Equal Size Clusters to Reduce Congestion in Wireless Multimedia Sensor Networks

Chaima Bejaoui, Alexandre Guitton, Abdennaceur Kachouri

Noname manuscript No.
(will be inserted by the editor)

Equal size clusters to reduce congestion in WMSNs

Chaima BEJAOUI · Alexandre GUITTON · Abdennaceur KACHOURI

Received: date / Accepted: date

Abstract Wireless Multimedia Sensors Networks (WMSNs) are a particular instance of wireless sensor networks (WSNs) that support the transmission of multimedia data such as video, image or sound. Those multimedia data should be delivered with variety and predefined levels of Quality of Service (QoS) that impose the development of routing protocols. In this paper, we propose a new routing protocol based on clustering that balances the number of nodes in clusters called Equal Size Clusters to reduce Congestion in WMSNs (ESCC). We seek to balance the number of members in a cluster in order to reduce congestion in intra-cluster and reduce the number of congested cluster-heads, so we propose a novel metric called MCUR (Maximum Cluster-heads Utilization Ratio) that designate the largest number of members assigned to a CH. In this way, we can ensure a reliable transmission of multimedia data. Our simulation results indicate that our proposed scheme outperformed the other protocols proposed in literature in terms of MCUR, the number of cluster-heads and the energy consumed.

Keywords WMSN · WSN · Clustering protocol · Load-balancing · MCUR

C. Bejaoui
University of SFAX, LETI Research Lab, National School of Engineers of SFAX, 3038 SFAX, TUNISIA
E-mail: bejaouichaima@gmail.com

A. Guitton
Clermont University, Blaise Pascal University , LIMOS, BP 10448, F-63000 CLERMONT-FERRAND; France CNRS, UMR 6158, LIMOS, F-63173 AUBIERE FRANCE
E-mail: alexandre.guitton@univ-bpclermont.fr

A.Kachouri
University of SFAX, LETI Research Lab, National School of Engineers of SFAX, 3038 SFAX, TUNISIA
E-mail: abdennaceur.kachouri@enis.rnu.tn

1 Introduction

Wireless Sensor Networks (WSNs) [1] consists of several tiny sensors [2] that poses the problem of depletion of their batteries. In these networks, each node is capable to monitor its environment and respond if necessary by sending the collected information to one or more collection points (nodes), using a wireless connection. They are used in many applications such as health care applications, military applications, precision agriculture, forest fires [3].

Nowadays, WSNs are based on techniques more and more oriented towards image, video and sound processing, hence the recent need of Wireless Multimedia Sensor Networks (WMSNs) [4][5]. Examples of applications for WMSNs include the monitoring of elderly people, the monitoring of fields in precision agriculture, intruder detection through video cameras, etc. Multimedia data are characterized by their large volume, and have strict requirements in terms of quality of service (QoS) such as bandwidth, delay, packet loss, delay jitter, etc.

The transmission of the multimedia data is a very challenging problem due to the strict requirements of QoS. Many works are proposed to provide solutions for this type of transmission. Existing protocols have been implemented for routing multimedia data, are classified into several classes [6]. The routing protocols based on QoS-aware [7, 8, 9, 10], this routing protocols aim to transmit data according to the applications requirements to ensure an efficient energy transmission, low delay, and high bandwidth. Another classe is the routing protcols based on cluster approach [11, 12] that can prolong the network lifetime, reduce the energy consummption and maintain the load balancing between clusters. Also the routing protocols that are designed to reduce the network congestion level [13, 14] to ensure a reliability transmission and to alleviate the load in inter-clusters communications.

In this paper, we are interested in routing protocols based on clusters that aim to reduce congestion in order to have reliable data transmission and a reduced loss rate. This is achieved by balancing the traffic load, which results into a balanced energy consumption within the network. Our ESCC balance the clusters based on neighbor, it make a comparison between number of members in clusters. The current CH search between its neighbor the CH that have more members, if the number of members of the CH found is more than the members of the current CH plus 2, A FORCE-JOIN is sent to the CH that have the more members.

More specifically, we focus on balancing the size of clusters in order to balance the processing load of cluster-heads. We introduce a new metric, called MCUR (Maximum Cluster-heads Utilization Ratio) to quantify this objective.

This paper is organized as follows. Section 2 describes the related work on clustering protocols for WMSNs. It includes a description of congestion-based clustering protocols and load-balancing clustring protocols. Section 3 presents the new metric called MCUR, the proposed optimal algorithm (based on integer linear programming), and our protocol ESCC. Section 4, evaluates our protocol. Section 5 concludes this work.

2 Related work

In this section, we describe some clustering protocols for WMSNs. We start by a description of the LEACH protocol. Then, we describe congestion based clustering protocols. Finally, we present load-balancing clustering protocols.

2.1 LEACH

LEACH (Low Energy Adaptive Clustering Hierarchy) [15] is the oldest clustering protocol for WSNs. It divides its operation into rounds. Each round contains two phases: the set-up phase and the steady-state phase. During the set-up phase, each node n in LEACH generates a random number between 0 and 1, and compares it with the threshold $T(n)$:

$$[h!]T(n) = \begin{cases} \frac{k}{N-k(r \mod \frac{N}{k})} & ifC_i(t) = 1, \\ 0 & ifC_i(t) = 0, \end{cases} \quad (1)$$

Where N is the number of nodes in network, k the expected number of cluster-heads, r the round number, and $C_i(n)$ indicates wether node n was a CH in the last $(r\ mod\ N/k)$. If the generated number is lower than a $T(n)$, the node becomes a CH.

LEACH decomposes the set-up phase in four steps as shown in Figure 1. In the advertisement step, each CH sends an advertisement message to their neighbors to announce its status. In the cluster setup step, the non-CH nodes join a CH based on the RSSI signal. In the scheduler step, each CH broadcasts a TDMA (Time Division Multiple Access) schedule to its cluster members, so that each member has a slot for transmitting data during the steady-state phase. During steady-state phase, the nodes transfer their data to their CH, during their slot. The CH aggregates all collected data and sends it to the sink.

LEACH does not take into account the problem of congestion in the network. Indeed, a cluster can have more members than another cluster, and therefore the load of some CHs might be large, causing congestion and packet losses.

2.2 Congestion-based clustering protocols

The main task in congestion-based routing protocols is to avoid congestion.

CAA (Congestion Avoidance and Alleviation routing protocol) [16] is designed to avoid congestion in nodes. It detects congestion and sets the rate of packets arriving at the nodes equal to the rate of packet service. CAA uses a clustering method based on residual energy to elect its cluster-heads, and a CDMA (Code Division Multiple Access) method for the inter-cluster communication , and a TDMA method for the communication between members and CH. In the transmission phase, a centralized method is established by the

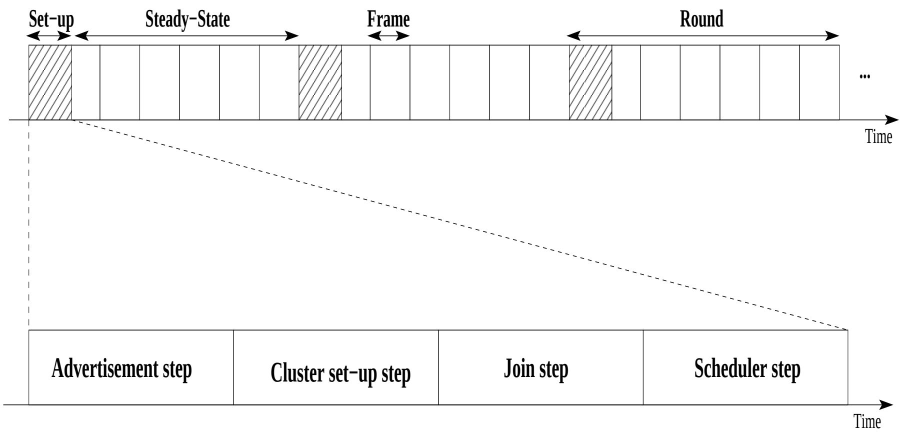

Fig. 1 LEACH operating diagram.

sink for routing. The sink broadcasts a flooding message with hop number 0 in the network, and the CHs rebroadcast this message with their distance to the sink. The congestion detected using a congestion degree. The cluster-heads forward their data over the route that has the minimum degree of congestion. An additional technique to avoid congestion is the use of a local buffer to store data during the congestion period.

CRAP (Cluster based congestion control with Rate Adjustment based on Priority) [17] monitors proactively the congestion and adjusts the traffic rate when a cluster has a high priority data flow to be transmitted. The adjustment rate is done by exchanging the estimated rate of traffic between clusters. This reduces the number of broadcast packets and the energy loss. Three kinds of nodes are present: the CH which schedules the transmissions, the gateway node which interconnects adjacent clusters, and the node members. The member nodes send data, trafic rate and other information to their own cluster-heads. This collected data is transmitted over routes using ZRP (Zone Routing Protocol). CRAP calculates the rate of trafic in the clusters in order to alleviate the CH congestion. The congestion degree is analysed by the CH. If this degree exceeds a given threshold, the CH broadcast this value to all neighboring CHs to adjust their congestion rate.

In summary, these protocols aim to reduce congestion by reducing the traffic rate. This solution causes a problem for the multimedia data. Indeed, the video data transmission tolerates only a small margin of packet loss. The MPEG compression codec provides three type of frames: I-frames, B-frames and P-frames [18]. The most important frames are I-frames and P-frames. Losing one of these frames degrades significantly the video quality.

2.3 Load-balancing clustering protocols

Load-balancing can be considered as a solution to the congestion problem. In fact, the load-balancing can be achieved either by balancing the load between nodes, or by decomposing the network into clusters of size equal. In this subsection, we discuss about protocols that take into account the traffic and those that takes into account the number of nodes in cluster.

2.3.1 Traffic-based protocols

Irkhede et. al [19] proposed a solution which builds routes for data transmission while distributing the traffic. They uses the RREQ and RREP to determine routes between source and destination, and in the case where a route fails, a Route Error message is sent to rebuild the routes. Irkhede et. al use a method to distribute traffic uniformly over the paths that are built.

Zhou et.al [20] aim to balance the load based on clustering method in order to increase the network lifetime. In their method, if the number of members is higher than the average number of members, the candidate CH is elected. The nodes join the CH that has the minimum number of members. This process is repeated at each round. To transmit data, authors designed a multi-hop transmission based on intra-cluster and inter-cluster communications.

DSCP (a novel Dominating Set based Clustering Protocol) [21] proposes to construct energy-balanced clusters. Nodes in DSCP take into consideration their energy, their traffic load, their number of neighbors and the traffic load of their neighbors . Then each node estimates the number of rounds it can be active for gathering data. According to this estimation, the node is either a CH or a provisional CH.

EL-LEACH (Energy and Load balance LEACH) [22] provides an improvement over LEACH by proposing a new method based on residual energy to elect CHs. First, it integrates into $T(n)$ the fraction of the remaining energy of node. Second, it introduces a mechanism where all cluster-heads in range compete: each ADV message contains a metric that includes both the fraction of remaining energy of the cluster-head, and its distance to the sink (which is not assumed to be directly connected to CH). Only the nodes having the largest metric remain cluster-heads for this round. Third, the members select the cluster-head in range that has the largest metric.

LEACH-P [23] is a recent extension of LEACH. It is based on three phases. In the first phase, each node compares its own energy with the energy neighbors to elect the one with the largest capacity. The second phase, aims to avoid energy exhaustion by introducing a load monitor mechanism, which controls the load of CHs. The third phase is the inactive phase, where the CH spends its energy and its role is alternate to PCH (Pseudo- Cluster Head node) to maintain connectivity in network. The PCH node is a normal node that replace the CH that can not manage its cluster.

Those protocols are intended to balance energy over the network. They aim to balance energy by choosing the cluster-heads based on their energy and the energy of their neighbors, or by choosing an appropriate method for transmitting data within and between clusters. However, when paths and CH, are chosen based on energy only, paths with high energy suffer from collisions.

2.3.2 Node-based protocols

Some protocols balance the number of members in clusters in order to balance the load over the network.

In BCA (Balanced Clustering Algorithm) [24], nodes calculates their own probability to become a CH based on neighbor detection. The aim is to distribute CHs equally over the network field with an identical coverage zone of all the clusters. BCA uses the duty cycle putting nodes to sleep mode in order to preserve energy and increase the network lifetime. BCA aims to reduce the collision ratio between clusters and as well as the number of nodes that communicate directly to the sink. It uses three phases: the first phase is for nodes density detection, the second phase is for cluster constructing, and the third phase for data transmission. During the nodes density detection phase, nodes sends their advertisement message randomly in broadcast. During the cluster-head election phase, BCA use a threshold $\tilde{T}(n)$ which is based on the LEACH threshold ($T(n)$) and their own formula of neighbor detection. BCA reduces the energy consumption by using the duty-cycle in the steady-state to make nodes sleep.

OABC (Optimized Algorithm for Balancing Clusters) [25] aims to balance clusters in order to reduce energy consumption. OABC uses two phases for cluster-head election, and one phase for data transmission. In the first phase, nodes use the same threshold formula as LEACH to elect temporary cluster-heads (TCH). In the second phase, CHs are elected based on the TCHs: nodes which receive messages from two TCHs or more are candidate to become CH. A probability based on the residual energy and the overlapping degree is computed to elect CHs, so each elected CH announces the nodes within $2R$ distance of its status, to avoid that two adjacent nodes become CHs. TCHs that do not receive messages from a CH elect themselves as CHs. Then, all CHs send messages over the network to announce this final status. The non-CH nodes join the nearest CH, which creates a TDMA schedule and send it to their members.

PASCCC (Priority-based Application-Specific Congestion Control Clustering protocol) [26] is another clustering protocol for congestion reduction in mobile WSNs. PASCCC is a hierarchical routing protocol based on LEACH, and contains two phases : the set-up phase and the steady-state phase. The authors explain that unequal size of clusters cause congestion, so they designed a balanced clustering to reduce congestion. Nodes are moved to empty regions to maintain balancing in the network.

V.Pal et. al [27] propose a clustering approach to make the number of clusters size equal. The authors prove that clusters of small sizes have more slots in the transmission phase, so they consume more energy than clusters of large size. Their clustering phase is made in two steps: initial formation step and transmission step. They use the same CH formation step as LEACH and the same schedule for nodes to send data. The authors use a threshold for number of members per cluster, and this threshold is updated at every round. Nodes join the closest CH with the highest RSSI. If the selected CH has less members than the threshold, the node joins this CH or waits for transmission step. A distance threshold is used to ensure that nodes join CHs that are close to them. Fig.2 explains the different phase of this work. The set-up phase consists of four steps; the first two steps involve the election of CH and the formation of clusters, the third step consist of clusters balancing and the last step consists of sending the calendar members for transmetting data.

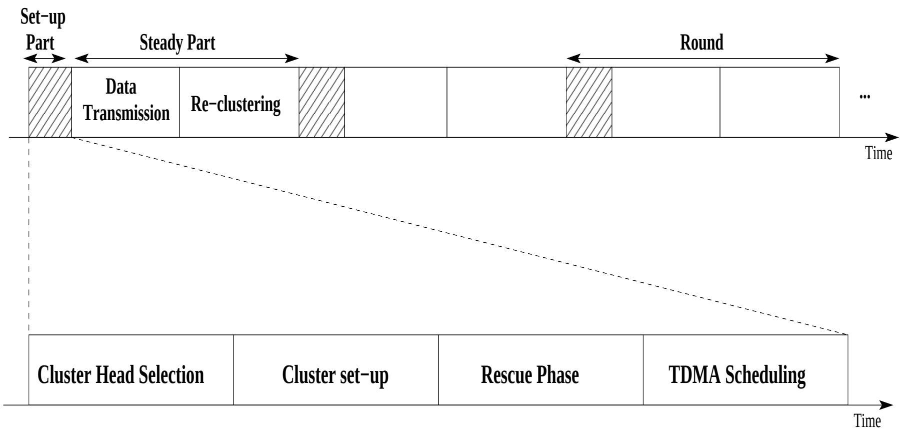

Fig. 2 Operating diagram of protcol cited in [27].

The equal size clustering protocols reduce congestion within clusters and avoid congested CHs, as they reduce the redundance packets and thus alleviate the load, which increases the network lifetime and ensures reliable transmission of multimedia data.

3 Proposition

In WMSNs, CHs receives process and aggregate the multimedia data from all their members. Thus, their load and energy consumption is releated with the number of members they have. In the following, we propose a new metric called MCUR, an optimal election and our ESCC.

3.1 MCUR

We introduce in this work a new metric to target a load-balanced network and alleviate congestion in CH nodes: The MCUR (maximum cluster-head utilization ratio) is equal to the largest number of members assigned to a CH. Figure 3 shows a topology with the same CHs but two member assignments. The filled nodes are the CH nodes and the other nodes are members. Arrows represent the assignment of members to CHs. In case (a), one CH has a single member, while the other CH has five members. Thus, MCUR is equal to 5. This shows that some CHs (the second CH in this example) have a heavy load, as well as a large amount of data to transmit, resulting into congestion. In case (b), the two CHs have three members each. Thus, MCUR is equal to 3. The total load (in terms of number of members) is well balanced in this case.

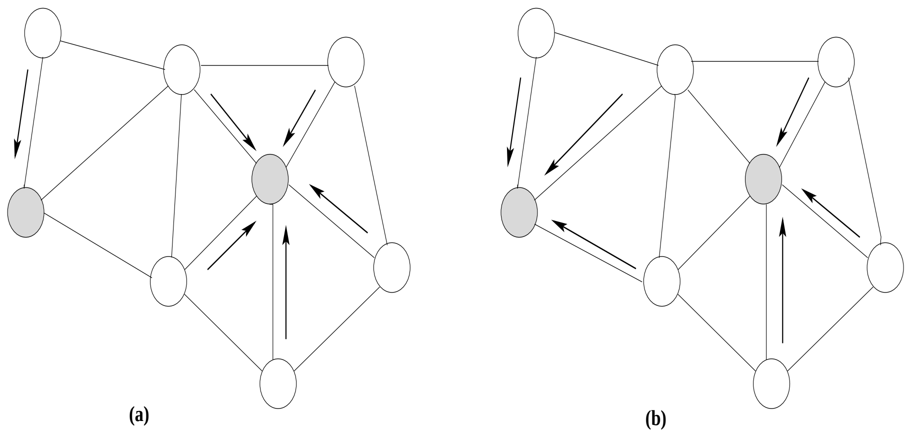

Fig. 3 Different member assignments result into different MCURs, the lower the MCUR, the better it is for load-balancing.

MCUR is not only related to the number of members per CHs but it is also related to the number of CHs. With a large number of CHs, the MCUR is expected to be small, while with a small number of CHs, MCUR is expected to be large. Figure 4 (a) shows a member assignment for three CHs, corresponding to a MCUR of 2 (which is the minimum possible with three CHs in this topology). Figure 4 (b) shows a member assignment for three CHs, corresponding to a MCUR of 3 (again, this is the minimum possible with three CHs). The comparison of MCURs of two assignments is meaningful only if the number of CHs is the same.

3.2 Optimization by ILP

In order to compute the optimal number of members per cluster, we decided to use an integer linear program that takes as input the whole network topology and the number of cluster-heads. The objective function and the constraints of our ILP program are summarized below.

$$\text{minimize} \quad \text{MCUR}$$

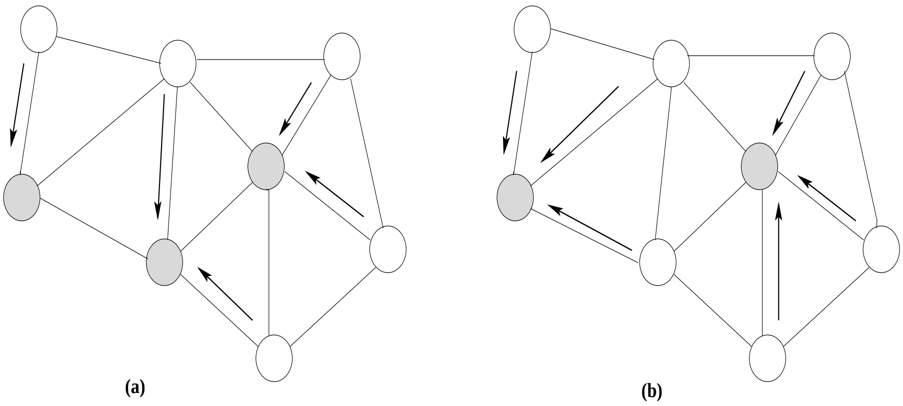

Fig. 4 Generally large number of CHs yield small MCURs, while small number of CHs yield large MCURs.

$$\forall\, v \,\epsilon\, N, \sum_{v \epsilon N} (1 - f(n, v)) \geq 1 \tag{1}$$

$$\forall\, (n\,, v) \,\epsilon\, N^2,\; f(n, v) \geq 1 - neighbors(n, v) \tag{2}$$

$$\forall\, (n\,, v) \,\epsilon\, N^2,\; f(n, v) \geq 1 - CH(v) \tag{3}$$

$$\forall\, (n\,, v) \,\epsilon\, N^2,\; f(n, v) \leq 2 - neighbors(n, v) - CH(v) \tag{4}$$

$$\forall\, n \epsilon\, N, \sum CH(n) \leq \alpha \tag{5}$$

$$\forall\, n \epsilon\, N, \sum_{v \epsilon N} member[n, v] = 1 \tag{6}$$

$$\forall\, (n\,, v) \,\epsilon\, N^2,\; member[n, v] \leq 1 - f(n, v) \tag{7}$$

$$\forall\, n \,\epsilon\, N,\; member[n, n] = CH(n) \tag{8}$$

$$\forall\, v \,\epsilon\, N,\; NMC(v) = \sum_{n \epsilon N} member[n, v] \tag{9}$$

$$\forall\, v \,\epsilon\, N,\; MCUR \geq NMC(v) \tag{10}$$

The inputs of this model are as follows: N is the set of nodes, $neighbors(n, v)$ represents the adjacency matrix. The variables we use are: $CH(n)$ indicates whether n is a CH or not, $f(n, v)$ is equal to 0 if n is a CH and v is neighbor of n, and to 1 otherwise, and the function $member[n, v]$ indicates whether n and v are neighbors or not.

$NMC(n)$ represents the number of members for the CH v, and α is the maximum number of CH in network.

Our objective is to minimize the maximum number of members for any CH.

The constraints of our program are the following. Constraints (1), (2), (3) and (4) model the fact that each node is either a CH or a neighbor of a CH. Constraint (5) indicates that the number of CHs should not exceed the value α. Constraint (6) indicates that each node in network is associated with exactly one CH. Constraint (7) ensures that a node can not have as CH another node that is neither its neighbor nor a CH. Constraint (8) indicates that a CH is its own member. Constraint (9) calculates the number of members per CH. Finally, Constraint (10) computes the maximum number of members for any CH.

3.3 The ESCC protocol

Our protocol, called ESCC (Equal Size Clusters to reduce Congestion), aims to reduce the MCUR in a distributed manner. It adds a new period to the election phase called balancing, that balances the size of clusters using a Force-Join message. Each member keeps track of neighbors CH (by receiving ADV message) and on their members (through overhead Join messages).

We introduce in the election step a modified method to elected CH and to join CH from that in LEACH to reduce the number of CH neighbors and to eliminate the isolated node [28]. In the election part, the nodes do not send their ADV messages together but it send it in randomly delay, so if one neighbor receive more than th ADV before sending its own ADV it decide to become a member. In the join part, the nodes that do not receive any ADV message, they called isolated nodes, decide to become CH or member of new CH (isolated node become CH in join step) in order to maintain connectivity over network.

Algorithm 1 Balancing members in ESCC

Require: m_{CHc}, m_{CHmin}
  wait for random delay
  find $CH_{neighbor}$ with $min_{members}$
  if $m_{CHc} \leq m_{CHmin} + 2$ **then**
    send message FORCE−JOIN to CH_{min}
  end if

Algorithm 1 describes the procedure used by members in ESCC to balance nodes in clusters. m_{CHc} represents the estimation of number of members for the current CH of the node, and m_{CHmin} represents the estimation of minimum number of members of a neighbor of the current CH.

In our protocol, after a random delay, the node of current CH find a neighbor CH with the minimum number of nodes. We compare the number of nodes of the current CH with the number of members of CHs found plus 2 ($m_{CHmin} + 2$). We use this inequality to ensure that the one CH with the most members does not become less than its neighbor after donating members. We look at the neighboring CH that has the maximum number. A FORCE-JOIN message is sent after a random delay from the member to its new CH. Fig.5 shows the difference between our algorithm and the balancing algorithm of literature [27] shown at Fig.2.

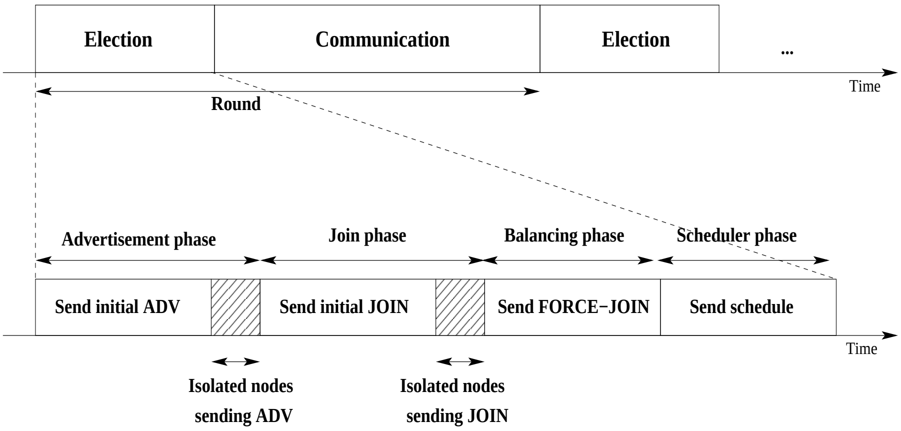

Fig. 5 Operating diagram of ESCC.

The Figure 6 shows an example of balancing two clusters. The continous arrows represents the JOIN message, and the discontinue arrows represents the JOIN message hard by nodes. Indeed, the node n send a JOIN message to CH 1, and at the same time it has an idea of other CHs in neighboring. It hear, the other JOIN messages, and he know that CH 1 has three members while CH 2 has one member.

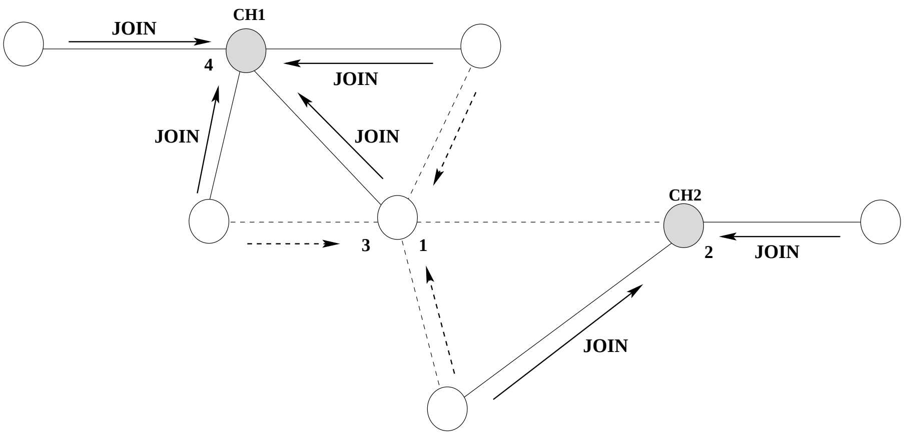

Fig. 6 Example of balancing of two clusters.

4 Simulation results

In this section, we present the simulation results and we analyze them. We analyze the performance of our protocol ESCC, our ILP, the protocol of the literature cited in [27] and the LEACH protocol.

4.1 Simulation parameters

We use the NS2 [29] simulator to simulate our parameters. We put in table 1 the different parameters used.

Table 1 Simulation parameters

Parameter Name	Value
Number of nodes	10, 20, 30
Field size	100 m x 100 m
Initial energy	1 Joule
Initial energy of sink	100 Joule
MAC Layer	IEEE 802.11
Propagation model	Shadowing
Transmission power	0.281838 watt
Path loss	2.5
Simulation Time	100 s (10 tours)

Each result is averaged over 100 repetitions, and each repetition consists of 100 seconds. We evaluate three parameters in our simulations, such as:

- the average of MCUR,
- the average number of CHs,
- the average number of isolated nodes,
- the average residual energy per round.

As shown in Figure 7, the ILP and the proposed algorithm have the high MCUR values. LEACH and our reference don't use a balancing mechanism in the cluster approach, so we can notice their low curves compared to the others. We can explain that in LEACH, the node can be CH, isolated node or maybe member of CH that's why we have an average of MCUR 1.5.

Figure 8 shows the average number of CHs as a function of the number of nodes for ESCC, our ref [28], LEACH and the literature protocol [27]. We can notice that the number of CHs in LEACH and the other protocol are very close, the two curves are overlapped, because they use the same threshold to elect CHs. The number of CHs in ESCC is lower than with LEACH and protocol of literature, that is because we avoid to have many CHs in neighborhoods.

Figure 8 represents the average number of isolated nodes according to the number of nodes, for the protocol of the literature and LEACH. Since our protocol ESCC, [28] and the ILP eliminates the isolated nodes, it is not mark in the figure. The results of average number of isolated nodes for the two

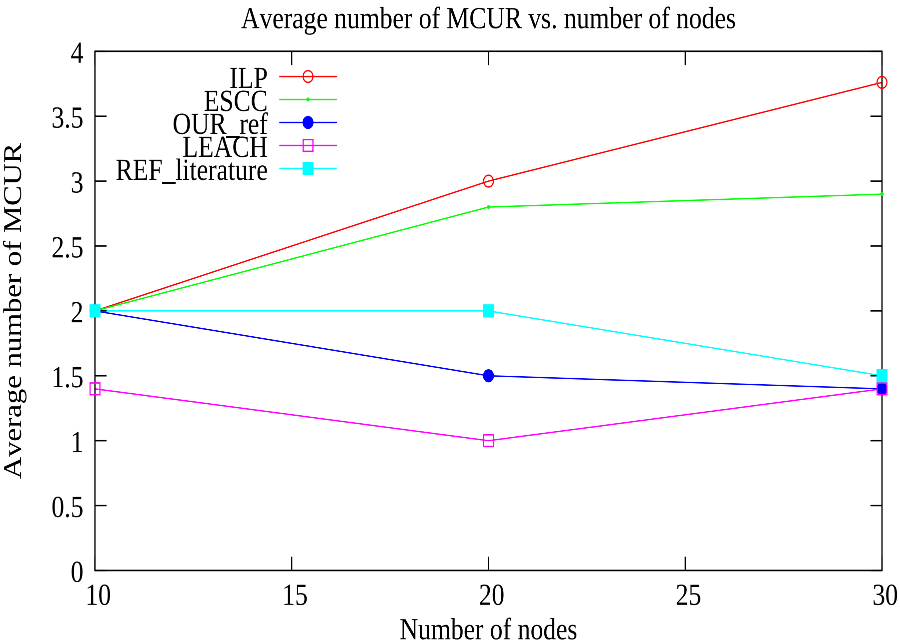

Fig. 7 Average number of MCUR vs. number of nodes

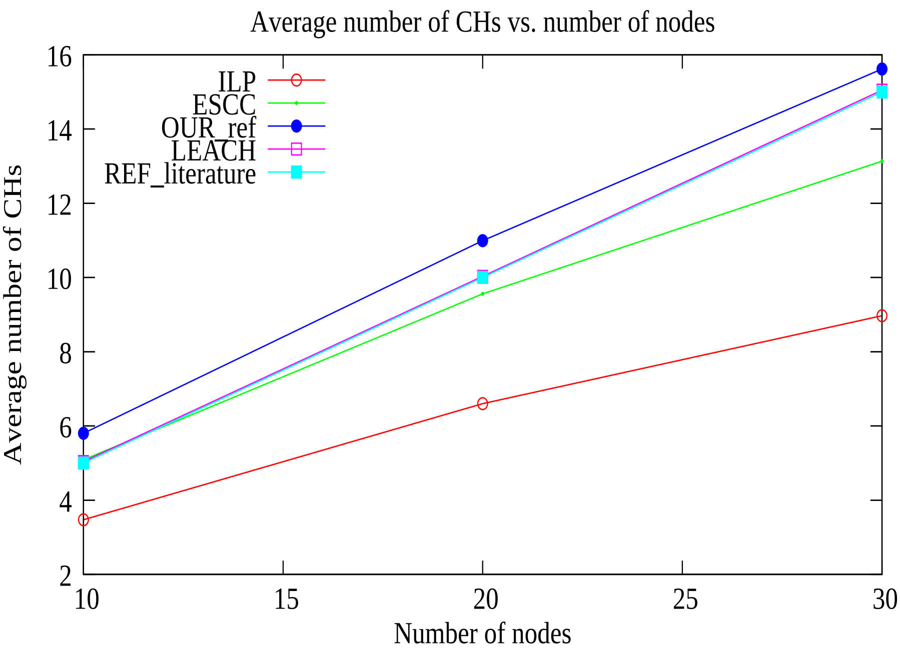

Fig. 8 Average number of CHs vs. number of nodes

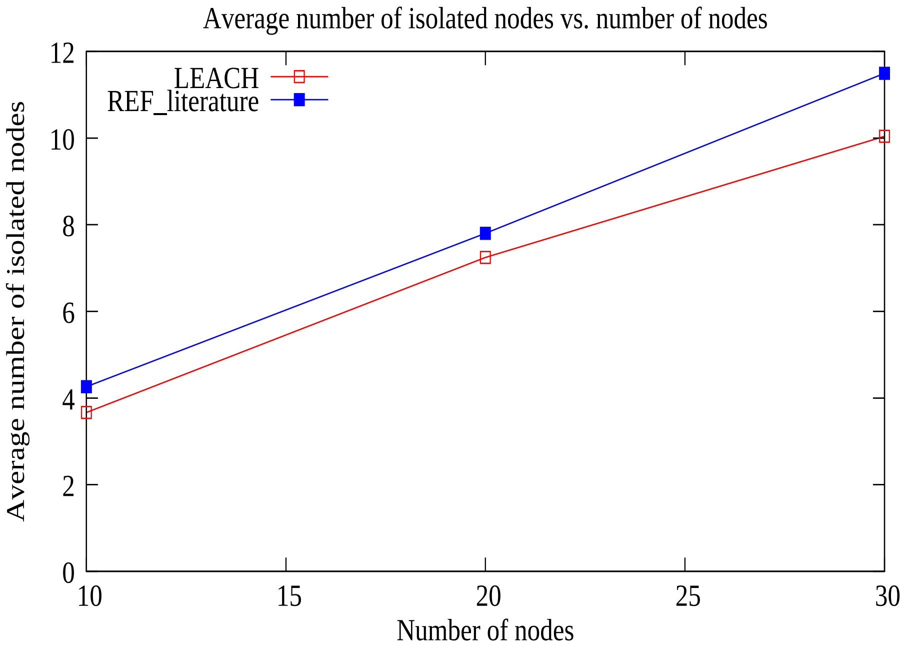

Fig. 9 Average number of isolated nodes vs. number of nodes

protocols are very close because it uses the same phase to join the CH. The number of isolated nodes increase with increasing the number of nodes.

Figure 7, 8 and 9 are in proportional relationship. The protocol that have the least nember of CHs must have more memebers in their clusters than other protocols, we can see that with the ILP's MCUR and our protocol in Figure 7 and 8. For our reference [28], we can notice the highst average number of CH because in the join period, it eliminate the isolated nodes and they become CH or member of new CH. The literature protocol [27] and LEACH have nearly the half of nodes as CHs so it's logic to have the minimum MCUR and some isolated nodes.

Figure 10, 11 et 12 shows the average residual energy per round as a function of the number of rounds, for ESCC, protocol [27] and LEACH. Figure 9 is for a network of 10 nodes, Figure 11 for 20 nodes and Figure 11 for 30 nodes. We can see in the results, that our ESCC outperforms our reference, the literature protocol and LEACH. The value of residual energy decreases with the number of rounds. We outperform the other protocols because we use first less control messages in the election and join steps. Second, the energy is distributed between nodes due to the balancing clusters. ESCC has a low performance in a small size of network, we consume more energy because of because of the new periods FORCE-JOIN and isolated nodes.

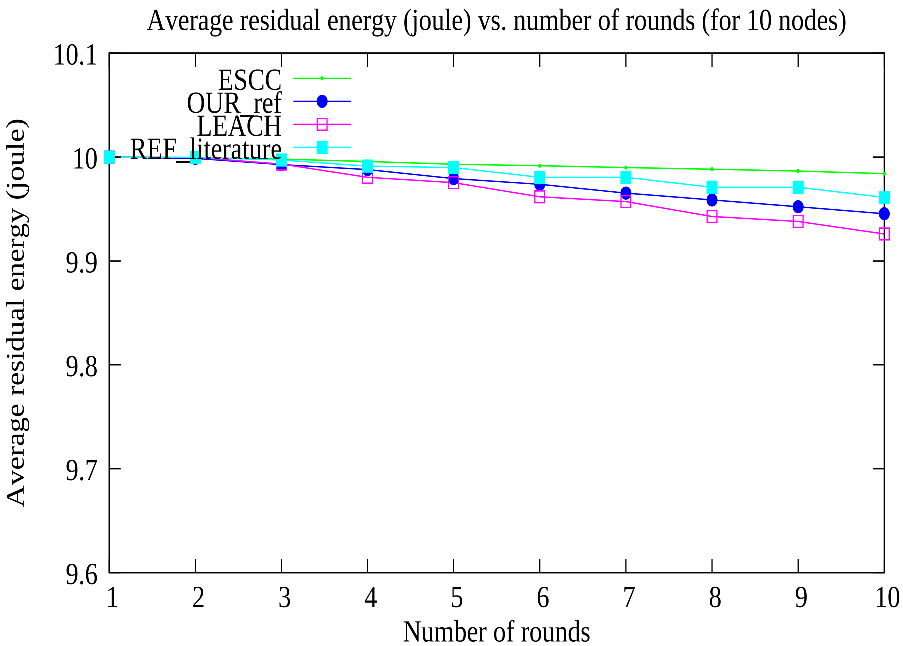

Fig. 10 Average residual energy in joule vs. number of rounds (for 10 nodes).

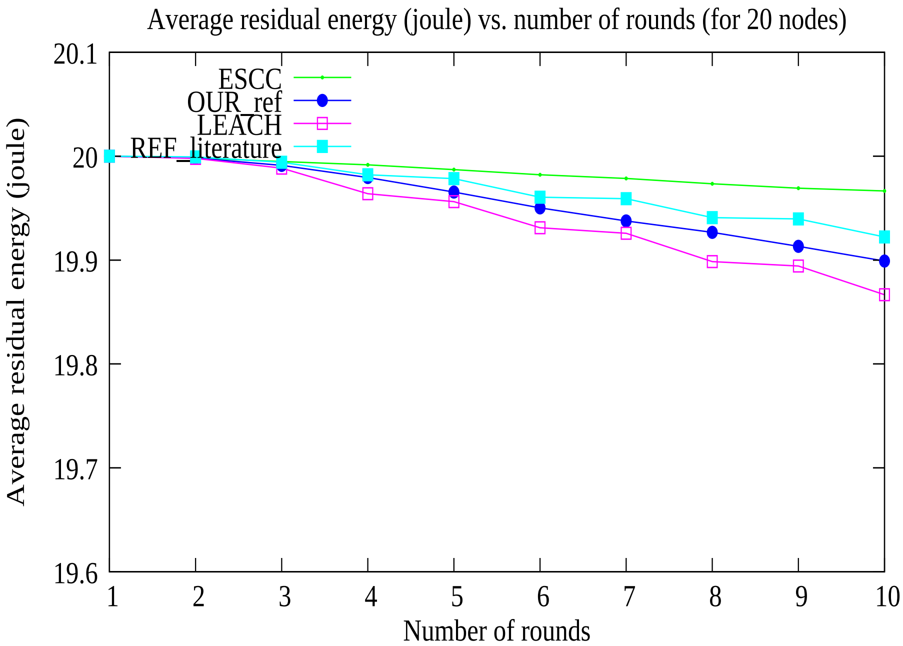

Fig. 11 Average residual energy in joule vs. number of rounds (for 20 nodes).

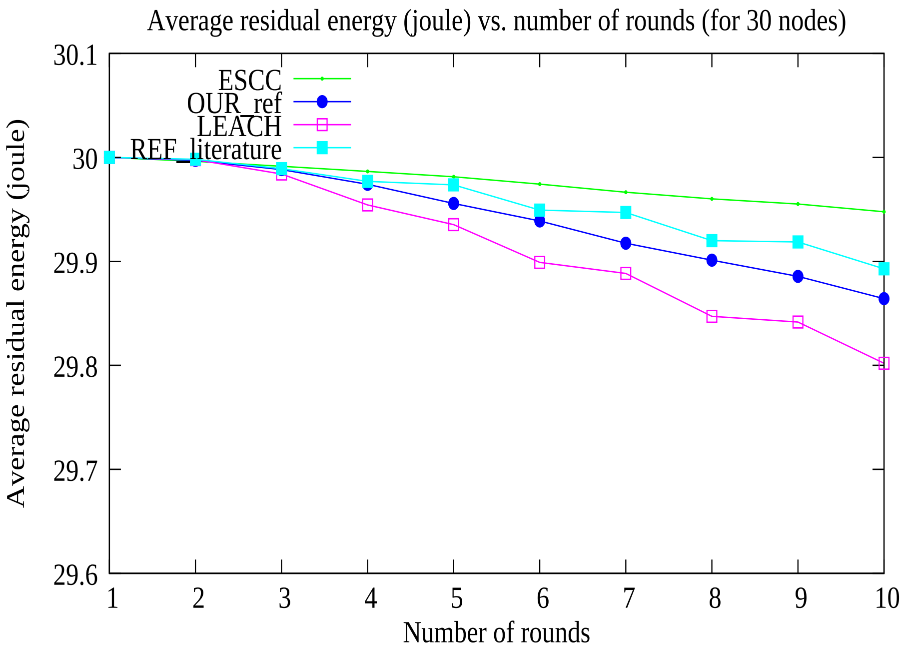

Fig. 12 Average residual energy in joule vs. number of rounds (for 30 nodes).

5 Conclusion

We presented in this paper, firstly the different load-balancing based on clustering protocols that aims to avoid congestion and load-balance the energy and traffic in WSNs. Secondly, we presented our protocol ESCC that aims to balance the number of members in clusters in order to reduces congestion in WMSNs, we proposed a new metric called MCUR, and we proposed our integer linear program that calculated the optimal minimum MCUR.

Simulation results showed that our protocol outperforms the literature protocol cited in [27] and the LEACH protocol. ESCC reduces the number of CHs and avoids isolated nodes compared to the two other protocols. Also, ESCC presentes more residual energy over 1000 seconds of simulation. The perspectives of this work include the data routing.

References

1. I.F. Akyildiz, W. Su, Y. Sankarasubramaniam and E. Cayirci, "Wireless Sensor Networks: A survey", Computer Networks, Elsevier, pp. 393-422, 2002.
2. H. Zara and H.B. Faisal, "QoS in Wireless Multimedia Sensor Networks: A layered and cross-layered approach", Wireless Personal Communications, Springer, pp.729-757, 2014.
3. C. Chih-Yung , S. Kuei-Ping and L. Shih-Chieh, "ZBP: A zone-based broadcasting protocol for Wireless Sensor Networks", Wireless Personal Communications, Springer, pp. 5368, 2005.

4. I.F. Akyildiz, T. Melodia and K.R. Chowdury, "Wireless multimedia sensor networks:A survey", IEEE Wireless Communications, pp. 1536-1284, 2007.
5. I.F. Akyildiz, T. Melodia and K.R. Chowdhury, "A survey on wireless multimedia sensor networks", Computer Networks, pp. 921-960, 2007.
6. A. Mohammed, F. Norshiela, Z. Suleiman, and A. Adel, "Routing protocols for Wireless Multimedia Sensor Network: A survey", Journal of Sensors, Hindawi, 2013.
7. K. Akkaya and M. Younis, "An energy-aware QoS routing protocol for wireless sensor network", in Proceedings Workshops in the 23rd International Conference on Distributed Computing Systems, pp. 710–715, 2003.
8. Y. Sun, H. Ma, L. Liu, and Y. Zhang, ASAR: an ant-based service-aware routing algorithm for multimedia sensor networks, Frontiers of Electrical and Electronic Engineering in China, pp. 2533, 2008.
9. L. Cobo , A. Quintero , S.Pierre , Ant-based routing for wireless multimedia sensor networks using multiple QoS metrics, Computer networks, pp. 29913010, 2010.
10. H. Tian, J.A. Stankovic, L. Chenyang, T. Abdelzaher, "SPEED: a stateless protocol for real-time communication in sensor networks", in proceedings of 23rd International Conference on Distributed Computing Systems, Providence, pp. 46–55, 2003.
11. R. Denis, C. Rodrigo, P. Helder, M. Kssio, C. Eduardo, B. Torsten and Z. Zhongliang, "A hierarchical multi-hop multimedia routing protocol for Wireless Multimedia Sensor Networks", Network Protocols and Algorithms, 2012.
12. L. Zhi-yuan, W. Ru-chuan, "Load balancing-based hierarchical routing algorithm for wireless multimedia sensor networks", Journal of China Universities of Posts and Telecommunications, pp. 5159, 2010.
13. S. Guannan, Q. Jiandong, Z. Zhe, and Q. Qiuhong, A reliable multipath routing algorithm with related congestion control scheme in wireless multimedia sensor networks, in Proceedings of the 3rd International Conference on Computer Research and Development, pp. 229233, 2011.
14. X. Mande and G. Yuanyan, Multipath routing algorithm for wireless multimedia sensor networks within expected network lifetime, in Proceedings of the International Conference on Communications and Mobile Computing, pp. 284287, 2010.
15. H. Wendi, "Energy-efficient communication protocol for wireless sensor networks", PhD thesis, Cornell University, 2000.
16. Y. Yong and C. Hongbo, "An congestion avoidance and alleviation routing protocol in Sensor Networks", Advances in Electric and Electronics Springer, pp. 99-106 , 2012.
17. S.S Jeya and B. Paramasivan , "CRAP: Cluster based congestion control with rate adjustment based on priority in Wireless Sensor Networks", International Journal of Multimedia and Ubiquitous Engineering, pp. 421-436, 2015.
18. L. Yanlin and C. Mark, "Using redundancy to repair video damaged by network data loss", in proceedinggs of ACM/SPIE Multimedia Computing and Networking (MMCN), 2000.
19. I. Tejal and J. Prachi, "Cluster and traffic distribution protocol for energy consumption in Wireless Sensor Network", Engineering and Systems, 2013.
20. Z. Zhiping and W. Ting, "An energy balanced cluster algorithm for Wireless Sensor Networks", 24th Chinese Control and Decision Conference IEEE, 2012.
21. X-y. KUI, J-x. WANG and S-g. ZHANG, "Energy-balanced clustering protocol for data gathering in wireless sensor networks with unbalanced traffic load", Journal Central South University, Central South University Press and Springer-Verlag Berlin Heidelberg, 2012.
22. Q.N.Thu Ngo, P.Kieu-Ha and Q.V Hoan, "Improvement of energy consumption and load balance for LEACH in Wireless", ICTC IEEE, 2012.
23. W. Wangang and P.Yong, "LEACH algorithm based on load balancing", TELKOMNIKA, 2013.
24. S. Heewook, M. Sangman, C. Ilyong and K. Moonsoo, "Equal-Size clustering for irregularly deployed Wireless Sensor Networks", Journal of Wireless Personal Communications, Springer, pp. 995-1012, 2014.
25. K. Mucheol, K. Sunhong, B. Hyungjin and H. Sangyong, "Optimized algorithm for balancing clusters in wireless sensor networks", Journal of Zhejiang University SCIENCE A, pp. 1404-1412, 2009.

26. J.A. Mian, N. Priyadarsi, H. Xiangjian and L.P. Ren, "PASCCC: Priority-based application-specific congestion control clustering protocol", Computer Networks, pp. 92-102, 2014.
27. P. Vipin, S. Girdhari and R.P. Yadav, "Balanced Cluster Size Solution to Extend Lifetime of Wireless Sensor Networks", Internet of Things Journal, IEEE, pp. 2327-4662, 2015.
28. B. Chaima, G. Alexandre and K. Abdennaceur, "Improved election of cluster-heads in LEACH", in proceeding of IEEE/ACS International Conference on Computer Systems and Applications, Morroco, 2015.
29. Network simulator: http:///www.isi.edu.ns/nam.