



HAL
open science

Approche décentralisée de sélection de noeuds appliquée à la surveillance photovoltaïque

Tatiana Aljamous, Joseph Asmar, Carol Habib, Nathalie Mitton, Jad Nassar

► **To cite this version:**

Tatiana Aljamous, Joseph Asmar, Carol Habib, Nathalie Mitton, Jad Nassar. Approche décentralisée de sélection de noeuds appliquée à la surveillance photovoltaïque. CORES 2026 - 11èmes Rencontres Francophones sur la Conception de Protocoles, l'Évaluation de Performances et l'Expérimentation des Réseaux de Communication, Jun 2026, Mandelieu-la-Napoule, France. <hal-05603520>

HAL Id: hal-05603520

<https://hal.science/hal-05603520v1>

Submitted on 27 Apr 2026

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons CC BY 4.0 - Attribution - International License

Approche décentralisée de sélection de nœuds appliquée à la surveillance photovoltaïque

Tatiana Aljamous^{1,2} et Joseph Asmar² et Carol Habib¹ et Nathalie Mitton¹ et Jad Nassar²

¹*Inria, France*

²*TICKET Lab, Antonine University, Lebanon*

Les panneaux photovoltaïques sont largement utilisés dans les systèmes modernes de gestion de l'énergie, en tant que source d'énergie renouvelable. Cependant, l'intermittence de leur production nécessite une surveillance de la production énergétique, afin d'en assurer une performance efficace. Les réseaux de capteurs sans fils offrent une solution efficace pour la surveillance en temps réel des panneaux photovoltaïque, facilitant l'analyse et la détection des pannes. Malgré leurs avantages, les réseaux de capteurs sont confrontés à divers défis affectant leur efficacité et leurs performances. Dans les applications de surveillance des panneaux solaires, la similarité des performances des panneaux entraîne des transmissions de données similaires entre les nœuds capteurs. Ces transmissions redondantes engendrent une surcharge de communication inutile et une augmentation de la consommation énergétique, affectant ainsi la durée de vie globale et l'efficacité du réseau. Ce travail présente une approche décentralisée de sélection des nœuds capteurs, qui consiste à choisir un sous-ensemble de nœuds pour la transmission. Cette approche repose sur la combinaison de 4 métriques, afin d'obtenir pour chaque nœud, un score de sélection, reflétant son éligibilité dans le processus de transmission. Les résultats montrent une réduction de la consommation d'énergie, ainsi qu'une amélioration en termes de délai et de fiabilité.

Mots-clés : Wireless sensor networks, Decentralized decision making, Weighted sum, Node selection

1 Introduction

Traditional electrical systems are evolving in response to technological advancements, with solar panels becoming a widely adopted renewable energy source. However, their performance is highly dependent on meteorological and environmental conditions, leading to a variability in energy output, which necessitates the need for continuous monitoring. Wireless Sensor Networks (WSN) have been widely used for real-time monitoring in various environments, including solar energy systems. Deploying sensor nodes on individual solar modules enables per-panel productivity monitoring, and the early detection of potential issues that could disrupt the energy infrastructure. In our scenario, we consider a WSN deployed for monitoring solar panels, by periodically collecting and transmitting module-based data information, such as the current and voltage produced, the module temperature and the dust accumulation, through a multihop communication to the destination. However, data transmission in such a large-scale network has a significant impact in reducing its lifespan and negatively affecting its performance, specially with the limited energy resources of the nodes, a problem that is even more critical in the context of Green IoT. Since solar modules under normal conditions operate similarly, this leads to the periodic collection and transmission of repetitive information, which results in unnecessary network overhead. To reduce the amount of data transmission in the network, one of the solutions is to select the most relevant nodes for transmission, rather than requiring all nodes in the network to transmit data periodically. One of the node selection strategies is to rely on centralized decision making, such as in [KHB⁺20] and [SS21], where a central entity determines the most relevant nodes for data transmission. Their selection was based primarily on correlation between the nodes, as well as the energy level of the node. However, such centralized selection strategies call for frequent

network-wide information exchange, which imposes excessive communication overhead. To overcome these limitations, a decentralized node selection strategy can be adopted. A scoring based routing protocol has been introduced in [UACR23], where each node is ranked based on the combination of different metrics, including energy level or ETX. Although this approach enables decentralized selection, it still necessitates inter-node information exchanges to coordinate decisions and share selection outcomes, thereby increasing packet transmission overhead. This leads to the following research question: *Can a sensor node autonomously decide whether to transmit or not using only local information, without coordinating with neighboring nodes? Can this approach reduce energy consumption, minimize overall transmissions, extend network lifetime, and still ensure reliable communication to the destination?* In this paper, we analyze the combination of different metrics for a self node selection in the context of a multihop WSN for monitoring solar panels. A score is computed prior to packet transmission, and the transmission decision is determined by comparing the computed score to a predefined threshold. This approach allows us to evaluate the impact of this selection on network performance and energy consumption.

2 Network Architecture

Our architecture is based on a clustered environment, where each solar panel is equipped with one sensor node to collect data. We suppose then that N sensor nodes are deployed within each cluster. Each sensor node periodically collects module level parameters, such as the current and the voltage being produced, the dust accumulation as well as the module temperature, and forwards them towards the cluster head via a multihop transmission.

3 The proposed node selection approach

In this section, we discuss how a node is able to decide whether to transmit or not, by considering the combination of different parameters.

3.1 Decision making process

Before making a decision, a node must first compute a score that reflects its transmission eligibility, emphasizing its ability to successfully complete a data transmission. The score is calculated using the weighted sum method, that consists of combining multiple objectives by assigning a weight to each one, to reflect its importance in the overall score calculation [PM22, GMU22]. The weighted sum function is defined as follows: $Score = \sum_{i=1}^n w_i s_i$, where n represents the number of decision making metrics, w_i represents the weight associated to the i^{th} metric, and s_i represents the value of the i^{th} metric. The metrics that we considered in our study will be further explained in section 3.2. After calculating the score, each node will compare it to a specific threshold in order to decide if it transmits its own data or not. The threshold value represents the minimum eligibility score for transmission, as determined by the combined strength of the weighted metrics, and is statically configured in this work. In that manner, each node is able to make a local decision regarding its participation in the transmission process, without requiring information exchange or decision coordination with neighboring nodes.

3.2 Decision making parameters

- **Node Energy Level:** In order for a node to select itself as a transmitter, it must have a sufficient energy level. This metric represents the remaining energy fraction of the sensor node and is defined as the ratio of the remaining energy level of the node to its initial energy level.
- **Silence Period:** In order for a node to select itself as a transmitter, low recent transmission activity is preferred. This metric quantifies how recently a node last transmitted, with respect to the current time, penalizing recent consecutive transmissions while promoting fairness among the nodes. To enable its combination with the other metrics in the selection function, it is normalized to the range $[0,1]$, with the use of MinMax normalization as follows: $TX = \frac{(t-t_{last})-P}{t-P}$, where t is the current time, t_{last} is the node last transmission time, and P represents a transmission period. Since nodes periodically transmit, the minimum possible silence duration at evaluation time corresponds to one period P .

- **Retransmission Ratio:** In order for a node to select itself as a transmitter, it must evaluate its link quality with its next hop. If a node exhibits a high number of retransmissions, then it must not be selected. This metric is used for this evaluation, and is calculated as the ratio between `RetransmittedPackets`, the number of all retransmission attempts done by the node, including retransmission of forwarded packets, and `TotalTransmittedPackets`, the number of all transmission attempts completed by the node, including transmissions of locally originated packets, retransmissions, and forwarded packets.
- **Relay Factor:** In order for a node to select itself as a transmitter, it must not be heavily used as a relay node, avoiding additional transmission overhead. This metric is used for this evaluation, and is calculated as the ratio between `ForwardedPackets`, the number of packets received from other sensor nodes, and forwarded by the node towards the CH, and `TotalTransmittedPackets`, the number of all transmissions attempted by the node, including transmissions of locally originated packets, and forwarded packets.

4 Simulation and Results

Simulations were performed using OMNeT++ simulator with the INET framework to evaluate the proposed approach. The simulated WSN consists of 15 sensor nodes, communicating with a cluster head via a multihop transmission. Data transmission occurs every 300s, over a total simulation time of 5h (18000s), using the IEEE 802.15.4, and DSDV routing protocol. The transmission decision is made periodically at each transmission interval, where each sensor node computes its score to assess its eligibility for transmission. During the first decision making period, nodes have very close energy levels and similar values for the remaining metrics, leading to nearly equivalent scores. To address this, we introduced a randomized mechanism where each node generates a random value in the interval $[0,1]$, and then transmits if the value is lower than a predefined probability p . We consider two scenarios: a baseline scenario in which all sensor nodes periodically transmit data, and a selective transmission scenario in which the proposed node selection mechanism is applied. We used an equal weights distribution for all the metrics to maintain a balanced contribution among them, without prioritization. We compared both scenarios using the following performance metrics: packet delivery ratio (PDR), end-to-end delay and energy consumption.

In the baseline scenario, each node performs 60 transmissions during one simulation, leading to a total of 900 packets transmitted across the network, the observed PDR value is around 83.71%. After applying the selection approach, we can see that the PDR has improved, reaching 94.31% and 85.31% for threshold values of 0.7 and 0.5, respectively, where the threshold denotes the minimum eligibility score a node must have to transmit its data.

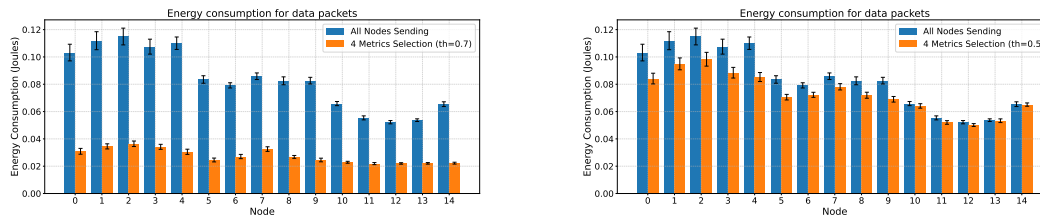


FIGURE 1: Energy Consumption

This improvement is not solely due to traffic reduction during each decision-making period, but rather to the proposed metric-driven scoring approach, which evaluates the node's retransmission risk together with additional performance metrics to guide the selection process. However, the improvement is smaller for a threshold of 0.5, since this value allows a larger number of nodes to be selected compared to 0.7, thereby increasing channel contention. Regarding the observed delay, the proposed selection mechanism reduces latency compared to the baseline scenario. It decreases to 101.472 ms and 181.380 ms for thresh-

old values of 0.7 and 0.5, respectively, in comparison to the baseline delay experienced, where all nodes transmit, including both the nearest and farthest to the destination, thereby increasing queuing time and retransmissions.

Using INET’s energy model, the energy consumption for data transmission is calculated as $\Delta t \times P_{\text{cons}}$, where P_{cons} is the power consumption, and Δt is the time interval since the last energy update. As illustrated in Figure 1, the energy consumed by the sensor nodes decreases when the selection mechanism is applied, primarily due to the reduction in the number of transmissions performed by each node, with higher energy usage recorded in nodes acting as relay node forwarding traffic. Moreover, a difference can be observed between the two threshold values: a threshold of 0.5 permits more transmissions compared to a threshold of 0.7, resulting in higher energy consumption.

Figure 2 illustrates the selected nodes and their corresponding scores over five consecutive periods, highlighting how both the scores and the selection decisions evolve over time. As observed, the selection dynamically alternates between nodes, introducing a load-balancing effect. The metric related to the silence period contributes to score variation and may either increase or decrease a node’s priority. However, it is not the primary determining factor. In successive periods, the same node may still be selected when its link quality and relay metrics remain strong. For example, Node 1 is not selected in consecutive runs despite being silent, due to lower values in its remaining metrics. However in a later period, it becomes selected even though those metrics remain the same, because the increase in its silence duration raises its composite score. Conversely, Node 13 is selected in consecutive periods owing to its consistently favorable link and relay conditions. These observations shows that the selection process is dynamically driven by the combined state metrics of each node.

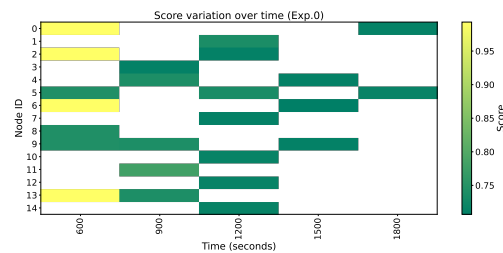


FIGURE 2: Node score variation

5 Conclusion and Future Work

In this paper, we have presented our first approach of a decentralized sensor node selection in a WSN applied for monitoring solar panels. The proposed approach combines four different metrics, to compute a score for each sensor node, enabling autonomous decision-making without inter-node coordination. The results show that this decentralized method was able to effectively enhance the network performance, and to reduce the energy consumed for data transmission. For future works, we will focus on implementing this method in a coordination based system to compare autonomous and coordinated decision-making. This analysis will allow us to evaluate the impact of the coordination in terms of energy efficiency, scalability, and overall network performance. Additionally, we will work on considering the variability of the data being collected to mitigate the loss of important information, while accounting as well for a dynamic selection threshold value.

References

- [GMU22] Atonu Ghosh, Sudip Misra, and Venkanna Udutalappally. Multiobjective optimization and sensor correlation framework for iot data validation. *IEEE Sensors Journal*, 22(23):23581–23589, 2022.
- [KHB⁺20] Manel Kortas, Oussama Habachi, Ammar Bouallegue, Vahid Meghdadi, Tahar Ezzedine, and Jean Pierre Cances. The energy-aware matrix completion-based data gathering scheme for wireless sensor networks. *IEEE Access*, 8:30772–30788, 2020.
- [PM22] Sarwesh P and Aneesh Mathew. Cross layer design with weighted sum approach for extending device sustainability in smart cities. *Sustainable Cities and Society*, 77:103478, 2022.

Approche décentralisée de sélection de nœuds appliquée à la surveillance photovoltaïque

- [SS21] Manjeet Singh and Surender Kumar Soni. Network lifetime enhancement of WSNs using correlation model and node selection algorithm. Ad Hoc Networks, 114:102441, 2021.
- [UACR23] Nilabar Nisha U, Manikandan A, Venkataramanan C, and Dhanapal R. A score based link delay aware routing protocol to improve energy optimization in wireless sensor network. Journal of Engineering Research, 11(4):404–413, 2023.