Optimal Routing and Clustering Technique for Wireless Sensor Networks

Amine Rais, Khalid Bouragba, and Mohammed Ouzzif
Laboratory RITM, ENSEM, Hassan II University of Casablanca, Casablanca, Morocco
Email: amine.343@hotmail.fr; {bouragba2008, ouzzif}@gmail.com

Abstract —Hierarchical routing protocols based on clustering involve a clustered organization of sensor nodes to enable data merge and aggregation. The CHs are responsible for retrieving data from the cluster's sensor nodes, and collecting the data received and sending them to the base station. These data are merged and aggregated at the CH level, which leads to significant energy savings. In order to improve the energy efficiency of this kind of routing, this article proposes a new protocol called Efficient Clustering Routing Protocol (ECRP). This protocol is based on the CLARANS algorithm, it takes into consideration the location and the energy level of the nodes to create uniform and balanced clusters with a CH located at the center of each cluster, which reduces data delivery duration to the CHs and minimizes energy consumption in the clusters. The simulations showed that our protocol outperforms the other hierarchical protocols in terms of the performance metrics.

Index Terms—Wireless sensors networks, routing, clustering, CLARANS, energy efficiency, latency.

I. Introduction

The Hierarchical clustering of sensor nodes can greatly contribute to the overall scalability, lifespan, and energy efficiency of the WSN. Hierarchical routing is an effective way to reduce power consumption within the WSN [1], by aggregating and merging data captured in clusters to reduce the number of messages transmitted to the sink. It is particularly useful for applications that require scalability to hundreds or thousands of nodes. In this context, scalability involves balancing the load and using resources efficiently. Applications that require efficient aggregation of data are also candidates for clustering.

In addition to supporting network scalability and reducing energy consumption through data aggregation, clustering has many other secondary benefits and related objectives [2]: it can determine the routing configuration in the clusters, and thus reduce the size of the routing table stored at each node. It can also preserve communication bandwidth because it limits the scope of inter-clusters interactions to the CHs, and avoids redundant message exchange between sensor nodes. In addition, clustering helps to stabilize the network topology at the sensor level, and reduce the maintenance cost of the topology. The sensors will only take care of the connection with their CH and will not be affected by the interactions between the CHs.

The data transmission for long distance will result huge energy dissipation. The clustering protocol must have the capacity to minimize the energy required for transmitting the gathered data to the base station. The clustering methodology of the nodes is a major parameter in the design of hierarchical routing protocols. A cluster can effectively group various nodes, aggregate data, and reduce the energy dissipation of the nodes [3]. These clustering advantages lead us to develop a new clustering protocol based on the CLARANS [4] algorithm for partitioning the network and creating the clusters. This protocol must achieve the following objectives: balance the size of the clusters, minimize the distance between the nodes belonging to the same cluster, and reduce the distance between the member nodes and the CH.

The rest of this paper is organized as follows. Section2 presents the related works. In section3 we present the radio model of communication. Section4 describes our protocol. The simulation and results are proposed in section5 and we conclude this paper in section 6.

II. Related Works

Heinzelmen et al. propose in [5] the LEACH protocol to divide the sensors of the network into two levels, they divide the sensors of the network into two levels: member nodes and cluster head nodes, LEACH uses the power of the received radio signal to create clusters, every sensor node decide autonomously to be cluster head node or a member node.

The LEACH protocol is broken into rounds, every round is composed from 2 phases: set up phase and steady state phase. In the set up phase the clusters will be created, the sensor nodes selected as cluster heads broadcast an advertisement message to the rest of sensor nodes, which decide the cluster head to join for the current round, the nearest cluster head is selected based on the received signal strength of the advertisement. In the steady state phase the member nodes may communicate with their cluster head nodes using the TDMA schedule, a time slot is allocated for every sensor node to transmit data to the cluster head.

The arbitrary selection of CHs in LEACH causes an unbalanced distribution of CH, dissipates the energy of the sensors and consequently reduces the lifetime of the network, for that a centralized version of LEACH named

Manuscript received February 20, 2019; revised August 8, 2019.
doi:10.12720/jcm.14.9.758-764

LEACH-C is proposed in [6], a global view of the network is formed and the mission of cluster creation is taken by the sink.

PEGASIS is proposed by Lindsey *et al*. in [7], which consists of creating a long chain of nodes which allows each node to communicate only with the closest node. The communication with the sink is organized in rounds allowing only one node to directly communicate with the sink. PEGASIS is known for its low dissipation of energy but suffers from long date delivery time. It also lacks reliability in the iterations when the cluster head is down. An enhanced version of PEGASIS: hierarchical PEGASIS was developed in [8] to address these issues, by adopting alternative ways of communication with the sink in the case of geographically remote nodes.

Hybrid Energy-Efficient Distributed clustering protocol (HEED) [9] for its part uses one-hop clusters like LEACH, except that it differs from the latter by its CHs election technique, which uses two parameters: the residual energy of the nodes and the cost of communication. This makes it possible to extend the service life of the network, by choosing the nodes, having a higher residual energy level, such as CHs. Although, the formation of clusters with one hop will generate a significant number of clusters if the number of nodes is large. HEED also adopts a direct communication between the CHs and the sink which can deplete the energy of these later.

The KOCA protocol (K-hop Overlapping Clustering Algorithm) is proposed in [10], it adopts overlapped K-clusters and thus multi-hop intra-cluster communication is used. It reduces the number of clusters generated while covering a larger area of the network. In addition, nodes belonging to several clusters are used as gateways during inter-cluster routing. The clustering algorithm KOCA generates clusters balanced in size which allows a good distribution of load on the clusters. There are also many recent hierarchical protocols that give good performances like: SECA [11], EE-LEACH [12], HEER [13], H-CERP [14], and EECR-PSO [15].

III. Radio Model of Communication

The transmission of data may consume a big amount of energy and exhaust the battery power of the sensor nodes. The client/server architecture is not efficient to save energy in WSN especially for networks with high traffic, the sensor nodes close to the sink are critical nodes; they gather their own data and transmit the data of the other nodes to the sink. The depletion of energy in these sensor nodes can collapse the whole network and routing data towards the sink becomes impossible. In order to resolve this problem a good policy of energy management must be followed.

According to Heinzelman *et al* [5], the radio energy used to send a message of l bits to a sensor node from d distance is:

$$E_{TX}(l,d)=E_{elec}*l + E_{amp}*l \qquad (1)$$

To receive this message the energy dissipated would be calculated as:

$$E_{RX}(l)=E_{elec}*l \qquad (2)$$

E_{elec} is the energy consumed to run the transmitter or receiver circuitry, and E_{amp} is the energy consumed to run by the transmission amplifier, this latter will be calculated by:

$$\begin{cases} Eamp = \theta_{fs} * d^2 & \text{if d} < d_0 \\ Eamp = \theta_{mp} * d^4 & \text{if d} \geq d_0 \end{cases} \qquad (3)$$

where $d_0=\sqrt{\frac{\theta_{fs}}{\theta_{mp}}}$, θ_{fs} and θ_{mp} are the radio amplified consumed energy for free space propagation and multipath fading channel model, according to Heinzelmen et al. in [6] the value of θ_{fs} and θ_{mp} are respectively 10pJ/bit/m^2 and 0.0013pJ/bit/m^4. The Fig. 1 below shows the radio model of communication between sensor nodes, used to transmit their gathered data in WSN.

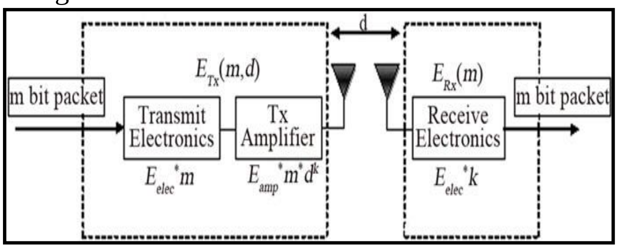


Fig. 1. Radio model of communication

IV. Description of our Protocol

The CLARANS algorithm is used to create clusters and to choose the cluster-heads of the network. In our protocol the cluster-head is approximately the sensor node located in the center of every cluster; this node is named the medoid node. CLARANS try to minimize the within-cluster scatter and find the best group assignments for each node.

Our protocol include two phases: set up phase followed by a steady state phase. The set up phase is running in the level of the sink which has an overview of the network to create clusters and determine the cluster head nodes. The steady state phase is where the data transmission begins between sensor nodes and their cluster head nodes.

A. *Set up Phase*

Initially, all the nodes of the network are in listening mode. The sink sends out requests to the nodes in order to obtain their coordinates and the remaining energy of each sensor in the sensing area. The sensor nodes are aware of their location using trilateration and triangulation techniques [16]-[18] and no GPS receiver is required for every sensor since the GPS system is costly. The signal reception is energy consuming and will not function where physical obstacle exists.

The duration of the execution of our algorithm to get the final clustering depends on the initial medoid nodes; we have to choose the suitable ones in the set up phase. Let M the medoid of all the nodes in the network. To find this node we have to calculate the average distance $\overline{X}_i$ between every node of the network and the other nodes, and then we can deduce the node M that has $\overline{X}_M$ equal to the minimal value of $\overline{X}_i$ (Min$\overline{X}_i$).

$$\overline{X}_i = \frac{\sum_{j=1}^{n} dij}{n} \tag{4}$$

With n is the number of sensor nodes in the network and d_{ij} is the distance between the nodes i and j. It will be calculated as:

$$dij = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \tag{5}$$

(x_i, y_i) and (x_j, y_j) are the coordinates of the nodes i and j, thus the coordinates of the initial medoid nodes will be calculated as:

$$\begin{cases} mdi_x = \overline{X}_M \times cos(\frac{2\Pi}{k} \times (i-1)) + M_x \\ mdi_y = \overline{Y}_M \times sin(\frac{2\Pi}{k} \times (i-1)) + M_y \end{cases} \tag{6}$$

With (M_x, M_y) is the coordinate of the node M, and k is the number of clusters in the network and i=1, 2, 3,…, k. The medoid node i is the closest sensor node to the coordinate (mdi_x, mdi_y), thus we can specify the initial k-medoids nodes.

Heinzelmen *et al* define in [6] the value of k with the following equation:

$$k = \frac{\sqrt{n}}{2\Pi} \times \sqrt{\frac{\Theta_{fs}}{\Theta_{mp}}} \times \frac{L}{d_s^2} \tag{7}$$

L is the side of the sensed square field and d_s is the average distance between sensor nodes of the network and the sink.

The objective of our protocol is to choose the most centralized node in every cluster as a cluster-head and to minimize the average distance between medoids and member nodes of its clusters:

$$\text{Min avgs} \sum_{i=1}^{k} \sum_{j \epsilon Ci} dij \tag{8}$$

With i is a cluster-head node, j a member node in the cluster C_i, and d_{ij} is the distance between i and j. After the choice of the initial medoid nodes, every non selected node j will be assigned to the nearest medoid m:

Algorithm1. The grouping algorithm for the set of non selected nodes (nSN)

Begin

For each node j in nSN **do**
  initialize min to a large value
  For i from 1 to k **do**
    Calculate d_{ij} between the node j and the medoid i
    If d_{ij}<min **then**
      min← d_{ij};
      m ← i;
    End if
  End For
  C_m ← C_m+ j;/*the node j will be assigned to the cluster represented by the medoid m*/
End For

End

A swap between a selected medoid node i and a non representative node h will be necessary to find the best set of medoids for our network and to improve the quality of clustering. $C_{i'}$ is the cluster represented by the node i' with i' is the second most similar medoid to the node j. To calculate the cost S_{ih} of this operation we will have four cases for every non selected node j (Fig. 2).

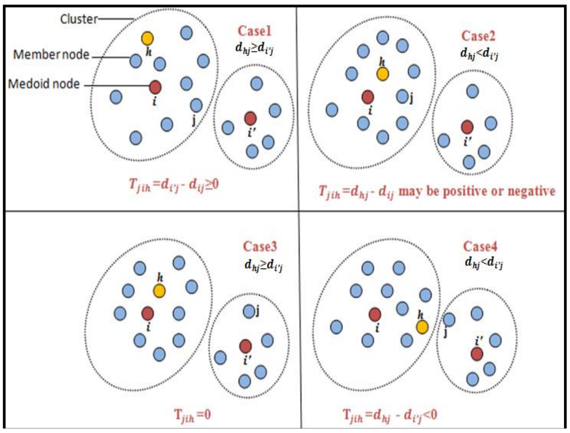


Fig. 2. Cases of swapping medoid node with a non representative node

Algorithm2. Calculation of the swapping cost

Initialization

S_{ih}← 0;

C_h←Ø;/*C_h is the cluster represented by the node h*/

Begin

For each node j in nSN **do**
  If j in C_i **then** /*if the node j belong to the cluster C_i */
    If d_{hj}≥$d_{i'j}$ **then** /*case1*/
      $C_{i'}$ ← $C_{i'}$+j;/*the node j will be assign to the cluster $C_{i'}$*/
      T_{jih} ← $d_{i'j}$-d_{ij}; /*with T_{jih} is always positive*/
    Else /*case2*/
      C_h← C_h+j;/*the node j will be assign to the cluster C_h*/
      T_{jih} ← d_{hj}-d_{ij};
    End if

End if
If j in $C_{i'}$ **then**
If $d_{hj} \geq d_{i'j}$ **then**/*case3*/
T_{jih}=0;/*the node j stay in the same cluster $C_{i'}$*/
Else /*case4*/
$C_{i'} \leftarrow C_{i'}$-j;/*the node j will quit the cluster $C_{i'}$*/
$C_h \leftarrow C_h$+j;/*the node j will be assign to the cluster C_h*/
$T_{jih} \leftarrow d_{hj}$-$d_{i'j}$; /*with T_{jih} is always negative*/
End if
End if
$S_{ih} \leftarrow S_{ih} + T_{jih}$;
End For
Return S_{ih};
End

We make some modification in the CLARANS algorithm to be suitable with the WSN environment, we divide our network into uniform and balanced clusters, and we search the cluster head node for every cluster. It will be in the center of each cluster and take the name of medoid. This algorithm allows the node to arrange itself into local clusters taking into consideration the distance between the nodes and the remaining level of energy in each node. The clustering of the neighboring nodes into the same cluster allows a better aggregation and a low level of data exchange within the same cluster.

Algorithm3. Modified version of CLARANS algorithm

Initialization
Based on the equation (6) we calculate the set of initial medoid nodes I;
counter← 1; /*counter of neighbors*/
Begin
Assign I as the current set of medoids C;
While counter < Maxneighbor **do**
Select arbitrary a neighbor V of C;
If $S_{cv} < 0$ **then**
Assign V as the current set of medoids C;
counter ← 1;
Else counter++;
End if
End While
Return set of medoids C;
End

The sets of medoids V and C are two neighbors, they differ only by one medoid, to get the set of medoids V we change in C the medoid c by the node v, thus the cost differential of the two neighbors C and V is equal to the swapping cost of c by v (S_{cv}) defined in the algorithm2.

Raymond *et al*. define in [19] the value of Maxneighbor like:

$$\text{Maxneighbor}=Max((1.25\% * k * (n-k)); 250) \quad (9)$$

With n is the total number of the sensor nodes and k is the number of cluster in the network, k is defined above in the equation (7).

We try to find the best set of medoids with the lower cost in the algorithm3; we compare the cost of exchanging a medoid node with other nodes. This operation will be repeated at maximum Maxneighbor times in order to find the best set of medoids with the lowest cost. If we are able to find a set of medoids better than the current set of medoids before the neighbor counter examined (counter) reaches Maxneighbor, then the current medoid nodes of the network will be changed with the new set of medoids and the counter of the examined neighbors will reset and take the value of 1, otherwise the current set of medoids will be considered as the best set of medoids in our network.

The process of finding the best set of medoids that represents the CHs of the network is presented in the flowchart of the Fig. 3 below:

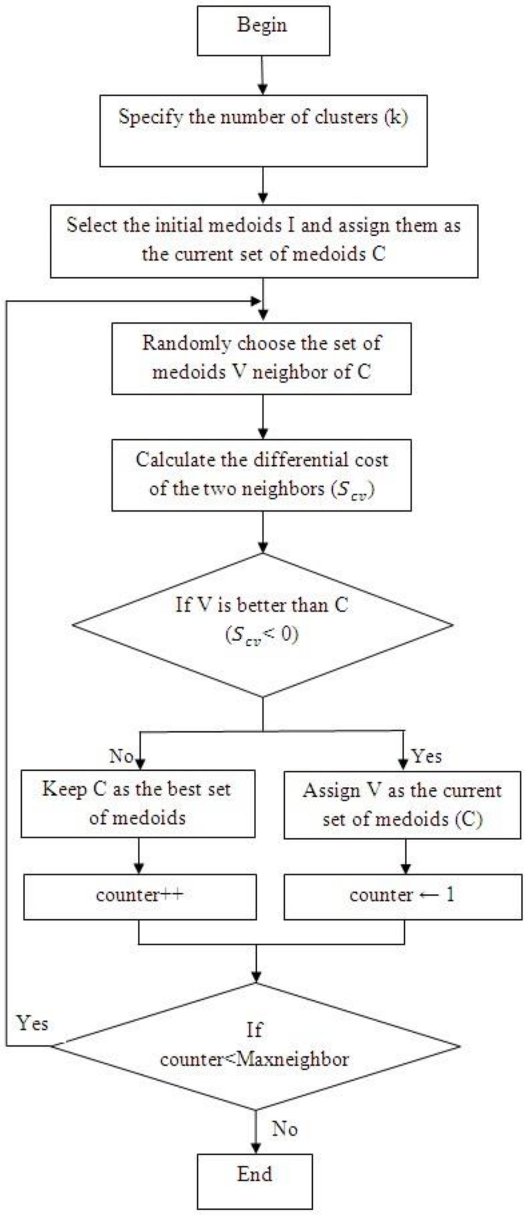


Fig. 3. Search flowchart of the best medoids for our network

Selected CHs must indicate to other nodes in the network that they have been selected for that role in the current round. To do this, each CH broadcasts a notification message (ADV: Data Advertisement), this message is small containing the identifier of the node and a header that distinguishes this message as a notification message.

Each node determines its cluster for the current round by choosing the nearest CH. Once a node has decided which cluster it belongs to, it must inform the CH that it will be a member of its cluster. Each node transmits a membership request message (Join-REQ) to the chosen CH. This message is composed of the ID of the node and the ID of the CH.

B. *Steady State Phase*

The steady state phase will start directly after the end of the set up phase. The member nodes gather data and transmit them to the cluster-head node in the cluster, each node verifies that the channel is clear before starting a transmission, and then listens during transmission to detect a possible collision. If the channel is clear, then the packet is sent. Otherwise, the node waits for a randomly chosen period of time, and then checks again to see if the channel is clear.

The cluster-head role can be rotated among the sensor nodes near to the medoid node if the level of the remaining energy of this latter becomes critical, allowing to save energy of control message overhead to create new clusters in every round. Therefore, only cluster-head selection will be necessary in the set up phase.

V. Results and Simulations

We compared the results simulation of our protocol to the existing protocols: LEACH, LEACH-C and PEGASIS. The simulation is done on ns2 [20], there are 500 nodes arbitrary distributed on a sensing area of 1000m×1000m and the sink position is 75m from the nearest sensor node, the standard IEEE 802.15.4 is adopted for the communication between nodes. The efficiency of our new protocol is based on the average energy consumption of the nodes and the number of data received by the sink. The parameters used in the simulation are shown in the Table I:

TABLE I: SIMULATIONS PARAMETERS

Parameters	Values
Node distribution	Random
Network size	1000m ×1000m
Initial energy	5 Joules
Total number of sensor nodes	500
Radio transmission range	60m
E_{elec}	50nJ/bit
θ_{fs}	10pJ/bit/m^2
θ_{mp}	0.0013pJ/bit/m^4
Critical remaining energy	0.01J

We assume the following properties about our network:

- The sink knows the location of sensor nodes.
- All sensor nodes are equal in resources (sensing, processing and initial energy level).
- The sensor nodes and the sink are stationary: static networks.
- Small number of anchor nodes is present in the network to determine the coordinates of the sensor nodes.
- Sensor nodes collect and disseminate data with a periodic manner.

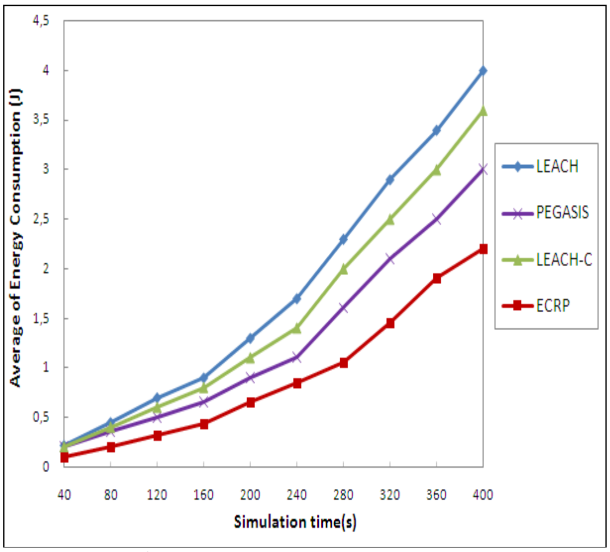


Fig. 4. Average of energy consumption through time

The average energy consumption of sensor nodes through the time is presented in the figure 4 for the four protocols. It shows that our protocol optimizes the energy consumption better than the other protocols. Our protocol reduces the average distance between cluster head and the nodes in the cluster for that the operation of transmission of data becomes optimized and less expensive than the other protocols. In this way, the energy dissipation of node to transmit data to the cluster head is reduced and optimized.

The difference in the average of energy consumption between the ECRP protocol and the other protocols increases over time, reaching between LEACH and ECRP protocols almost 2 Joules after 400s. The average energy consumption in LEACH increases rapidly as the CHs are selected in a probabilistic manner, which generates a bad distribution of CHs. Over time, there is a good chance that a node with a low energy level in LEACH will be selected as CH, which generates an imbalance in energy consumption.

The average data delivery latency of the simulated protocols is presented in the Fig. 5, it is the time required to aggregate and transmit data from the source nodes to the base station. At the beginning of the simulation, the data gathered in the LEACH, LEACH-C and PEGASIS protocols take a long time compared to ECRP to reach the base station, because the nodes in ECRP take less time to reach the CH since it is located in the center of the cluster. PEGASIS is the least efficient protocol in terms of data delivery latency, since it groups all the nodes of the network in the form of a long chain. This increases the time needed to deliver the data to the CH, and therefore increases the average data delivery latency.

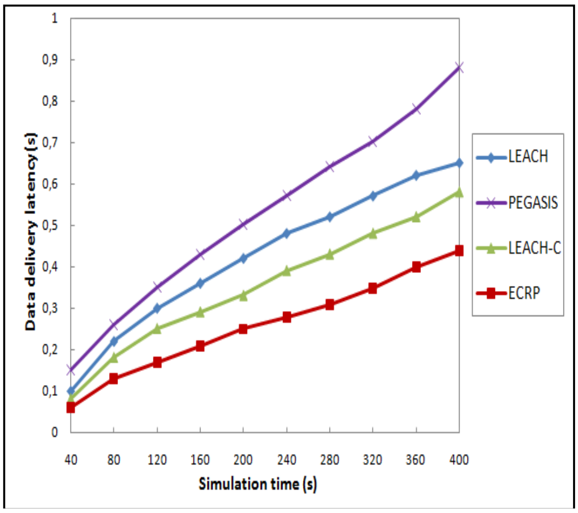


Fig. 5. Latency of data delivery to the base station

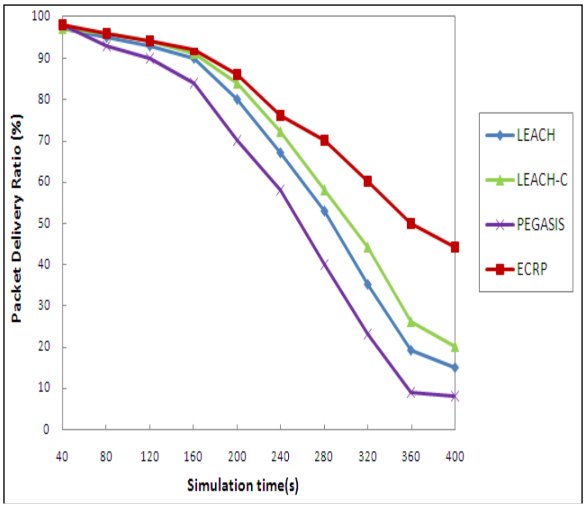


Fig. 6. Ratio of received data by the base station

The Fig. 6 shows the packet delivery ratio through time for the four protocols. ECRP is better than other protocols in terms of the data delivery ratio, this is explained by the fact that the data received by the nodes does not need to travel a long distance to reach their destination, since the CHs are located at the cluster centers, which facilitates the transmission of data to the base station. The results showed proven the efficiency of ECRP protocol in term of the packet delivery ratio, thus our protocol delivers more data to the sink than the other protocols. The three experimental results prove that our protocol outperforms the other hierarchical routing protocols and has the best performances.

VI. CONCLUSION

The hierarchical routing protocols based on clustering suffer from a bad distribution of CHs, with a high probability that a node with a low remaining energy is selected as CH, which generates an imbalance in energy consumption. The ECRP protocol has made it possible to create uniform and balanced clusters, which has ensured a good distribution of the nodes on the clusters, and a balanced distribution of energy consumption in the network. In ECRP the CH is positioned at the center of the cluster. This has reduced the data delivery duration, and minimized the energy consumption when transmitting data to the CH, since the nodes do not need to consume a lot of energy to transmit their gathered data to the CH. The results of the simulations demonstrate the superiority of our protocol over the existing hierarchical protocols, which translate into better data delivery ratio, lower energy consumption, and reduced data delivery duration.

REFERENCES

[1] Y. Seung-Su, S. Jae-Sung, J. Young-Hwan, J. Yong-Wan, and P. Seok-Cheon, "Design of clustering algorithm for efficient energy management in wireless sensor network environments," in *Proc. International Conference on Multimedia and Ubiquitous Engineering*, Seoul, Korea, May 2017, pp. 607–612.

[2] A. A. Ameer and Y. Mohamed, "A survey on clustering algorithms for wireless sensor networks," *Computer Communications*, vol. 30, pp. 2826–2841, 2007.

[3] Y. Liang-Xue, G. Zhi-Qun, L. Zhi-Hua, and G. Xin-Ping, "Joint design of clustering and in-cluster data route for heterogeneous wireless sensor networks," *International Journal of Automation and Computing*, vol. 14, no. 6, pp. 637–649, 2017.

[4] T. Ng. Raymond, and H. Jiawei, "Efficient and effective clustering methods for spatial data mining," in *Proc. International Conference on Very Large Data Bases*, Santiago, Chile, 1994.

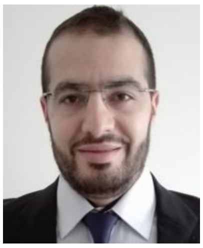
[5] W. R. Heinzelman, A. Chandrakasan, and H. Blalakrishnan, "Energy-efficient communication protocol for wireless microsensor networks," in *Proc. 33rd Annual Hawaii International Conference on System Sciences*, Hawaii, USA, 2000.

[6] W. R. Heinzelman, A. Chandrakasan, and H. Blalakrishnan, "An application-specific protocol architecture for wireless micro sensor networks," *IEEE Transactions on Wireless Communication*, vol. 1, no. 4, pp. 660-670, 2002.

[7] S. Lindsey and C. S. Raghavendra, "PEGASIS: Power-efficient gathering in sensor information systems," in *Proc. IEEE Aerospace Conference*, Los Angelos, USA, 2002.

[8] S. Lindsey, C. S. Raghavendra, and K. Sivalingam, "Data gathering in sensor networks using the energy *delay metric," in *Proc. IPDPS Workshop on Issues in Wireless*

Networks and Mobile Computing, San Francisco, USA, 2001.
[9] O. Younis and S. Fahmy, "HEED: Hybrid energy efficient distributed clustering approach for ad hoc sensor networks," *IEEE Transactions on Mobile Computing*, vol. 3, no. 4, pp. 366-379, 2004.
[10] M. Youssef, A. Youssef, and M. Younis, "Overlapping multi-hop clustering for wireless sensor networks," *IEEE Transactions on Parallel and Distributed Systems*, vol. 20, no. 12, pp. 1844–1856, 2009.
[11] J. Chang and P. Ju, "An efficient cluster-based power saving scheme for wireless sensor networks," *EURASIP Journal on Wireless Communications and Networking*, vol. 2012, no. 172, 2012.
[12] G. S. Arumugam and T. Ponnuchamy, "EE-LEACH: Development of energy-efficient LEACH Protocol for data gathering in WSN," *EURASIP Journal on Wireless Communications and Networking*, vol. 2015, no. 76, 2015.
[13] **000000**D. Yi and H. Yang, "HEER – A delay-aware and energy-efficient routing protocol for wireless sensor networks," *Computer Networks: The International Journal of Computer and Telecommunications Networking*, vol. 104, pp. 155–173, 2016.
[14] P. C. Subha and S. Malarkkan, "H-CERP: Energy efficient scheme for industrial WSN applications," *Journal of Wireless Pers Commun*, vol. 94, no. 4, pp. 1937–1950, 2017.
[15] P. Kuila and P. K. Jana, "Energy efficient clustering and routing algorithms for wireless sensor networks: Particle swarm optimization approach," *Engineering Applications of Artificial Intelligence*, vol. 33, pp. 127–140, 2014.
[16] A. Boukerche, H. A. B. F. Oliveira, E. F. Nakamura, and A. F. A. Loureiro, "Localization systems for wireless sensor networks," *IEEE Wireless Communications*, vol. 14, no. 6, pp. 6-12, 2007.
[17] Z. Fang, Z. Zhao, X. Cui, D. Geng, L. Du, and C. Pang, "Localization in wireless sensor networks with known coordinate database," *EURASIP Journal on Wireless Communications and Networking*, vol. 2010, no. 2, 2010.
[18] R. Misra, S. Shukla, and V. Chandel, "Lightweight localization using trilateration for sensor networks," *International Journal of Wireless Information Networks*, vol. 21, no. 2, pp. 89-100, 2014.
[19] T. Ng. Raymond and H. Jiawei, "CLARANS: A method for clustering objects for spatial data mining," *IEEE Transactions on Knowledge and Data Engineering*, vol. 14, no. 5, pp. 1003-1016, 2002.
[20] Network Simulator (ns2). [Online]. Available: http://www.isi.edu/nsnam/ns



Amine Rais was born in Morocco in 1984, and received his Bsc and Msc degree in computer science from the department of mathematics and informatics in the college of sciences at Sidi Mohamed Ben Abdullah University, FEZ, Morocco in 2006 and 2008 respectively. He is now working towards the Ph.D. at RITM Laboratory in the National High School of Electricity and Mechanic (ENSEM) at Hassan II University. He served as a member in the student comity of the third edition of SYSCO'2016 conference. He published several articles in international journals and conference proceedings, his main interest fields include clustering and mobile agents in wireless sensor networks.

Khalid Bouragba received his Msc degree in networking and telecom From Chouaib Doukkali University of El Jadida, Morocco, in 2002, and Ph.D. degree in computer science from Hassan II University of Casablanca, Morocco, in 2012. Currently, he is a professor of computer engineering at the Superior School of Technology of Casablanca and a member of the RITM laboratory at ENSEM. His research domains are: distributed computing, workflow interoperability, networks and systems management, requirement engineering, and sensor networks.

Mohammed Ouzzif received his Ph.D. degree in the field of collaborative systems at the University Mohamed V - Rabat Morocco. He is a professor of computer engineering at the Superior School of Technology of Casablanca, Morocco and he served as a chair of the computer department from 2006 to 2010. He is a member of the RITM laboratory at ENSEM. He published almost 70 articles in international conferences and journals. He served as the co-chair of the third edition of SYSCO'2016 conference and a technical committee member in many leading conferences in Morocco. Currently, his research interests concern distributed and collaborative systems, sensor networks, data mining, and big data.