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Efficient Gatherings in Wireless Sensor Networks Using Distributed Computation of Connected Dominating Sets

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Abstract: In this paper, we are interested in enhancing lifetime of wireless sensor networks trying to collect data from all the nodes to a "sink"-node for non-safety critical applications. Connected Dominating Sets are used as a basis for routing messages to the sink. We present a simple distributed algorithm, which computes several CDS trying to distribute the consumption of energy over all the nodes of the network. The simulations show a significant improvement of the network lifetime. *Copyright © 2012 IFSA.*

Keywords: Sensor network, Lifetime, Distributed algorithm.

1. Introduction

In this paper, we investigate the communication efficiency in wireless sensor networks (WSN), which are consisted of sensors with a limited energy resource (batteries). Each sensor is able to communicate with a few other sensors in its neighborhood within its communication range, which we assume to be roughly the same for all sensors (however, this assumption is not restricting the application of our algorithm). The sensors regularly perform measurements and the measured data is collected to a single special node of the network called the sink (this operation is called gathering). Our goal is to maximize the number of gatherings that can be done by the network. For each gathering, the set of nodes used for transmissions have to be connected and to dominate the graph associated to the network (backbone).

We also assume that there is no central entity to compute an optimal routing for communication, therefore we are interested in developing distributed algorithms for this purpose.

In Sections 2 and 3, we present related work, the model and the main assumptions we made in order to get realistic results. Then a distributed algorithm is proposed in Section 4 to compute backbones, which distributes the use of sensors for transmissions to maximize network lifetime. Section 5 shows experimental results achieved by simulations about the lifetime of the network on grid and random topologies. We conclude and give tracks for future works in Section 6.

2. Related Work

Because of the critical importance of energy saving in WSN, literature regarding this subject is extensive. In order to do so, one typical way is to use Connected Dominating Sets (CDS) also called backbones to route the messages where only the nodes belonging to the backbone use energy to forward messages [1, 2]. The goal is then to minimize the number of nodes in the backbones [3]. Because of robustness and scalability requirements, most algorithms are operating in a distributed manner with local election of the nodes belonging to the backbone [4]. Since this problem is NP-hard, some authors work to find guarantees on the approximation ratio [5].

With this strategy, the nodes belonging to the backbone will consume more energy. Thus after a certain period of time, the network will be disconnected while the other node may still have a lot of energy. An improvement (in order to increase the lifetime) is to compute several backbones. One then try to alternate as possible the belonging of the nodes to the backbones and use those backbones alternatively. Unfortunately, computing the maximum number of disjoint CDS (called connected domatic number) is a hard task. Furthermore, this number may be very small. For example, in [6] the authors show that for a grid graph where one of the dimensions is greater or equal to 3, the connected domatic number is 1. Thus in such a graph, one cannot expect to increase the lifetime of the network using disjoint CDS.

One may relax this constraint by trying to find a set of CDS such that the maximum number of CDS a node belongs to is minimized. Such a distributed algorithm is proposed in [7]. Nevertheless, this model does not take into account the real consumption of energy of the nodes, which depends (among others) on the number of received messages, i.e. on the degree of the node. In [8], the authors dynamically construct backbones taking into account the remaining energy of each node. In our case, all data have to be gathered to a fixed sink. We thus only have to compute a directed in-tree rooted at the sink, and the sink may initiate this computation (the algorithm is not localized but only distributed). This specification allows us to need only a small number of messages to compute a backbone.

3. The Model

A WSN can be modeled by a graph $G=(V, E)$ where V is the set of sensors and an edge $e=(v, w) \in E$ if v and w can communicate. We suppose that if v can communicate with w, the contrary is also true (G is not directed). Results on WSN are highly dependent on several parameters of the network (density, model of energy consumption, measurement frequency, etc.). We thus have to make several assumptions in order to specify the global framework of our work.

We suppose that the frequency of the measurements is small enough so that there is enough time to collect data from all sensors to the sink without new measurements being sent. If a routing is computed for data collection, then aggregation technique can be used at each node. Therefore we just have to find a directed in-tree rooted at the sink to perform a gathering. We also assume that the size of the

data is small enough so that even after several aggregations the size of the messages sent will be less than one packet. Thus for each gathering, the emission cost will be the same for all sensor. This is our unit to measure the energy consumption.

Note that these assumptions are just done to fix the conditions of the experiments: our algorithm still works if the size of the messages (and thus the energy needed to send them) is not constant and the sensors know their remaining energy.

To meet realistic conditions, the cost for a reception cost will not be supposed to be equal to zero. Although this cost is not often taken into account especially in theoretical models, this seems to be a reasonable assumption regarding for example [8] or [9]. In real life, both emission and reception costs depend on the sensors type and on the transmission range but they usually have the same order of magnitude.

The energy needed for performing measurement depends on the kind of measurement performed and the device used to do so. Taking into account this energy in the model would make it highly dependent on the application. In order to avoid this dependency, we will suppose that auxiliary batteries provide the energy needed to make the measurements and thus the cost for measurement is null. One can remark that this cost would not be difficult to take into account in our model and since for each gathering, each node will make exactly one emission, we just need to increase the cost of emission of this value for the messages containing data.

4. Distributed Search of Various CDSs (DSVB)

4.1. Main Algorithm

The principle of our algorithm is that each node will choose as a father in the backbone the first node from which he received an "invitation" message. Since all the nodes but the sink send their invitation after receiving one and waiting a certain time, this ensures that we built a directed in-tree rooted at the sink. More formally, for each search of a backbone *b*, the algorithm works as follows:

- The sink *s* sends invitation <INV> with its id and *b*'s id (broadcast to all of its neighbors)
- For all other nodes *v* do
  - Father ← sender's id in the first <INV> received
  - Send acceptation <ACC> (with *v*'s id, Father's id and *b*'s id)
  - Chose a delay *w*
  - Wait *w*
  - Send <INV> (with *v*'s id and *b*'s id)
  - If (number of received <ACC> = number of neighbors) and (*v* is a father in none of the received <ACC>) then $v \notin b$
  - If, in a received <ACC>, (Father's id = *v*'s id) then $v \in b$

For each node, computing a backbone with this algorithm needs only to send two messages and so a number of receptions equal to twice the degree of the node.

4.2. Computing the Delay

Fine-tuning of the algorithm is done by the computation of the delay each sensor has to wait before sending an invitation. The influence of this delay obviously depends on the time needed for one node

to run the algorithm (if the algorithm needs 100 μs to be run, adding a delay of 2 μs will not have much influence).

Let t be an upper bound of the time a node needs to run the algorithm (receive and process a message, compute the delay and send a message). Our unit to measure the energy of a node will be the amount e of energy needed to send or receive a message.

Let $e \cdot E_{init}(i)$ be the initial energy of the node (thus $E_{init}(i)$ is the number of messages a node can send), $e \cdot E_{rem}(i)$ its remaining energy after a certain duration of use. This remaining energy may by known by the sensor or evaluated considering the numbers of emissions and receptions already done (in this second case, the battery model is supposed to be linear).

A "penalty" $p_i = f(E_{rem}(i))$ is computed for each node i. It has to increase when the remaining energy of a node decreases. In order to differentiate nodes that would have the same penalty, the delay of node i is randomly chosen in a range $[0, mxd_i]$ where mxd_i is the maximum delay for node i. Let p_{max} be the greatest penalty for all nodes and MXD be the maximum delay allowed for any node (i.e. the maximum delay for the node such that $p_i = p_{max}$). The maximum delay for node i is $mxd_i = MXD \cdot p_i / p_{max}$. The variable MXD is a factor that ensures that the time needed to compute a CDS is not too long and that the delay chosen by the nodes are generally not too small In this second case, the choice of the father in the CDS would only depend on the time needed to run the algorithm. The variable MXD depends on t and on the size of the network. Note that if the delay is constant for all nodes, then our algorithm is formally identical to a Breadth First Search (BFS).

5. Main Results

In order to validate our approach and be as near as possible of the functioning of a real network, we use WSNET simulator. Despite NS-2 is more often use in the literacy, WSNET is reported to have a more realistic model for transmission [10]. We simulate the effective communications between the nodes with an autonomous functioning of the nodes. The sink is supposed to have an unlimited energy. In our simulations, we set $t \approx 2$ μs. Those values are chosen considering the devices Micaz of MEMSIC on which we plain to make experiments on in further works.
For the delay, f is chosen according to equation (1).

$$f\left(E_{rem}(i)\right) = \left(\frac{1 + E_{init}(i)}{1 + E_{rem}(i)}\right)^k \tag{1}$$

The value of $f(E_{rem}(i))$ is at least 1 (with much bigger values in a realistic setup). In order to know the highest penalty p_{max} when a backbone is computed, each node has to transmit the maximal current penalty it knows (from its penalty and its children) when returning a data. It is included in the invitation message. The latency to built a backbone is at most $|V| * MXD$.

5.1. Networks

Two kinds of networks are used to do the simulations.

1) Grids
In many potential applications, sensors are not randomly spread and the network has a "grid-like" shape (deployment in fields, cities, building, containers on a boat). Furthermore, grids have interesting properties for our studies since they both have low density (which make the computation of disjoint

CDS difficult) and relatively high connectivity (which helps to avoid degenerated cases that may occur because of the presence of isthmus or lowly connected parts).

We made simulations on two kinds of grids. The first one $G_R(p, q)$ is the usual $p \times q$ grid. In the second one $G_{R\sqrt{2}}(p, q)$, each node cannot only communicate with its 4 neighbors but is also connected on the diagonal and thus has 8 neighbors. The sink is always the center of the grid. The main part of the simulations are made using $p = q = 11$.

2) Random networks
The networks are unit disk graphs. In our experiments, the number of sensors $|V|=100$ and the density (average number of neighbors) is 10. We choose the 50 first networks generated with a connectivity greater than 2 (in a network of connectivity 1, the node(s) in the smallest vertex cut has to be in every CDS and thus will be obviously the first to deplete if all nodes have the same initial energy).

5.2. Results

1) Setting the parameters
In order to see how the different parts of the delay influence the construction of the CDSs, we try several combinations of the parameters.

In order to evaluate the best value for k (the exponent in formula 2) we made experiments for different values of k ($k \in \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 32, 64, 128, 256\}$). The energy $E_{init}(i)$ is set to 16000 for each sensor. A new CDS is computed every 116 gatherings (see section 5.2.2). The values for $G_R(11, 11)$ and $G_{R\sqrt{2}}(11, 11)$ are means of 10 runs. Results are presented in Fig. 1.

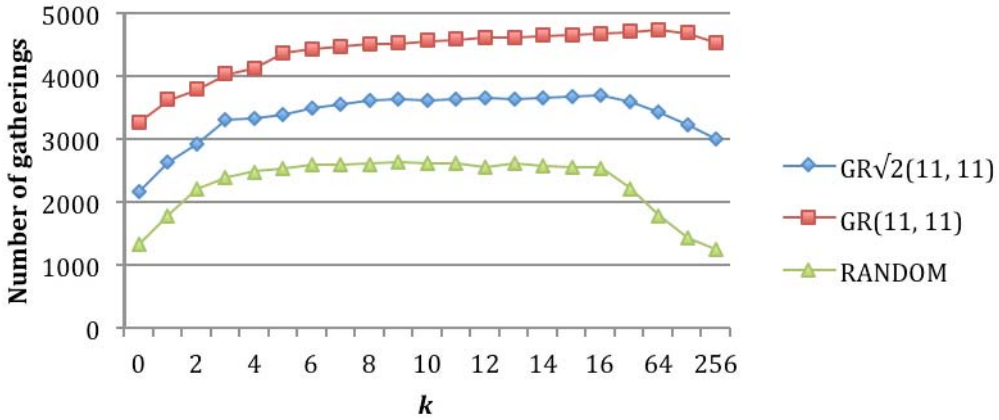

Fig. 1. Number of gatherings regarding the value of coefficient k.

Regarding these results and in order to save time computation when the algorithm will be deployed on real sensors, we chose k between 6 and 8.

Next step consists in fixing the parameter *MXD* related to maximum latency expected. Fig. 2 shows how the number of gatherings, the depth of the CDSs and the maximum effective latency to build a CDS vary regarding the value of *MXD*. In these simulation, $E_{init}(i)$ is set to 8000 for each sensor.

As expected, when $MXD = 0$, the depth of the CDSs is equal to 10 since with this value, DSVB constructs a BFS tree and in $G_R(11, 11)$, the eccentricity of the sink is 10.

The chose of *MXD* is done making a tradeoff between the efficiency of the algorithm (number of gatherings) and the latency to built the backbone or the depth of the CDS. Increasing *MXD* leads to a larger number of gatherings, but also a larger latency and a larger depth of the CDS (which implies that the node have to be awake longer to compute CDS and do gatherings). In the rest of the paper, we chose *MXD* = 4000, which correspond to an effective latency lower than 20 ms to build a CDS.

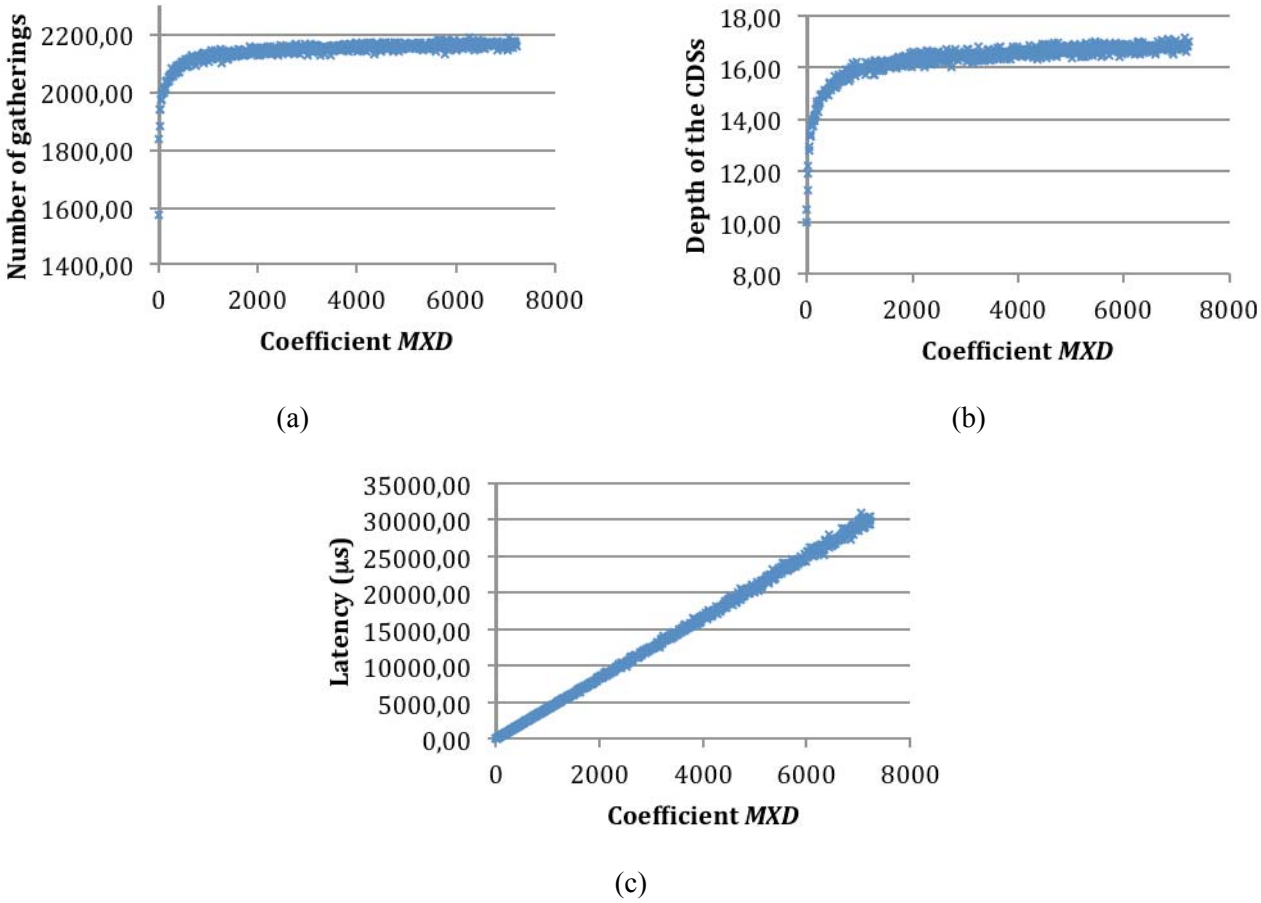

Fig. 2. Number of gatherings, depth and latency regarding the coefficient *MXD*.

2) Frequency of CDS computation

The easiest way to implement our algorithm is to compute new CDS regularly (that is what we did in the previous paragraph by computing a new CDS every 116 gatherings). In order to know if this assumption is acceptable, we compute, given a set of CDSs the optimal way to use them (i.e. how many gatherings should be done with each CDS. For a given set $C=(C_1, C_2, \ldots, C_D)$ of CDSs, let α_j represent the number of time the CDS C_j is used in a solution. We set a variable b_{ij} equal to 1 if the node i belong to the CDS C_j and 0 otherwise. We note $d(i)$ the degree of a vertex i in G and $N(i)$ the set of neighbors of i. The linear program given by (2), (3), and (4) gives the optimal way to use this set of CDSs:

$$\max z = \sum_j \alpha_j \tag{2}$$

$$\forall i \notin N(s), \quad 2 \cdot D \cdot (1 + d(i)) + \sum_{j=1}^{D} \alpha_i (1 + b_{ij} d(i)) \leq E_{init}(i) \tag{3}$$

$$\forall i \in N(s), \quad 2 \cdot D \cdot (1 + d(i)) + \sum_{j=1}^{D} \alpha_i b_{ij} d(i) \leq E_{init}(i) \tag{4}$$

Equation (3) and (4) ensures that for each node, the energy used to build the D CDSs and to do the gatherings is lower or equal to the initial energy. Each node needs an amount of $2e \cdot (1+d(i))$ of energy to build a CDS (each node sends 2 message (ACK and INV) and consequently receives $2d(i)$ messages). For each gathering, each node but the sink sends one message and each node in the current CDS receives $d(i)$ messages (one from every neighbor), the neighbors of the sink receiving only $d(i)$-1 messages.

For a set of networks, we run DSVB computing new CDSs regularly. We then compute the optimal number of gathering to do with those CDSs in order to maximize the lifetime of the network. Fig. 3 presents the number of gatherings collected at the sink ($E_{init}(i)$ = 16000) when:
- Every CDS is used for 116 gatherings, (regular).
- The same set of CDS is used optimally (optimal).

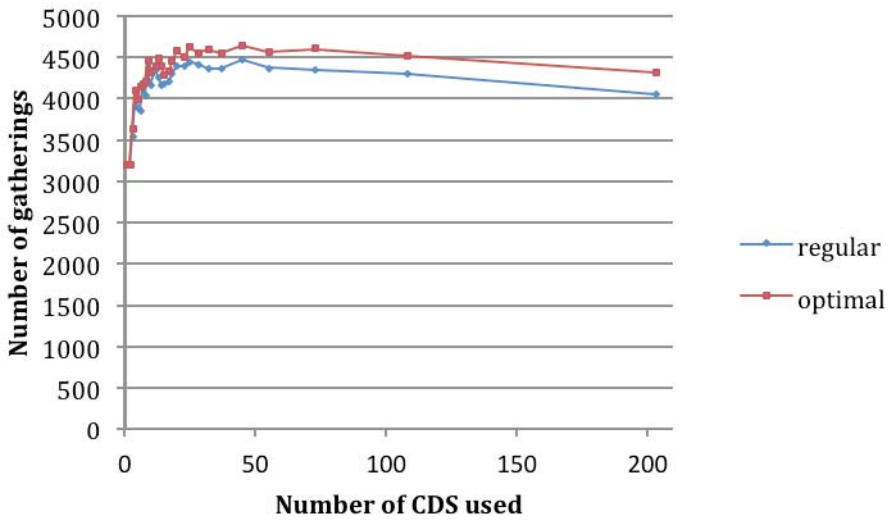

Fig. 3. Ratio of gatherings collected at the sink regarding the frequency of backbone computation for different initial energy.

The lost due to the regular computation of the CDSs is always below 7 % of the optimal value. Consequently, in the rest of the paper, we will suppose that the CDSs are regularly computed which is obviously much easier to implement.

Fig. 4 presents how the initial energy and the frequency of the CDS computations influence the ratio of gatherings achieved (number of gatherings / initial energy). We give average values obtained considering 16 runs on $G_{R\sqrt{2}}(11, 11)$.

As expected, when the number of gatherings per backbone is higher than the number of gathering collected (low frequency), the ratio is constant and corresponds to the use of a single backbone. On the contrary, computing many backbones has a cost, which becomes excessive when the frequency is too high. Furtherer experiments show that for an initial energy of 16000, the optimal frequency is to compute one CDS every 116 gatherings.

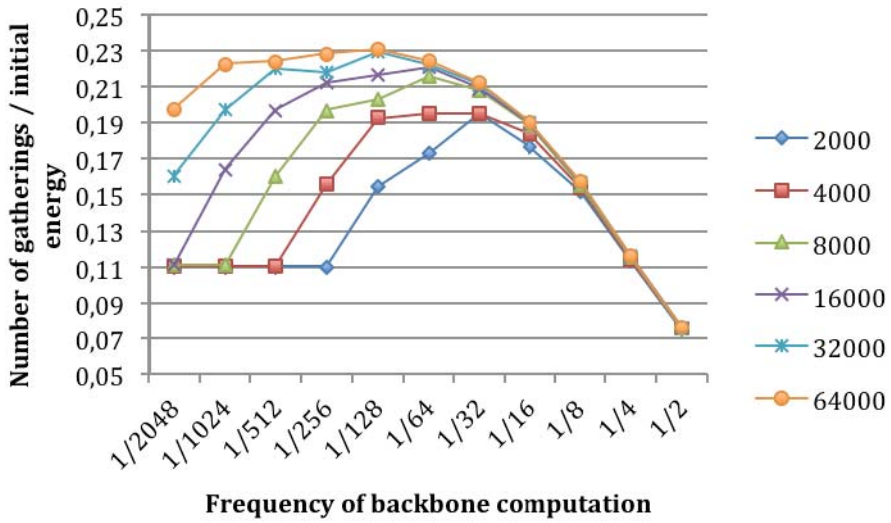

Fig. 4. Ratio of gatherings collected at the sink regarding the frequency of backbone computation for different initial energy.

3) Efficiency of DSVB

In order to know how our algorithm performs, we compute lower and upper bounds for the number of gathering that may be achieved.

The number of gathering made using a single CDS (for example, found by a BFS) C gives a lower bound. In this case, for a node i in the CDS, the energy used for each gathering is $(d(i)+1).e$: this node receives messages from all its neighbors (cost $d(i).e$) and transmits its aggregated data to its father (cost e). Using this strategy, the maximum number of gatherings allowed is $\min_{i \in C}(E_{init}(i)/(d(i)+1))$. We thus have to find a CDS C such that $\max_{i \in C}(d(i))$ is minimum.

To compute an upper bound for the number of gatherings we extend the idea proposed in [10] to our model. For each vertex-cut S that disconnect G (for convenience, we will suppose that S does not contain any leaf of G), we need, for each gathering, to use at least one of its vertices. The energy used by a node i for a gathering is $(d(i)+1).e$ if i is in a CDS and e else. So if x_i is the number of CDSs a node i belong to, for each node i we must have

$$(d(i)+1)x_i + \sum_{j \neq i} x_j \leq E_{init}(i) \tag{5}$$

The number z of gathering that can be supported by the set S is then: $z = \Sigma_i x_i$. In order to obtain an upper bound, we can solve the relaxation of this linear program. If every constraint is tight ($x_i = (E_{init}(i) - z)/d(i)$) it leads to:

$$z = \sum_{i \in S} \frac{E_{init}(i)}{d(i)\left(1 + \sum_{j \in S} \frac{1}{d(j)}\right)} \tag{6}$$

Since it is possible to find a solution of the dual having the same value (set $y_l = 1/(d(i)(1+\Sigma_j(1/d(j)))$ for all l in S), this solution is optimal.

Finding the set S of vertices disconnecting G such that (6) is minimized gives an upper bound for the maximum number of gatherings. For example, for a network $G_R(p, q)$, a set S achieving the minimum number of gatherings is composed of the two neighbors of a corner.

In order to evaluate the efficiency of our algorithm, Table 1 shows the number of gatherings collected using DSVB compared to the use of a single CDS, to the use of a random delay instead of a delay depending on the energy, and to an upper bound. A new CDS is computed every 116 gatherings, $E_{init}(i) = 16000$ for every node.

Table 1. Efficiency of DSV.

Network	Number of gatherings achieved			
	Single CDS	***Random Delay***	***DSVB***	***Upper bound***
$G_R(11, 11)$	3200	3285	4510	6400
$G_{R½}(11, 11)$	1776	2100	3602	5508
Random graphs	1108	1301	2574	3526

Although the actual result using a single CDS may be see as a feasible lower bound, the upper bound may be overestimated (because there are not feasible solution for this value), which suggests a better performance of our algorithm.

4) "real" lifetime
Lifetime of WSN is not a well-defined notion [11]. Especially in the case of networks where the measures made by the sensors are redundant, one may accept a reasonable ratio of loss of messages (i.e., lifetime is not equal with the guaranteed message transfer). This logically influences the lifetime of the network. We have seen that in usual grid networks, the main (theoretical) problem occurs for the corners since they are only connected to the rest of the network by 2 nodes of degree 3. Nevertheless, if we accept a loss rate of 4% those nodes are not any more limiting as soon as the grid has more than 100 nodes. Fig. 5. shows how the number of transmitted measurements (i.e. connected nodes) decreases regarding the number of gathering for two representatives runs on $G_R(11, 11)$.

We fix a threshold of 90 % such that a new backbone is computed either if 100 gatherings are done or if less than 90 % of data are collected. For 16 runs, the first failure occurs in mean at the gathering number 2215, whereas we achieve 2341 gathering collecting more than 90 % of data. For random networks, the lifetime increases of 10 % with a threshold of 95 % and 13 % with a threshold of 90 %.

6. Conclusions

In this paper, we presented a distributed algorithm to collect data in a Wireless Sensor Network. Easy to implement, it computes several Connected Dominating Sets sharing out the use of the sensors for the transmissions. Simulations have shown a significant improve of the network's lifetime. One of the next steps is to validate our approach on real sensors. In several applications, measures are redundant and some algorithms exist to optimize the energy used for measuring. In a future work, we will try to combine our technique with an efficient k-coverage of the network. We aim to save energy globally for both measuring and communicating.

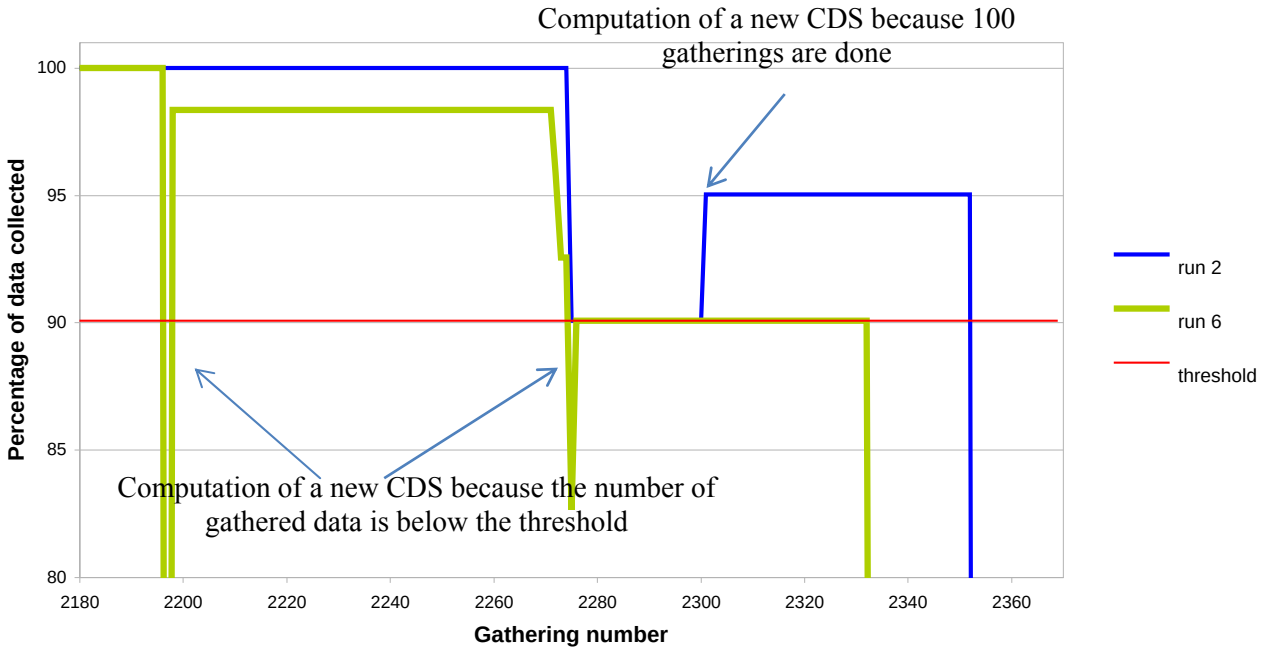

Fig. 5. Percentage of data effectively collected regarding the number of gatherings on $G_R(11, 11)$.

Acknowledgements

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References

[1]. Z. Wang and J. Zhang, *Sensor and Ad Hoc Networks* : Theoretical and Algorithmic Aspects, Makki S. K., Li X.-Y., Pissinou N., Makki S., Karimi M., and Makki K., *Springer*, 2008, pp. 147-160.

[2]. R. C. Shah, D. Petrovic, and J. M. Rabaey, Handbook of Sensor Networks: Compact Wireless and Wired Sensing Systems, M. Ilyas and I. Mahgoub, *CRC Press LLC*, 2005.

[3]. S. Guha and S. Khuller, Approximation Algorithms for Connected Dominating Sets, *Algorithmica*, Vol. 20, Apr. 1998, pp. 374–387.

[4]. C. Adjih, P. Jacquet, and L. Viennot, Computing Connected Dominated Sets with Multipoint Relays, *Adhoc & Sensor Wireless Networks*, Vol. 1, No. 1, 2004, pp. 27-39.

[5]. K. Islam, S. G. Akl, and H. Meijer, A Constant Factor Localized Algorithm for Computing Connected Dominating Sets in Wireless Sensor Networks, in *Proceedings of the International Conference on Parallel and Distributed Systems*, 2008, pp. 559-566.

[6]. B. L. Hartnell and D. F. Rall, Connected domatic number in planar graphs. [Online]. Available: http://dml.cz/dmlcz/127636 [Accessed: 02-18-2011].

[7]. K. Islam, S. Akl, and H. Meijer, Distributed Generation of a Family of Connected Dominating Sets in Wireless Sensor Networks, in *Distributed Computing in Sensor Systems*, Vol. 5516, B. Krishnamachari, S. Suri, W. Heinzelman, and U. Mitra, Ed., *Springer* Berlin / Heidelberg, 2009, pp. 343-355.

[8]. B. Chen, K. Jamieson, H. Balakrishnan, and R. Morris, Span: an energy-efficient coordination algorithm for topology maintenance in ad hoc wireless networks, *Wireless Networks*, Vol. 8, Sep. 2002, pp. 481–494.

[9]. T. Val, A. Van Den Bossche, and E. Campo, Technologie ZigBee / 802. 15. 4 - Protocoles, topologies et domaines d'application, *Techniques de l'ingénieur*, Vol. 7508, May. 2008.

[10]. E. Ben Hamida, G. Chelius, and J. M. Gorce, Impact of the Physical Layer Modeling on the Accuracy and Scalability of Wireless Network Simulation, *Simulation*, Vol. 85, No. 9, 2009, pp. 574 -588.

[11].J. Champ, C. Saad, and A.-E. Baert, Lifetime in Wireless Sensor Networks, presented at the *CISIS: International Conference on Complex, Intelligent, and Software Intensive Systems*, Fukuoka, Japan, 2009.

Sensors & Transducers Journal

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Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because of it is a peer reviewed international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per year by International Frequency Sensor Association (IFSA). In additional, some special sponsored and conference issues published annually. *Sensors & Transducers Journal* is indexed and abstracted very quickly by Chemical Abstracts, IndexCopernicus Journals Master List, Open J-Gate, Google Scholar, etc. Since 2011 the journal is covered and indexed (including a Scopus, Embase, Engineering Village and Reaxys) in Elsevier products.

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Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

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- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
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