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Optimized Energy Cluster Routing for Energy Balanced Consumption in Low-cost Sensor Network

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Abstract

Energy balanced consumption routing is based on assumption that the nodes consume energy both in transmitting and receiving. Lopsided energy consumption is an intrinsic problem in low-cost sensor networks characterized by multihop routing and in many traffic overhead pattern networks, and this irregular energy dissipation can significantly reduce network lifetime. In this paper, we study the problem of maximizing network lifetime through balancing energy consumption for uniformly deployed low-cost sensor networks. We formulate the energy consumption balancing problem as an optimal balancing data transmitting problem by combining the ideas of corona cluster based network division and optimized transmitting state routing strategy together with data transmission. We propose a localized cluster based routing scheme that guarantees balanced energy consumption among clusters within each corona. We develop a new energy cluster based routing protocol called "OECR". We design an offline centralized algorithm with time complexity O ($log\ n$) (n is the number of clusters) to solve the transmitting data distribution problem aimed at energy balancing consumption among nodes in different cluster. An approach for computing the optimal number of clusters to maximize the network lifetime is also presented. Based on the mathematical model, an optimized energy cluster routing (OECR) is designed and the solution for extending OEDR to low-cost sensor networks is also presented. Simulation results demonstrate that the proposed routing scheme significantly outperforms conventional energy routing schemes in terms of network lifetime.

Keywords: Energy balance, network lifetime, energy hole, energy balanced consumption, corona network

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1. Introduction

Low-cost sensor networks are a class of wireless networks used in monitoring environmental phenomena in a given physical space; such networks find increasing use in areas as diverse as military applications, object tracking, structural health monitoring, and agriculture and forestry, among others. In such applications, hundreds or even thousands of wireless sensor nodes may be dispersed over the monitoring area, and these nodes self- organize into a wireless network, termed wireless sensor network, in which each sensor node must frequently send its sensed data to the sink node. Sensor nodes in such wireless sensor networks are generally powered by small inexpensive batteries in expectation of surviving for a long period. Therefore, energy is of least importance in power-constrained wireless sensor networks, and energy consumption should be well managed to maximize the network lifetime [1]. Probably the most important thing is due to the fact that sensor nodes usually operate on limited battery power, which means that the maximization of network lifetime (and, consequently, minimization of power consumption) is a necessary and sufficient condition for sensor networks. On contrary, power consumption is seldom a critical requirement for sensor networks. We know that lopsided energy consumption among the sensor nodes is unavoidable (that is, the energy hole problem is unavoidable) in the circular wireless sensor networks with uniform node circulation and constant data sending. However, under the condition in which the energy hole is unavoidable, the network lifetime can still be increase a number of times if the sensor nodes transmit data with optimal transmission power levels. To achieve a balanced energy consumption network, the densities of the sensor nodes whose distances from the sink node are uniform should be different nodes. Even if the sensor nodes were in the same cluster, the densities of sensor nodes in different places should not be the same. Through nonuniform node division and wavering between dormancy and work, the efficiency of a network can increase several times and the residual energy of a network is nearly zero when the network lifetime ends. Therefore, in this paper can give an efficient scheme for optimizing energy balance consumption in wireless sensor networks. According to [2], the condition of minimal energy consumption translates into two distinct nodes, yet they are closely related in design requirements: First, the communication efficiency has to be maximized through the design of simple yet flexible and effective communication protocols and functions. Second, theses protocols and functions have to be implemented by small chips with limited computational and memory resources.

In this paper, we propose the scheme for balancing energy consumption and maximizing network lifetime for low-cost sensor networks. Similar to the models in [3] and [4], it is assumed that the sensor nodes are uniformly deployed since near uniform node deployment is one of the easiest and most practical approaches to provide full sensing coverage and connectivity. The network is divided into coronas centered at the sink with an equal number of nodes, and all nodes in the same corona use the same probability for direct transmission and the same probability for hop-by-hop transmission. As shown in **Fig. 1**, the corona network is divided into subcoronas. The basic idea of the routing scheme is explained as follows: each corona is divided into subcoronas and each subcorona is further divided into clusters. There is an elect multipoint relay node mapping between the clusters in two neighborhood coronas. The objective is to design an optimal multipoint relay node elect scheme so that the amount of data received by nodes in each cluster can be balanced.

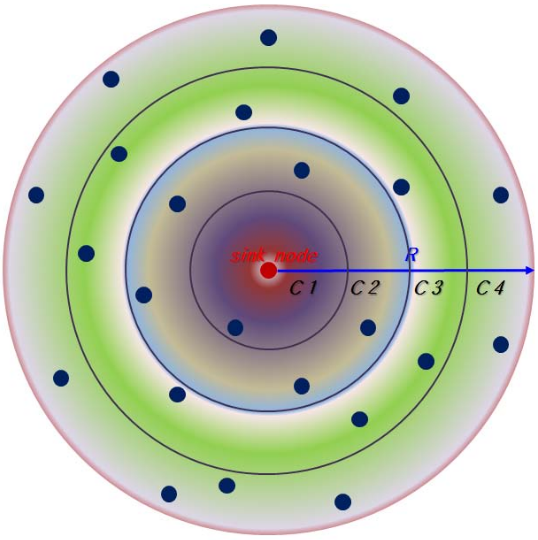


Fig.1. Illustration of corona network model.

Then the energy consumption balancing problem is divided into two sub problems: intra-corona energy consumption balancing (Intra-CECB) and inter-corona energy consumption balancing (Inter-CECB) [2]. Intra-CECB is proposed by optimally dividing each corona to evenly distribute the amount of data received by the nodes in each corona. Inter-CECB is proposed by optimally allocating the amount of data for direct transmission and hop-by-hop transmission. Finally, the Network Lifetime Maximization (NLM) problem [4] is solved by calculating the optimal number of coronas that the network should be divided into. The main contributions of this paper can be summarized as follows: First, we propose a fully cluster based routing scheme for the energy consumption problem. By optimally subdividing the coronas into clusters and establishing the mapping between clusters in different coronas, the cluster based routing scheme can evenly distribute energy consumption among the nodes in each corona. We divided the network into a linear network model, and designed an algorithm with time complexity $O(\log n)$ (n is the number of coronas) to calculate the optimal data distributions for all coronas with the objective to balance energy consumption among the nodes in different coronas. Second, we formulate the NLM problem as a balanced energy consumption minimization problem and propose a solution for computing the optimal number of coronas to maximize network lifetime. This paper proposes a network model with a balanced energy consumption routing scheme. Based on the corona cluster network model, we present a new routing scheme which provides the data transmission path with balancing energy to complete the sensing data transmission task. The new algorithm reduces the network division and the energy hole by the shortest path computations and resets the cost weight by a cost evaluation function which could balance the energy consumption and maximize the life of the wireless sensor network. The simulation results show that the routing algorithm has better performance than traditional algorithms in maintaining the network and balancing energy consumption.

The rest of the paper is organized as follows. Section 2 gives the related work and Section 3 presents the network model and a new balanced energy consumption routing algorithm based on the corona cluster network model. Simulation results are presented in Section 4. Finally, some concluding remarks are made in Section 5.

2. Related Work

The energy consumption of each sensor node includes transmission, receiving, idle and sleep. This paper focus only on issues related to balance and minimizing power consumption during communication. The energy consumption of receiving messages is less than that of transmitting.

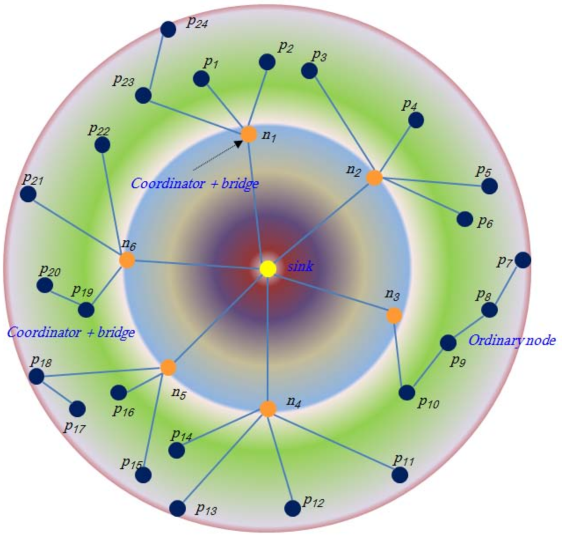
Olariu and Stojmenovic [5] were the first to analyze how to avoid the energy hole problem, assuming a WSN with uniform node distribution and constant data reporting. They used an energy model in which the energy consumed in transmitting a message of unit length was $E = d^{\alpha} + c$, where α is the energy attenuation parameter related to a specific field, d is the distance between the data sender and receiver, and c is a positive system parameter. They proposed that if the transmission range of each sensor node is modifiable, the energy exhausted in routing is minimized when each corona has the same width. However, that would lead to lopsided energy reduction in the network. They proved that when $\alpha > 2$, unbalanced energy depletion is preventable, but when $\alpha = 2$, it is inevitable. A balanced network strategy can be adopted to mitigate the energy hole problem. Zabin et al. [6] discussed the possibility of avoiding energy holes by a nonuniform node distribution strategy in WSNs. However, assume a more sensible energy consumption model, considering the energy lost in both data transmission and reception. We assume that the nodes in the network constantly report data to the sink, as in [7], [8]. We conclude that balanced energy reduction is impossible, but balanced energy reduction is achievable in the considered network. Additionally, we devise a novel nonuniform node distribution strategy and a tailored routing algorithm with which nearly balanced energy depletion can be achieved in the network [8].

Recently, there has been increased interest in studying energy-efficient clustering algorithms, in the context of both ad hoc and sensor networks. The authors proposed the LEACH algorithm [9], in which the CH role is dynamically rotated among all sensors in the cluster. Cluster-head rotation schemes (e.g., LEACH) achieve fairly even energy consumption among the nodes in each cluster by periodically performing cluster head rotation among all nodes in the cluster. Clustering schemes such as EECS and UCS [10] were further proposed to balance energy consumption among cluster heads by partitioning the network into clusters of unequal size. However, to achieve a desirable balance of energy consumption, cluster-head rotation must be performed repeatedly, which may add extreme communication overhead to the network, resulting in much energy consumption. The OLSR protocol [11] inherits the stability of a link state algorithm and has the advantage of reduced latency in route discovery due to its proactive nature. OLSR is an optimization over the classical link state algorithm that is tailored for low-cost sensor networks. The OEDR [12] is used to calculate the energy consumed and delay experienced during transmission from the neighbors and from the energy levels of the neighbors, along with the neighbor sensing. Power-adjusted transmission is another interest scheme for balancing energy consumption in wireless sensor networks. In [5], the paper researched the problems of avoiding energy holes and maximizing lifetime in sensor networks with uniform division and regular reporting based on corona-based network division and power-adjusted transmission. A mixed-routing scheme, in which each node alternates between direct transmission and multihop transmission to transmit data, was first proposed in [2]. Efthymiou et al. [7] proposed a slice model and designed a supposition data propagation algorithm for balancing energy consumption in sensor networks with a uniform node deployment and uniform event generation rate. Jarry et al. [13] used the probabilistic data propagation algorithm in the lifespan sensor network and proved that there is a relationship between energy balancing and life-span maximization. However, those schemes did not give a solution for balancing energy consumption among clusters in the same portion or a the solution for maximizing network lifetime. In [14], the authors gave a formal definition of an optimal data propagation algorithm with the objective of maximizing network lifetime, and employed a spreading technique to balance energy consumption among sensors within the same slice [2].

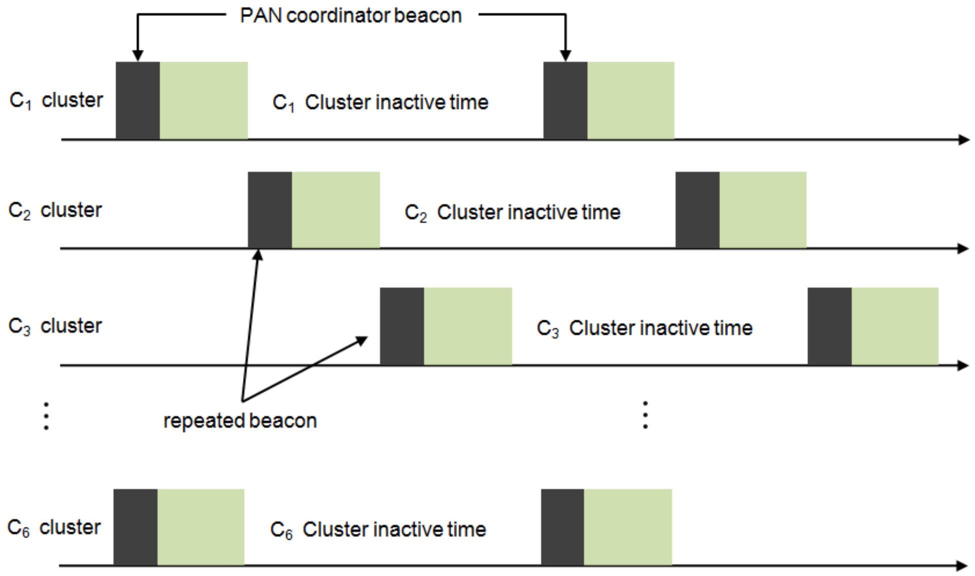
3. Optimized Energy Cluster Routing Model

3.1 Network Model

Assume a network with a cluster as shown in **Fig. 2-(a)**. We suppose that all clusters operate in a beacon enabled mode, that is, a slotted CSMA-CA mode under the control of their individual cluster coordinators. The coordinator of the C_1 corona acts as the network sink, while the coordinators of the $C_2,\ldots,C_n$ corona act as bridges which employ the CSMA-CA access mode to deliver their sensing data. All clusters contain plentiful nodes, which allows the duty cycle of individual nodes to be reduced, and the network lifetime to be extended through appropriate activity cluster management. The goal is to maximize the lifetime of the total network while maintaining the prescribed throughput at the sink node, with each coordinater (MPRs) used the uniform data distribution scheme that guarantees balanced energy consumption among clusters within each corona. The coordinator is to be balance in the data communication. The general nodes are battery operated, and their battery power is finite. However, the coordinators/bridges have to work constantly, therefore they do not sleep and their power resource is assumed to be infinite. A cluster switching time slice is schematically presented in **Fig. 2-(b)**. All six clusters operate on the same RF channel, and use the same values for the mainframe duration and beacon interval. As a result, the time between successive bridge visits to the C_1 upper cluster is therefore the same as the period between following beacons in its own C_n lower cluster. Because the sensor network often works in unreachable conditions, the goals of the balanced energy consumption routing are to maximize the network life and guarantee a balanced energy consumption for the total network [15].



(a) Cluster network.



(b) Cluster time slice.

Fig.2. Cluster network and cluster timing

3.2 MPR Selection Algorithm

This section shows an optimized energy cluster routing algorithm based on the wireless sensor network model in **Fig. 3**. The algorithm includes 3 steps as follows: First, start with an empty MPRs of node s. Second, nodes $p_1,..., p_6$ each have only one next cocona in the same corona network N(s). Add n_1 and n_2 to MPR(s) = $\{n_1, n_2\}$. Third, for each node in a corona for which a MPR node is not selected, continue this routine.

Each node nominates a few of its symmetric 1-hop neighboring nodes as Multi-Point Relays (MPR*s*). MPR*s* are selected in such a way that they ensure delivery of control messages to all nodes 2-hops away clusters. Thus the broadcast messages, which are flooded by *p* node, are received and processed by all nodes in the neighborhood of that node but are only retransmitted by their MPR*s*. This is called a proactive protocol. The OECR is similar to the OEDR algorithm used by the MPRs selection. OLSR maintains the routing information of all the nodes participating in the network by flooding control messages, thereby increasing the control traffic. The use of MPRs decreases the flooding of control messages. The optimization achieved using MPRs works well for large and dense networks. The larger and denser the network, the better the optimization achieved. OLSR is a passive routing protocol for mobile network ad-hoc networks. The protocol is an optimization of the classical link state algorithm which floods in the entire network all the states of the links with neighbor nodes [16]. The key concept of OECR is the proposal of the notion of MPR. The idea of multipoint relays is to minimize the flooding of transmit packets in the network by reducing duplicate packets in the same cluster. This algorithm is used in this scheme. Each node n in the network selects a set of nodes in its locality, which retransmits its packets. This set, called multipoint relays set MPR(n), is calculated so that it contains a subset of one hop zone which covers all of two hop zones; the union of the neighbor sets of all MPR*s* contains the entire 1-hop neighbor cluster. Consider a node with one-hop neighbors: $n_1,..., n_6$ and 2-hop neighbors: $p_1,..., p_{24}$ reachable as shown in **Fig. 3**. The 1-hop neighbors that are selected as MPRs are $n_1,\ldots,n_6$ because these 1-hop neighbors reach the maximum number.

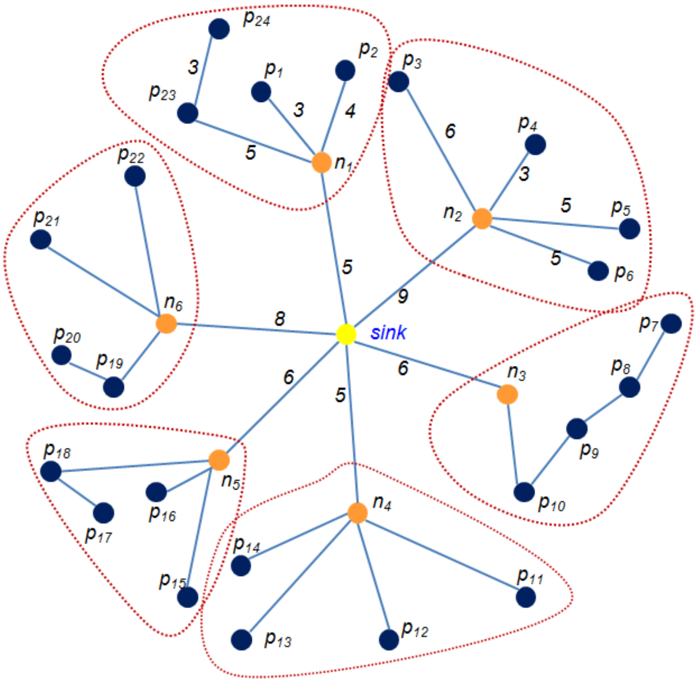
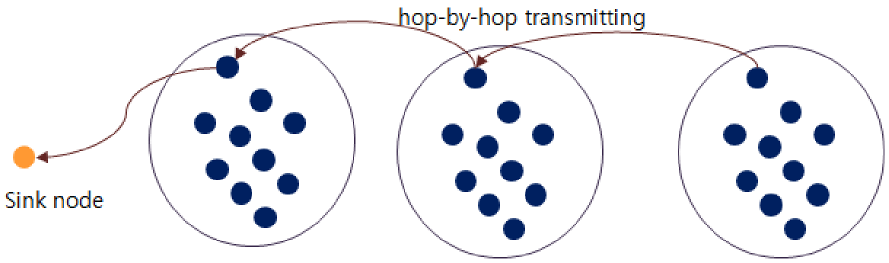
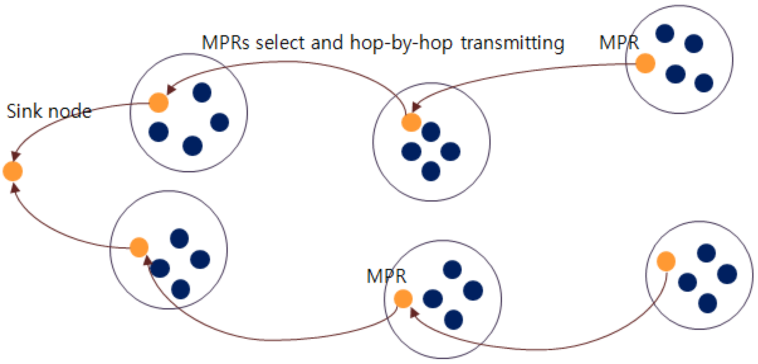


Fig.3. Optimized Energy Cluster Routing Model

As shown in **Fig. 4-(a)**, the sink node transmit for data by hop-by-hop transmission. Because each cluster received and transmitted data to all nodes in each corona, it resulted in increased transmission costs and lopsided energy consumption. However, as the shown in **Fig. 4-(b)**, MPRs selected and maintain a balance between the MPSs in the coronas. As a result, this does not increase the cost of data transmission or increase the network lifetime.



(a) hop-by-hop transmission



(b) MPRs select and hop-by-hop transmitting between MPRs
Fig.4. Data transmission Model

The OECR uses the concept of multipoint relays similar to the OLSR protocol. The OECR minimizes the energy cluster product which, in turn, minimizes the transmission energy and cluster between two coronas on the route relay, thus guaranteeing optimal cost, in contrast with OLSR. The main steps in the proposed OECR operation are neighbor sensing, energy cluster metric calculation, MPR selection, declaration of energy-cluster information, and routing table calculation. To proceed further, the following notations in **Table 1** are used in the next Equation (1).

Table 1. Equation Parameter

Parameter	Notation of calculation
N	Set of nodes in the network
S	Sink node
$N(s)$	Same corona of node s
$N^2(s)$	2-hop corona of node s
$MPR(s)$	Selected MPR set of nodes s
$RT(s)$	Routing table of node s, containing the route entries
$C_{x,y}(Energy[x \to y] \times Delay[x \to y])$	Energy-delay (cost) of the direct link between nodes x and y
E_x	Energy level or total available energy of node x
C_{S,C_1,C_2}^{MPR}	Cost for MPR selection of node s, to reach the 2-hop corona of the cluster C_2, with 1-hop neighbor C_1 as the intermediate node $(s \to C_1 \to C_2)$

It is given by

$$C_{S,C_1,C_2}^{MPR} = C_{S,C_1} + C_{C_1,C_2} + C_{C_n,C_m} \qquad (1)$$

where $C_1 \in N(s)$ and $C_2 \in N(s)$, then, $Cost_{s,d}$ Energy-delay (cost) of the entire path between a source *s* and the destination *d*, given by

$$Cost_{s,d} = \sum (C_{S,C_1}, \dots, C_{C_k,d}) \tag{2}$$

where $C_1, \dots, C_k$ are midway nodes on the path in the same cluster the optimal route between any source-destination pair s and *d*, the route with minimum energy-delay cost ($Cost_{s,d}$). Each node in the same corona infrequently generates HELLO messages and transmits to 1-hop corona, similar to the OLSR implementation given in the spanning-tree. However, changes are made to the HELLO message header format to include various fields, like the transmission time, transmission energy, and the energy level of the source node, for calculating the energy-delay metrics. Additionally, the HELLO messages also contain information about the list of the 1-hop cluster and the link costs ($C_{x,y}$) between the source node and its neighbors[17][18]. As shown in Equation (2), the minimum transmission distance that guarantees all nodes in clusters can communication with any node in $C_{s,d}$. By Corollary, Where $C_s, \dots, C_d$ are midway nodes on the path in the same cluster. Optimal route, between any source-destination pair s and d, the route with minimum energy-delay cost ($Cost_{s,d}$). It can be implemented using iteration (as shown Equation 2), or recursion. The binary search algorithm is a logarithmic algorithm and executes in $O(\log n)$ time. Equation (2) has the same input data and run time of the binary search. Thus, if the same input type and the formula, This Equation has time complexity $O(\log n)$.

The objects for MPR selection in the routing protocol are to minimize the energy-delay cost to reach the 2-hop neighbors and to consider the energy balance of the same corona nodes to increase network lifetime. The proposed routing protocol uses the following algorithm to select the MPR nodes. The MPR selection algorithm used by the OECR protocol is shown in **Fig. 5**. and the MPR algorithm flow is shown in **Table 2**.

Table 2. MPR Algorithms Flow

```
Initialization: Start with an empty MPR set MPRs of node s.
    Begin
    1. First identify those same corona nodes in $N^2(s)$ which have only one corona in the set $N(s)$.
    2. Add these nodes of $N(s)$ to the MPR set MPRs if they are not already in MPRs.
    3. If there exists a node in $N^2(s)$ for which MPR node is not selected, do the following: For each node in
       $N^2(s)$, with multiple corona from $N(s)$ as MPR node which results in minimum cost s to the
       node in $N^2(s), C^{MPR}_{s,N(s),N^2(s)}$
    4. Add that node of $N(s)$ in MPRs if it is not already in MPRs
    End
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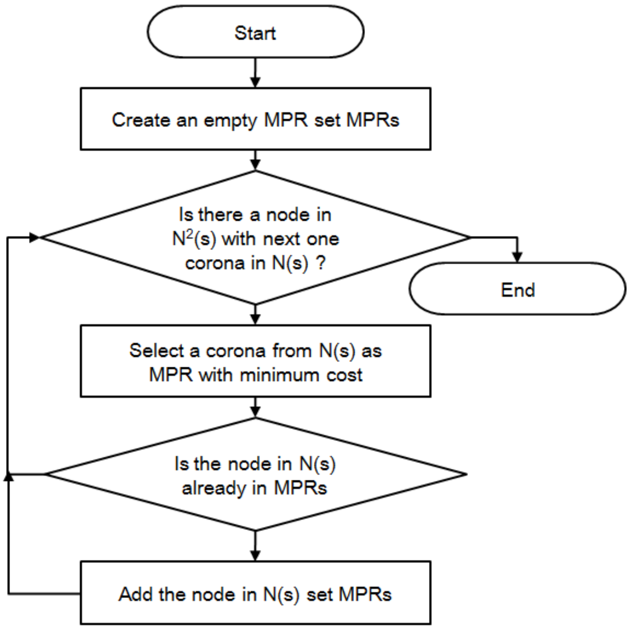


Fig.5. MPR selection algorithm

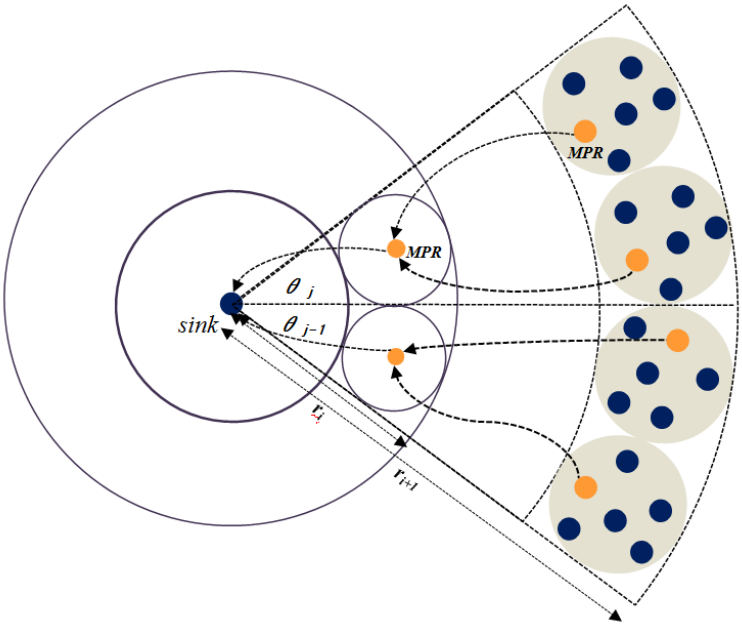


Fig.6. Illustration of the balanced energy consumption model

As a shown **Fig. 6**, if same the amount of data from a cluster transferred to MPR , then the energy consumption is balanced. A balanced approach to data outside the cluster to transmit data inside a cluster of data is sent to MPR. If the data transmission in each cluster is to be balanced, energy consumption will be used evenly.

3.3 Balanced Energy Consumption Calculation

In this section, we analyze the gain that can be introduced by our balanced routing scheme over the basic routing schemes. To achieve this scheme, we use the simple networks shown in **Fig. 2-(a)**. These clusters are enough to exhibit many of the specific challenges. While the group organization extends the lifetime of each cluster, personality cluster lifetimes are not equal, and the network lifetimes is determined by the reliable cluster lifetimes. In order to equalize cluster lifetimes, which maximizes the network lifetimes, individual node utilizations must be the same in each cluster. As the traffic load differs from one cluster to another node utilizations differ, and their values can be equalized by assigning a different node population to each cluster. The algorithm to calculate a node number considers one cluster at a time in a repeated sequence, starting with the cluster which is farthest away from the sink. Let us present the common approach and then instantiate the values for each cluster in turn, beginning from the inside cluster.

For every node $p \in C_i$, let $R(p)$ and $Dep(p)$ denote the total amount of data received and total amount of energy depleted by p in R rounds of data gathering. In this model, the energy spent by transmitting 1 bit data over distance x is $E(x) = \varepsilon_{elect} + \varepsilon_{amp} \cdot x^j$, where ε_{elect} is the energy spent by transmitter electronics, ε_{amp} is the transmitting amplifier and $j(1 \le j)$ *id* the propagation loss exponent. In this equation,using the energy notation given in Equation (3)

$$Dep(p) = HbH(p) \cdot E(x) + D(p) \cdot E(x) + R(p) \tag{3}$$

where the first term $HbH(p) \cdot E(x)$ represents the energy spent by hop-by-hop transmissions, $D(p) \cdot E(x)$ denotes the energy spent by direct transmissions, and the last term $R(p)$ is the energy consumption for receiving data from *p* node.

4. Simulation

4.1 Environment

The proposed EBDC algorithm was applied to different sensor network environments based on clusters, corona sensor network dimensions and network node density and simulated using MATLAB. The corona sensor network is assumed to have dimensions 200×200 with 100 nodes uniform randomly deployed. The sink node is positioned at coordinates (0,0). The first energy of a node is assumed to be 1*J*. For clarity, we assumed the possibility of packet collision and intervention to be unimportant. The values for the following parameters are extracted from ε_{elect} = 50 *nJ/bit*, *ml* = 0.0013 *pJ/bit/m4*, ε_{amp} = 10 *pJ/bit/m2* and d_n = 5 *nJ/bit/message*. The announcement or sets up packet size is 64 bits in length. Data packets are 2000 *bits* long. Further the packets are assumed to be 64 *bits* in length. This will result in something like 10 clusters with 10 nodes each. The cluster calculation parameter *c* = 0.95 obtained using the method described in Equation (1) and Equation (3). We further suppose that each cluster can produce one single fixed length data packet from the data received from its cluster members. The diagram in **Fig. 2** shows the variation of the life time of the above sensor network setup for different *a*. It is observed that the lifetime of the sensor bed is maximized to the ideal situation when $a \approx 0.5$.

4.2 Evaluation of Lifetimes

In this section, we evaluate the performance of the proposed nonuniform node distribution strategy and routing using the energy model stated in Section 3. The following **Table 3**. shows the link cost, calculated according to Equation (1), to reach the 2-hop neighbors from s, when the MPR selection is performed using the OLSR, OEDR protocols, and the proposed routing. It can be observed from this table that the proposed OECR protocol extensively reduces the cost to reach the 2-hop cluster, compared to OLSR and the proposed routing protocol.

Table 3. MPR Selection algorithm Comparison of OLSR, OEDR, Proposed-Routing Protocols

	Cost to reach the same corona (Via the MPR node) According to E_{n1} =0.5					
Protocol	P_1	P_2	P_3	P_4	P_5	P_6
OLSR	18(n_1)	28(n_1)	30(n_2)	24(n_2)	28(n_2)	28(n_2)
OEDR	18(n_1)	28(n_1)	15(n_2)	12(n_2)	14(n_2)	14(n_2)
Proposed-Routing (OECR)	18(n_1)	28(n_1)	8.5(n_2)	6(n_2)	7(n_2)	7(n_2)

Let us denote energy consumption per back off period during sleep, receiving, and transmitting with $\varphi_s, \varphi_r, \varphi_t$ respectively. They can be obtained by consulting the manufacturer datasheets for the hardware in question. As an example, the current and energy consumption for the low power *xmote*_2430 mote operating in the ISM band are shown in **Table 4**. For reference, transmission power of 0 *dBm* allows a transmission range of about 30 meters indoors and up to 1000 meters outdoors, depending on topography conditions. The energy consumption values in **Table 3** are calculated for the nominal supply voltage of 2.85*V*; according to the specification, the *xmote*_2430 requires an operating voltage between 2.1 and 3.6*V*, which can be supplied by standard 1.5*V* batteries. Battery capacity depends on the implementation: typical values are 400 to 900 *mAh*(*milli-Amp-hours*) for lithium batteries.

Table 4. Current and energy consumption for the *xmote*_2430 mote

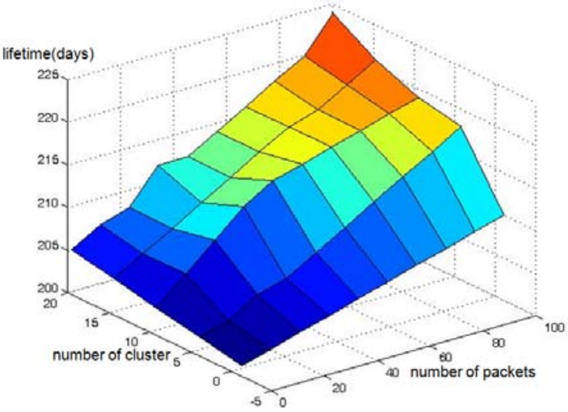
Operating mode of the radio subsystem	Parameter	Current consumption	Energy consumption at 2.85 *V*
transmitting at 0 *dBm*	φ_t	17.4 *mA*	15.8 μj
transmitting at -1 *dBm*	φ_t	16.5 *mA*	15.0 μj
transmitting at -3 *dBm*	φ_t	15.2 *mA*	13.8 μj
transmitting at -5 *dBm*	φ_t	13.9 *mA*	12.6 μj
receiving	φ_r	19.7 *mA*	17.9 μj
Switched off (idle)	φ_s	20.0 *mA*	18.2 μj

From the analysis and the numerical results presented above, there is a definite need for equalization of cluster lifetimes, which may be accomplished by adjusting the number of nodes in each cluster so as to make the individual node utilization uniform across all clusters. Let us assume that the required throughout is R=10 packets per second per cluster, and that the each protocol has 100 nodes. Then, we have solved Equation (3) to obtain the population of 100 nodes in the cluster. The relevant network parameters, in this case, are shown **Table 5**, with node counts rounded to the next highest integer.

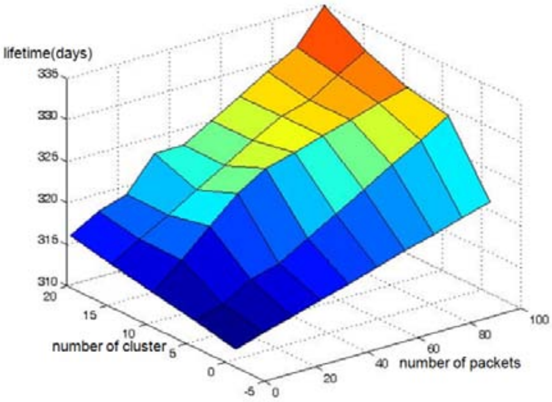
Table 5. Calculated network parameters for equalized cluster lifetimes(R=10)

Parameter	OLSR	OEDR	Proposed – Routing (OECR)
number of nodes	100	100	100
inactive period(seconds)	10.799	10.399	10.00
Success probability	0.7872	0.8649	0.9420
utilization	0.00218	0.00217	0.00218
lifetime(days)	223.12	326.86	334.78
std. deviation	0.061%	0.059%	2.465%
skewness μ	1.38E-9	1.3E-9	1.68E-14

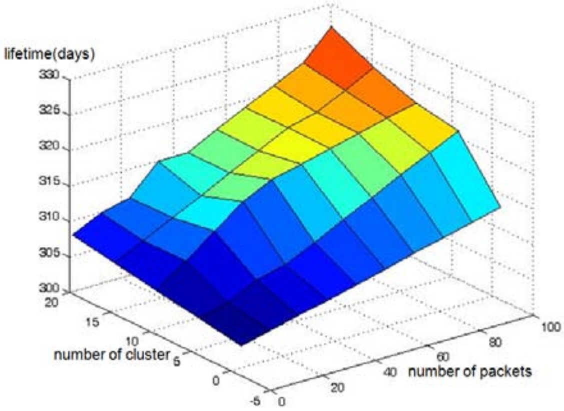
Considering **Fig. 3**, the sensor nodes form a cluster, which can be representative of a cluster network model. The distance between sequence sensor nodes is fixed to 20 *m*. The sink node, which is denoted by node 0, is located between centers in the network model. The sensor nodes report their data to the sink node. In this case, both OECR routing schemes dictate transmitting through the shortest path. Mainly, node p_5 can use the n_2 possible routes. The n_2 in cluster is MPR. Assume that node p_5 always transmits through MPR n_2. As a result, all the nodes of half of the network transmission will consume more energy than those of other half of the network transmission. Typically, node n_2 has the highest load since it deals with the maximum route-through load. This results in a shorter lifetime for this node, which yields to loss of coverage when node n_2 depletes its energy, thus leading to premature corona network death. From the analysis and the numerical results presented above in **Table 5**, there is a definite need for equalization of cluster lifetimes, which may be accomplished by adjusting the number of nodes in the cluster so as to make the individual node utilization uniform across all clusters. Let us assume that the required throughput is R=10 and packets per second per cluster, and that the cluster has p=100 nodes. Then, we have solved Equation (3) to obtain the population of p_min=95 nodes in the cluster, and p_max=105 nodes in the cluster. The relevant network parameters, in this case, are shown in **Table 5**, with node counts rounded to the next high-test integer. As can be seen, the node utilization is about the same in all clusters and, accordingly, the result and curves for cluster lifetimes in **Fig. 7-(a)** and **Fig. 7-(c)** are virtually distinguishable, the curves for cluster lifetimes in **Fig. 7-(b)** and **Fig. 7-(c)** are virtually indistinguishable. Although the increase in the R is only 10%, the lifetime of the twenty-cluster network has been extended to 334.78 days, which represents an increase of more than 3% over the previous value of 326.86 days.



(a) Average lifetime in days for R=10 under the OLSR



(b) Average lifetime in days for R=10 under the OEDR



(c) Average lifetime in days for R=10 under the OECR(Proposed-Routing)

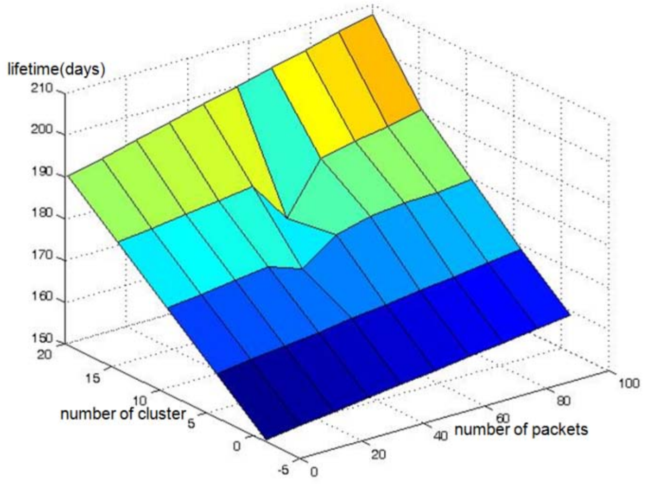
Fig.7. Cluster performance with initial node population adjusted to achieve equalized cluster lifetime.

From the analysis and the numerical results presented above **Table 6**, there is a definite need for equalization of cluster lifetimes. Let us assume that the required throughput is R=20 and 100 packets per second per cluster, and that the cluster has p=100 nodes.

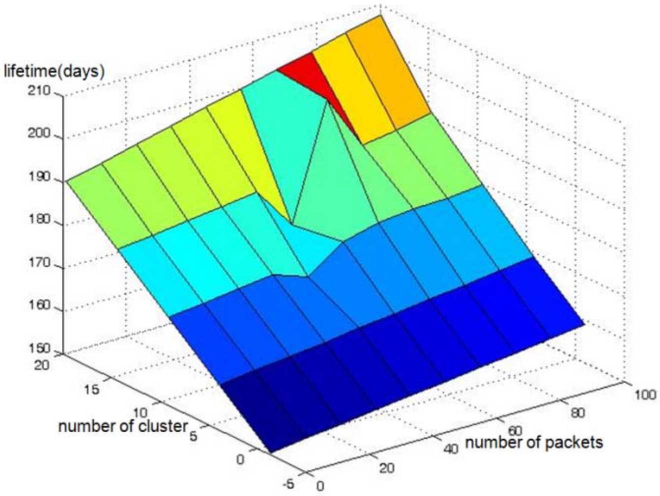
Table 6. Calculated network parameters for equalized cluster lifetimes(R=20)

Parameter	OLSR	OEDR	Proposed – Routing (OECR)
number of nodes	100	100	100
inactive period(seconds)	11.999	10.400	10.996
Success probability	0.6872	0.7649	0.8420
utilization	0.00318	0.00517	0.00518
lifetime(days)	201.11	203.67	314.88
std. deviation	0.061%	0.059%	2.465%
skewness μ	1.38E-9	1.3E-9	1.68E-14

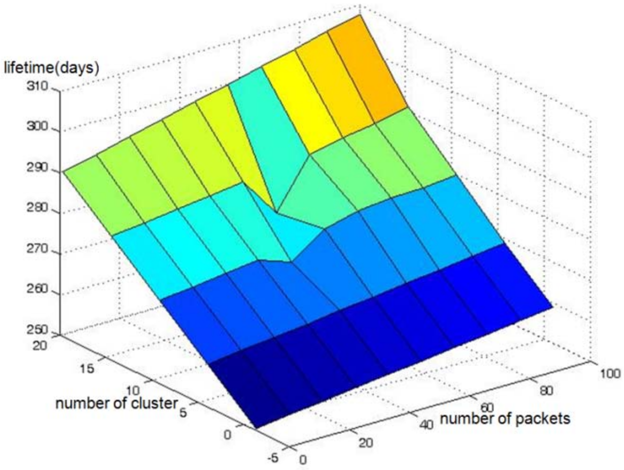
In addition, while the skewness values are somewhat different, all three of them are well below 9.1%, and it is the neighborhood with zero that counts. The cluster lifetime and the ratio of standard deviation and mean node lifetime, for required per-cluster throughout of R=20 and 100 packets per second, are shown in **Fig. 8**. Notice that the ratio of standard deviation and mean node lifetime is even lower than in the case where cluster populations were uniform; **Fig. 8** shows that all the nodes are operational almost up to the end.



(a) Average lifetime in days for R=20 under the OLSR



(b) Average lifetime in days for R=20 under the OEDR



(c) Average lifetime in days for R=20 under the OECR(Proposed-Routing)

Fig. 8 Cluster performance with initial node population adjusted to achieve equalized cluster lifetime.

Fig. 8 presents access probabilities for different clusters in the same corona, assuming that the cluster uses the MPRs transfer mode in the sink node. The values of throughput at different points in the network are shown in **Fig. 8**. An interesting point is that the throughput is admitted by the MPR nodes. As can be seen, the node utilization is about the same in all clusters and, accordingly, the result and curves for cluster lifetimes in **Fig. 8-(a)** and **Fig. 8-(c)** are virtually distinguishable, the values for cluster lifetimes in **Fig. 8-(b)** and **Fig. 8-(c)** are different, being 29.1%. Although the increase in the number of nodes is only 2.4%, the lifetime of the twenty-cluster network has been extended to 314.88 days, which represents an increase of more than 29.5% over the previous value of 203.67 days. Therefore, R=20 cases showed a good performance to OECR. The proposed algorithm performance was enhanced in a wide network. In the performance evaluation results between R=20 and R=10, the lifetime is increased 7.92 days. In **Fig. 8** notice that the ratio of standard deviation and mean node lifetime is even lower than in the case where the cluster populations were uniform.

5. Conclusions

Unbalanced energy consumption and energy holes are an important problems in wireless sensor networks and can considerably reduce network lifetime. We present a new routing algorithm called OECR that is tailored for the proposed energy balancing strategy in a corona network. In this paper we have presented to a scheme to increase network lifetime that uses a 802.15.4 standard [19] and discussed the OECR model for performance evaluation of balanced consumption in a corona network. Although the increase in the number of nodes is only 100 nodes and R=10, the lifetime of the twenty-cluster network has been extended to 334.78 days, which represents an increase of more than 3.1% over the previous value of 326.86 days. When R=20, the lifetime of the twenty-cluster network was extended to 314.88 days, which represents an increase of more than 29.5% over the previous value of 203.67 days. We proposed a routing model to maximize network lifetime through balancing energy consumption for regularly deployed optimized energy cluster routing. We formulated the energy balancing problem as a problem of cluster organization of transmitting data by clustering the ideas of a large scale sensor model and energy hole. In all simulations, the network achieves increased network lifetime, and less than 3% energy is wasted in the large scale network. Simulation results also show that the proposed balancing energy strategy has advantages over its two counterparts in terms of the network lifetime and energy hole.

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