot(x, y)$
/* **Calculate the polar coordinates**

$$r = sqrt(x^2, y^2)$$

$$\theta := atan(y/x)$$

/* **Position of nodes** */
for i ***from*** $1 to s.no$ **do**
  if $node_{layer(i)} == r$ then

$$k = (2 * k - 1) * a$$

  for j ***from*** $1 to k$ **do**
    if $node(i)_{angle} \leq sector(i)_{angle}$ then

$$node\,(i)\,.position = sector\,(i)\,.position$$

  end
end
end

5.1. Cluster head (CH) selection in RSC

In the deployed area, each virtual layer is divided into a number of sectors known as clusters and the nodes deployed in the sectors identifying their location. For the nodes within the cluster, Euclidean distance is measured to identify the local CH. The node which is available nearest to the center point of a cluster would become the cluster head (CH) initially. Later on, if the battery level of CH gets less than the threshold rate, then the reelection process begins. The sensing nodes located in a cluster, whose battery level is greater when compared to the remaining nodes, would become the CH to that cluster. Since the corner of the cluster might have curve-shaped, geodesic distance is calculated for finding the path between multiple hops towards the Sink. The procedure for selecting the CH is given in algorithm 2.

Algorithm 2: CH selection in RSC

Input: $-Size_A$: Number of nodes randomly deployed
$-Size_grp$: Cluster midpoints
$-a$: Size of a cluster
$-r$: Transmission radius
Output: C_k : Each cluster with cluster head
begin **for** i ***from*** $1 to Size_g rp$ **do**
  Find minimum and maximum of x, y **coordinates for each grid with** a
  $k := 1$ **for** j ***from*** $1 to Size_A$ **do**
    if $min(x) \leq node.x \leq \max(x)$ *and* $\min(y) \leq node.y \leq \max(y)$ then Calculate radius, angle and the distance between node ids
  end
end
for l ***from*** $1 to m$ **do**
  $Min_i(l) = min(Dist_i(l))$ if $(Min_i(l) == Min_i(l-1)$ then Verify the energy level of each node and select the one with maximum energy
  $k < -k + 1$
end

When the CH identifies that its energy level touches to the threshold limit, the message is broadcasted from the CH to the all nodes within a cluster. Then the new CH is selected by considering (i) lesser distance to the center of the cluster and (ii) highest residual energy. Then the remaining nodes get informed about new CH by the old CH. The advantage of using RSC through angular routing is it reduces the number of hops while transmitting the data. In that way, it minimizes the reclustering cost.

5.2. Angular routing model

In the routing model of RSC, single hop transmission is followed for communication within the cluster from cluster member to the CH. To transmit the aggregated data from CH to the Sink, multi hop routing is established.

The Sink may be positioned anywhere within the deployed area and the path to be established according to the direction of the Sink node location. Transmitting the data is a bit tedious process if traditional clustering and routing models like CH to CH based on the nearest distance, a chain based routing from cluster to cluster, etc. are applied. To find a routing path with reduced number of hops, a new routing algorithm is proposed where the method uses an angular inclination based routing technique to transmit the data towards the Sink. The major objective of angular routing model is to identify the optimal routing path as followed in [23–25] from every CH to the Sink. The procedure to discover the routing path is clearly depicted in the algorithm format 3 as shown below:

Algorithm 3: Angular routing in RSC.

Input: $-alpha$: Threshold value
$-n$: Number of CHs
-S(x,y): Location of the Sink
Output: $path(ch)$: A routing path to the Sink
begin **for** i ***from*** $1ton$ **do**
  Find the polar coordinates and angle between CH and the Sink using $alpha$ **for** j ***from*** $1tom$ **do**
    if $ch_j! = ch_m$ then Calculate the angle and the distance between CHs
  end
end
for i ***from*** $1topath_n$ **do**
  if $path(ch_i, ch_i + 1)! = 0$ then Find the CH with minimum distance $Min_dst(node.id) = path(ch_i)$
end
$Next_hop(ch_i) = Min_dst(node.id)$

In this work, a radial structure is framed between two CHs and the data forwarding is done with the angular aligned from one CH to another. Normally, the neighbour CH will be selected based on shortest distance but there may be the possibility of visiting more number of hops to reach to the Sink if the location direction differs from CH to the Sink. This issue is greatly reduced in angular routing as given in Algorithm 3.

6. Performance Evaluation

The RSC clustering and routing model is implemented using MATLAB and executed for about twenty different scenarios. The network region is supposed to be the circular shaped area and sensors are distributed arbitrarily. The amount of nodes deployed as well as the number of execution rounds are changed often to get the various sizes of data from clusters for further analysis. At the beginning, the Sink is positioned in the middle of the circular area. The location of the Sink is changed randomly in multiple scenarios. The energy model used in the proposed solution and the parameters used for RSC in MATLAB are given in Table **??**.

The sensor nodes' transmission radius is set as 100 m. The radial shaped clustering is drawn as an example scenario in Figure 2. The node is considered as alive up to 80% of energy utilization. When the residual energy of a node is less than 20% , it is considered as dead node. The radius of the inner circle and the remaining circles are considered. The angle θ is taken as 90° for the first circle. Then, it is subdivided into three sectors for the second circle. Again, the angle is subdivided into five sectors for the third circle and so on.

The routing process is required whenever the node wants to transmit its data to the CH. If the routing is required within a cluster, direct transmission is possible. Otherwise, if routing path required from one cluster to another cluster towards the Sink, then finding the CH with nearest distance to the direction of the Sink position will be a binomial polynomial problem. This angular inclination based routing is one of the options to ensure that the data from CH reached the Sink. Here, CH, in turn forwards data towards the next lower layer from the corresponding layer CH, which is the same scenario as the one theoretically discussed in [26] and [27]. This procedure continues towards the angle of the Sink until the data reached the Sink. This was shown in Figure 2 as a scenario.

Table . Simulation parameters used in RSC.

Parameters used	Values
The diameter of network area	500 m
Number of Sensor nodes	1000
Initial energy	2J(Joule)
E_{elec}	50nJ/bit
$epsilon_{fs}$	10pJ/(bit $_*$ m2)
$epsilon_{mp}$	0.0013pJ/(bit $_*$ m4)
Transmission Power E_{tx}	0.02J
Receiving power E_{rx}	0.01J
Distance d_0	$\sqrt{E_{fs}/E_{mp}}$
Processing power E_{DA}	5nJ/(bit $_*$ signal)
Size of control packet P_ctrl	100 bits
Size of data packet size P_data	2500 bits
Size of aggregated data packet	3000 bits
Energy threshold for CH	0.04J
Transmission radius of a sensor	100m

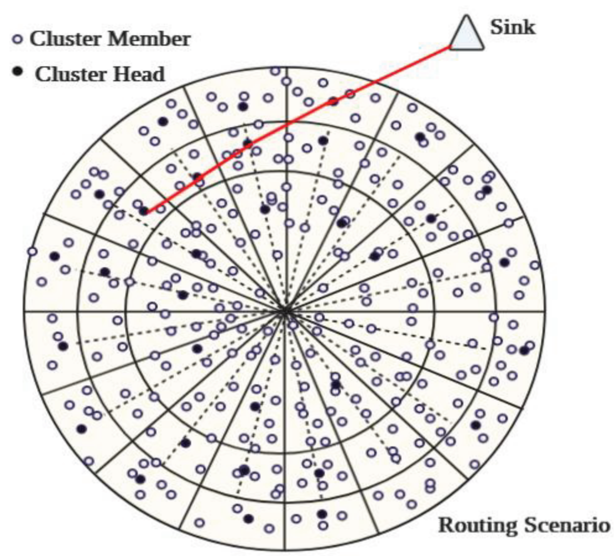

Figure 2. Routing scenario

6.1. Comparison of RSC and fan shaped clustering (FSC)

The parameters considered for the proposed solution are based on the FSC. In FSC, the parameters used for simulation are the number of nodes alive, total residual energy, and the packet collection rate or packet received ratio. Here, the terms packet collection rate an the packet received ratio are used interchangeably. The fan shaped clustering (FSC) was considered as the choice of comparison because of the similar deployment shape of FSC. The circular shaped area was framed in FSC with fixed transmission radius and the circular shape is further divided into a number of virtual rings. As the focus of implementation and the major contribution of both the algorithms are found to be the same, FSC was taken as the choice of comparison with the proposed solution.

As the RSC is compared with FSC, the same parameters were taken for simulation but the duration is increased. The simulation time for FSC is 2000 s, but in the proposed solution, both RSC and FSC are simulated up to 3500 s. The sensed data was aggregated before transmitting to the Sink. The type of aggregation measure depends on the application. To identify which aggregation measure suits better for most of the applications, statistical measures are considered as parameters.

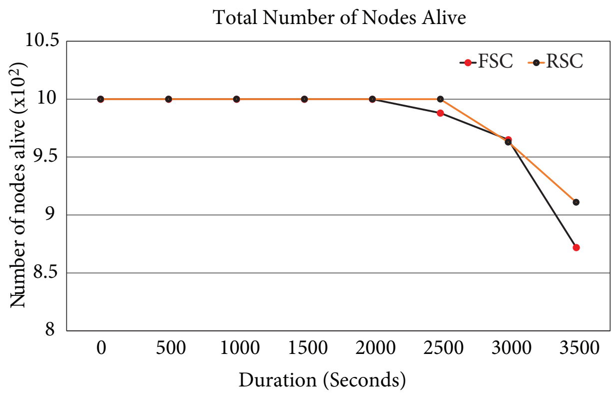

Figure 3. Number of nodes alive

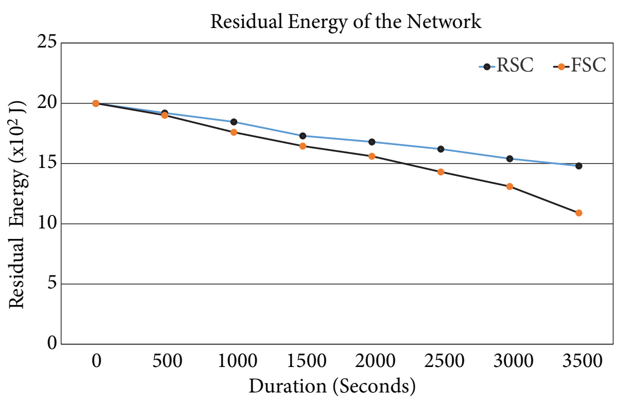

Figure 4. Residual energy

The performance of RSC and FSC is almost same up to 2000 s (i.e. up to 2000 rounds) and the number of alive nodes in FSC starts to decrease gradually due to the reclustering process in Figure 3. RSC outperforms FSC in 2500 s as the angular routing is applied. However, both algorithms produce the same result in 3000 s due to the raise of hop distance. Even though hop distance increases, RSC could accommodate and outperform FSC in 3500 s because of the reduced number of hops compared to FSC.

Overall residual energy reduces gradually with the execution time as shown in Figure 4, since the nodes have to discover the path to reach the Sink and due to the reclustering process. The energy utilization of each node will increase when the sensing duration increases. So, the overall network energy decreases as simulation time increases. This phenomena was illustrated with RSC and FSC. Compared to FSC which has the residual energy of 1097 Joules, RSC outperforms with its residual energy of 1496 Joules. Generally, the network energy will decrease if it is subjected to simulation time for any of the algorithms, but RSC produces better results compared to existing FSC.

The packet collection rate is taken as the substantial measure as it deals with packet loss in the network and also the dead nodes. This may occur when

i. None of the sensor nodes is selected as CH in the cluster due to energy threshold limit, ii. CH node might not able to find the forwarder node to locate the Sink , iii. Distance is much higher to transmit data to the Sink.

Considering these factors and the large-scale applications, packet collection rate is analyzed deeply with statistical measures. For example, for real-time traffic applications, mean values are considered as effective, but event-based applications might prefer median values.

The Figure 5 and Figure 6 show the packet collection rate when mean and median value is taken as the aggregation measure, respectively. Initially, the packet received rate is high in RSC i.e. 0.82, whereas in FSC, it is 0.6. RSC starts to decrease gradually after 2700 s and reaches 0.5 at the time of 3500 s. This is due to the fact that the radius used for framing the layers. RSC maintains uniform size for all the layers, whereas FSC establishing the size of inner layer is twice when compared to the outer layer. The outer layer is very thin in FSC and probably less energy consumed, but it reduces the packet collection rate also. The figure 6 reveals that the RSC outperforms FSC and can able to collect data packets up to 3500 s. As the number of control packets are very less in RSC compared to FSC, RSC outperforms FSC and when more number of nodes start to reach the threshold level, then the packet collection rate decreased. It indirectly reveals that the number of nodes alive in the network is higher in RSC when median is taken as the aggregation measure.

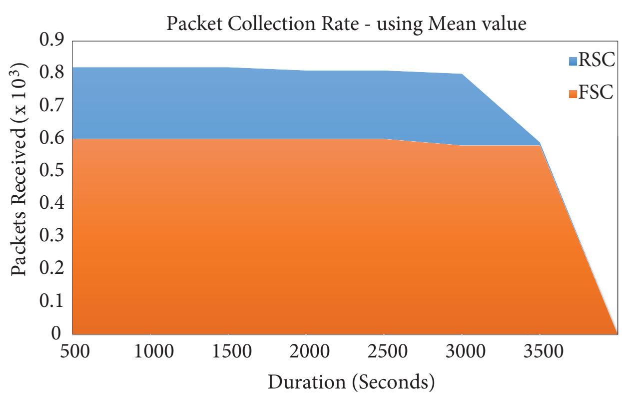

Figure 5. Packet collection rate-mean

Both RSC and FSC give a paramount result with minor deviations with the statistical measures like mode and maximum. Both the algorithms aim at reducing the reclustering cost and it is fulfilled up to 2700 s in FSC and 3000 s in RSC. This scenario is presented in Figures 7 and 8. Then the packet received ratio decreases much quickly due to identifying the relay CH node and the transmission distance with current alive nodes. Even though the collection rate reduced when the duration increases, RSC outperforms FSC when mode is taken as the measure and RSC could withstand constantly up to 3470 s when maximum is taken into account.

The execution results given by RSC and FSC found for variance measure shows the size of the data varies with respect to time and transmission range. In a certain period of interval, the packet ratio of packets received reduces owing to the nonexistence of CHs to forward the data. If the variance is higher, the data range

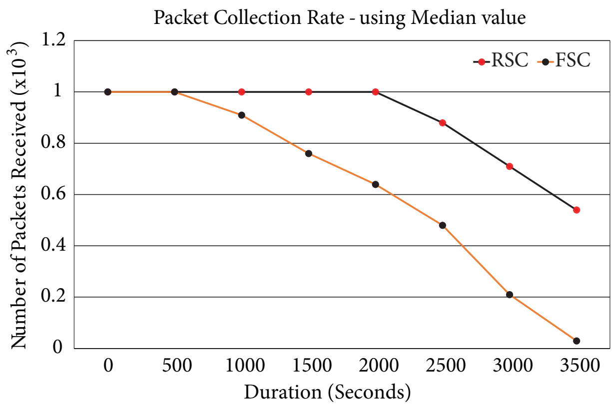

Figure 6. Packet collection rate-median

deviation is also high which indirectly leads to meagre analysis. This issue is identified in FSC because of the size of the inner layer in FSC. Data transmitted from the outer layer cluster towards the inner layer cluster until the data reached to the Sink positioned in the inner layer. The frequent data gathering in the inner layer leads to frequent reclustering which might decrease the energy level of nodes. In FSC, after 200 rounds, the number of packets received gets decreased gradually and reaches 0 at 3500 s, whereas in RSC, initially the nmber of packets received is 100, and it starts decreasing gradually from the 3400 s and reaches 0. 85 at the range of 3500 s.

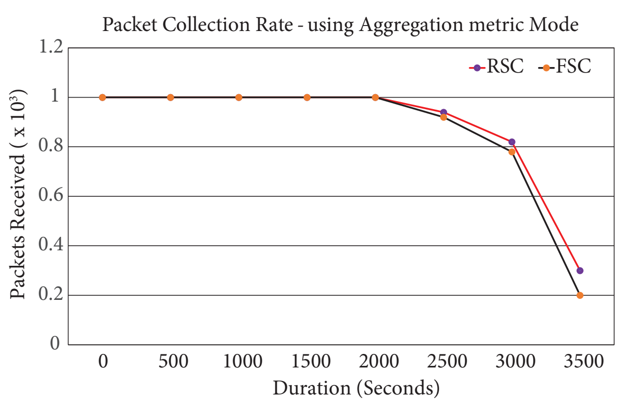

Figure 7. Packet collection rate-mode.

The figures numbered from 5 to 8 are used to represent the packet collection rate with different statistical measures. Even though slight deviations encountered between the performances, results reveal that it varies when the aggregation measure gets changed. Among the measures considered, median and mode produces better results compare to the remaining measures. All these changes are come across due to the reduced number of hops in data transmission. Figure 9 depicts that the proposed solution maintains stability and gives an immense packet received ratio when compared to the previous algorithms. On the whole, this proposed work conveys that, in compare to the other application-oriented algorithms [28–30], RSC outperforms the time-critical as well as event –based applications.

When the Sink position is changed from middle to upper left (or) right corner or from lower left(or)right

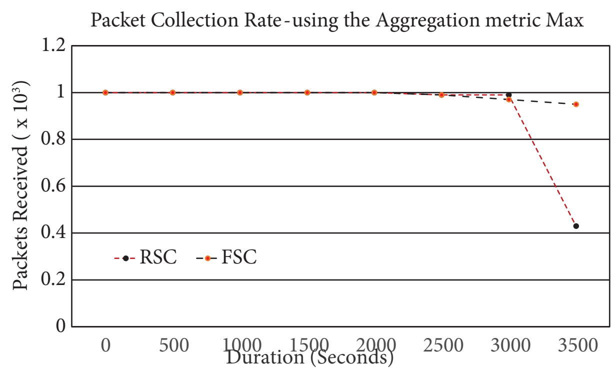

Figure 8. Packet collection rate-max.

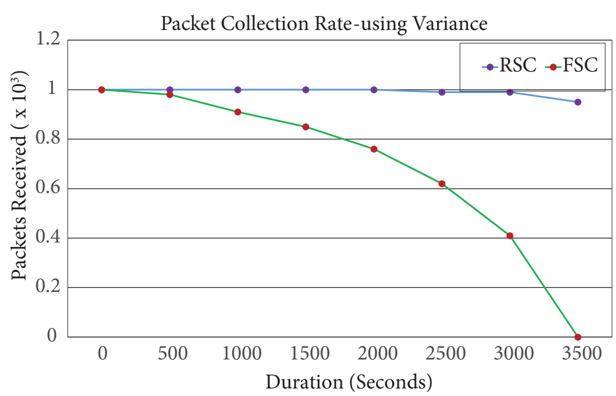

Figure 9. Packet collection rate-variance.

corner, the energy level of CH located in the layer $k+1$ towards the polar coordinates of the Sink gets depleted soon. However, the angular routing prevents the hop count considerably compared to the previous techniques. The network performance was slightly reduced when the Sink position changed to the outside deployment area yet it can withstand up to 2800 s.

7. Conclusion and future scope

This work proposes RSC with radial shaped clustering and angular inclination based routing. The network deployment area is taken as the circular area and it is separated into equal-sized virtual rings called layers based on the radius of the circle. Each layer is further separated into a number of sectors based on the angle and the quadrants. The node which is closure to the mid-point in terms of distance is selected as CH in the cluster. Further, CH is updated which depends on residual energy and the number of nodes alive in the cluster to ensure load balancing, since RSC is implemented specifically for large scale deployment. To identify the suitable aggregation method for large scale heterogeneous applications, all the statistical parameters are taken into account with the objective of increased number of packets received with reduced number of hops. The proposed solution is compared against FSC and RSC outperforms FSC in total residual energy, the number of nodes alive, and the packet collection rate.

Even though RSC produces better results, it may not be suitable if the surface of the area is sloppy or layered with different width size. Angular routing is applied to reduce the number of hops towards the Sink, but the transmission distance may increase due to the location of CH. These two issues are to be addressed in future to bring the optimal deployment structure with enhanced network lifetime for WSN.

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