Amelioration of MPR by a Backbone-Based Broadcasting Algorithm for WSNs

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Abstract— **Wireless Sensor Networks (WSNs) are sets of many sensors that gather data and collaborate together. So, the procedures of broadcast or multicast are more important than traditional point-to-point communication in computer network. This paper focuses on broadcasting in structured WSNs. In such a kind, the procedure of network communications is easier than in unstructured WSNs. Thus, we will make an overview of MultiPoint Relay: (MPR) to show its weakness. Then, we will define a cluster-based architecture for WSNs which is constructed using MPR. Next, we will provide a new broadcast algorithm based on the previous cluster architecture and called 3B: Backbone Based Broadcasting. By the end, an illustration of 3B shows that it minimizes the energy consumption for accomplishing broadcast compared to MPR.**

Keywords-component; Wireless sensor networks; backbone; broadcasting; MPR; energy aware.

I. INTRODUCTION

WSNs have attracted the attention of the research community during the last few years, due to their low cost, their huge capabilities of collecting data, and their various fields of applications i.e. health care, surveillance, environment, military [1,2]. The most important disadvantage of WSN is their limit in energy, so many methods, algorithms and protocols were introduced and developed taking in consideration this constraint. Since WSN are considered ad-hoc networks with other characteristics, many algorithms and methods of ad-hoc networks could be reused and reconfigured according to the WSN specificity.

Broadcasting is usually used in WSNs. So, many methods and broadcasting heuristics were applied in unstructured WSNs, especially algorithms based on relaying like MPR [3] or RDS-MPR [4]. These methods decrease the consumed energy and avoid broadcast storm problem caused by flooding. For structured WSNs, several cluster-based architectures have been proposed recently. They transform usual WSNs to WSNs composed by a set of clusters connected by a backbone [16, 17]. To broadcast a packet of data over cluster-based WSNs, the data will be first sent in the backbone, then in intra-clusters. In this paper we try to combine the two types of broadcasting methods. Thus, we define a new algorithm which is executed in two stages: It begins with constructing the backbone using MPR. Then, it ends by using this backbone to broadcast packets from sink node.

The remainder of this paper is organized as follows: section 2 outlines the most known broadcasting methods and algorithms which have been proposed recently over unstructured and structured WSNs. In section 3, we make an overview of MPR heuristics proposed in [3], and we illustrate the weaknesses of this method in some kinds of WSNs. In section 4, we define a new cluster-based architecture for WSNs and we carry out an example of application of our new clustering heuristic over a sensor networks. In addition, we provide our new broadcasting algorithm. The illustration of this new algorithm show that it minimizes the energy consumption to accomplish broadcasting compared to MPR.

II. RELATED WORK

A. Relay-based broadcasting.

These heuristics are essentially based on relaying approaches such as MPR [3] which is firstly proposed by Qayyum and al. This method treats broadcasting from the sink node to all nodes in network and it is based on levels i.e. the neighbors of sink are considered as level 1 nodes. The neighbors of level 1 node are considered as level 2 nodes. So, the broadcasting is done by levels and every time we choose the best nodes to relay. These nodes are a subset of a unique level of nodes. The selection of relaying nodes is done according to many factors.

The aim of MPR method is to minimize the redundant packets and the cost of communication. Next, a new method called DS-MPR [10, 12] is defined basing on searching a dominated connecting set with the use of MPR.

Some other researchers define new methods that aim to apply MPR in realistic environment as shown in [7, 8] aiming to maximize the accessibility of the original heuristic. In the same way, there is a proposition of DS-MPR in a realistic environment which is called RDS-MPR [4]. We can also talk about heuristics aiming to reduce the size of dominated connecting sets [11], or defining an extension of MPR in order to facilitate the determination of dominated connecting sets. In [9], the authors propose a broadcasting protocols MPR-based

called gateways multipoint relays GMPR. This method can minimize the number of redundant messages.

B. *Cluster-based broadcasting.*

Recently, there are a lot of proposed cluster-based architectures for WSNs. In [15], the authors propose an organization of WSNs that takes into consideration node energy. In [6, 13, and 15], the authors suggest a cluster based broadcasting for dynamic sensor networks. The architecture helps to carry out broadcast and multicast protocols with a low complexity compared to the existence. The proposed protocols can take into consideration the dynamic behavior of WSNs because it manages the apparition and the absence of new nodes in the field of coverage.

In [6], the authors present static and dynamic cluster broadcasting for mobile ad hoc network. This method can be considered in dynamic WSNs since WSN is a sub type of ad hoc networks. In [14], a dynamic cluster based object tracking algorithm is proposed. The algorithm wakes up or put the sensing node into sleeping mode, though predicting the moving track of the target and reduces the number of tracking nodes in order to minimize network energy consumption.

In fact, the cluster based broadcasting or multicasting method aims to organize WSNs into set of clusters. Clusters are linked to each other by special nodes called getaways, and every cluster has a special node called cluster head. In such network, we have found a node called root which is the sink node in most cases or the first sender node of the packet of data to be broadcasted. The backbone in such network is composed by root, cluster head, and getaways.

III. MPR: OVERVIEW

A. *MPR heurestic*

Firstly proposed by Qayyum and al. this method treats broadcasting from the sink node to all nodes in network and it is based on levels i.e. the neighbors of sink are considered as level one nodes, the neighbors of level one nodes are considered as level two nodes. So, the broadcasting is done by levels and every time we choose the best nodes to relay. These nodes are a subset of unique level nodes. The selection of relaying nodes is done according to many factors. The aim of MPR method is to minimize the redundant packets and the cost of communication.

B. *Energy model*

In [15], the authors define an energetic model to compute the consumed energy during a reception and during a sending, bellow this model is given:

- Energy consumption (1) for sending a message :

$$t_i = s.(\alpha + \beta.d^2) \quad (1)$$

Where:

$\alpha = 50nj/b$ and $\beta = 0.1nj/b/m^2$

s : size of message (b)

d: transmission distance (m)

- Energy consumption (2) for receiving a message :

$$v_i = s.\gamma \quad (2)$$

Where:

$\gamma = 50nj/b$

s : size of message (b)

C. *MPR weakness*

In this section we try to use to the famous network used in [3] with some modification (figure 1).

After applying MPR in the network of figure 1, it will be transformed to the network of figure 2. Using the previous energy model the graph of figure 4 is given. We can conclude that links between nodes in the same level cause a lot of redundant receptions of the same packet sent from the sink node. This fact is induced by blue links. Without blue link the broadcasting task is accomplished with less amount of energy. Because, the cause of redundant receptions is eliminated. So, having links between nodes in the same level is a big source of energy losing.

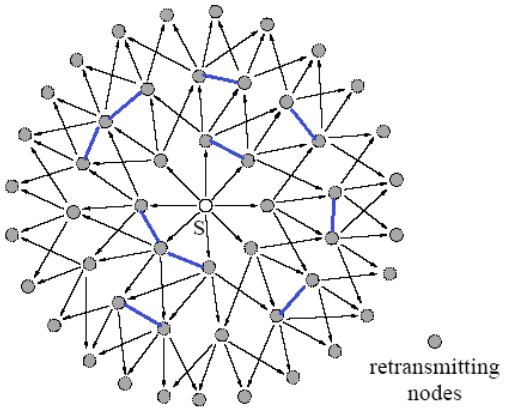

Figure 1. The famous network of MPR with some modification

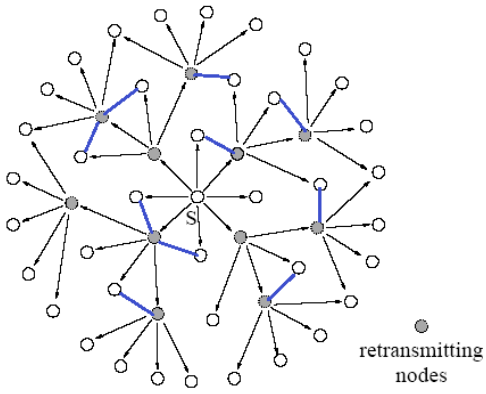

Figure 2. The network of figure1 after applying MPR

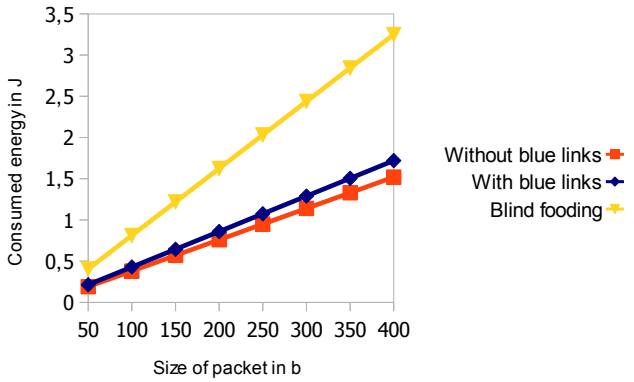

Figure 3. Comparison of consumed energy to accomplish broadcasting on the network of figure 1 (blind flooding) and figure2 (with blue links: after applying MPR) and in figure2 (without blue links: after applying MPR and deleting blue links).

IV. A NOVEL BROADCASTING ALGORITHM

In this section, we try to solve the problem caused by redundant receptions. So, we propose a novel cluster based architecture formed after the application of MPR over the network.

A. *Symbols and notation.*

A WSNs can be considered as a graph G (V, E), where the nodes constitute the set of vertex V and E the set of edges. An edge exists between two nodes A and B in this graph if a packet sent from A can be received at B or from B to A. In table I, we introduce the symbols used in this paper and their definitions.

TABLE I. SYMBOLS AND NOTATIONS

Symbol	Signification
G(V, E)	Graph connectivity where V is the set of vertex and E is the set of edges.
sink	Initial sender node
root	Id of initial sender node
Gc(Vc, Ec)	Clustered graph where Vc is the set of vertex and Ec is the set of edges.
ch	Id of cluster head
leaf	Id of a member in a cluster
Temp	Set of temporary cluster heads

B. *Cluster architecture .*

The cluster architecture construction is based on MPR. The sink node is called root. Every node chosen as a relay node by MPR will be a cluster head. Next, the rest of nodes will be leaves. If a leaf is connected to more than one cluster head it will choose the cluster head with maximum remaining energy to be linked and cut others links. Bellow the algorithm is defined. CC constructs Gc(Vc, Ec) according to G(V, E).

Algorithm1: CC: Clusters-Construction

1: id(sink) ← root
2: Vc← Vc U {root}
3: Vc←Vc U **MPR**(G)
4: **for all** node n in Vc\ {sink} **do**
5: id(n)←ch
6: **End for all**
7: Temp← Ø
8: **for all** node n **in** G\Gc **and** ch **in** Gc **do**
9: **If** (n,ch) ϵ G **then**
10: Temp← Temp U {ch}
11: **End if**
12: **Choose** ch **in** Temp having the maximum remaining energy
13: id(n)←leaf
14: Ec←Ec U (n,ch)
15: Temp← Ø
16: **End for all**

C. *3B: Backbone-Based Broadcasting.*

The broadcasting algorithm proposed is based on the previous cluster architecture. In fact, a packet sent from the root will reach all nodes in the network by the backbone which is consists of root and cluster heads.

Algorithm2: 3B: Backbone-Based Broadcasting

1: Applying CC to G.
2: The backbone is consists of root and cluster heads induced by CC.
3: Broadcast the packet form the root over the backbone.

In figure 4, an illustration of 3B is given. The algorithm begins with selecting cluster heads. In fact these cluster heads are nodes of the network selected by MPR to relay the packets sent initially from S. Next, an organization intra-cluster is done. Moreover, this organization helps to eliminate links which are the cause of receipting redundant packets.

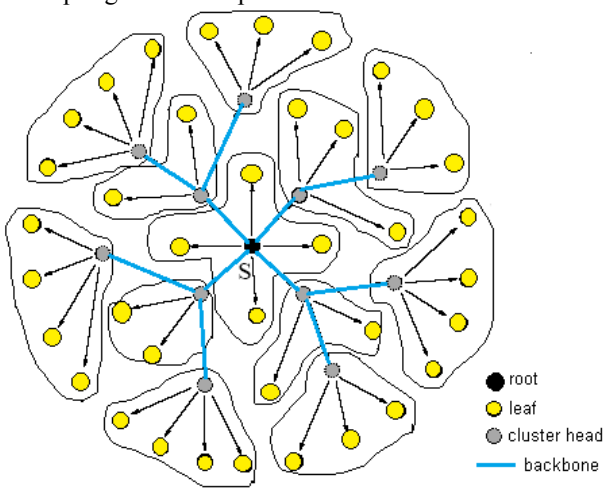

Figure 4. The network after applaying the clustering architecture and 3B

D. *Illustration*

The measurement of 3B performance to accomplish broadcasting shows that this new heuristic method makes an important improvement of MPR in term of energy which is a critical constraint in WSNs. In figure 5, there is a comparison between MPR and 3B for a network with 150 nodes and in figure 6 for a network with 250 nodes. These comparisons confirm the previous deduction. The amount of saved energy is between 17% and 22% according to the intra-level links in the graph of network. While, there are many intra-level connections, 3B provides a good performance and save more energy compared to MPR.

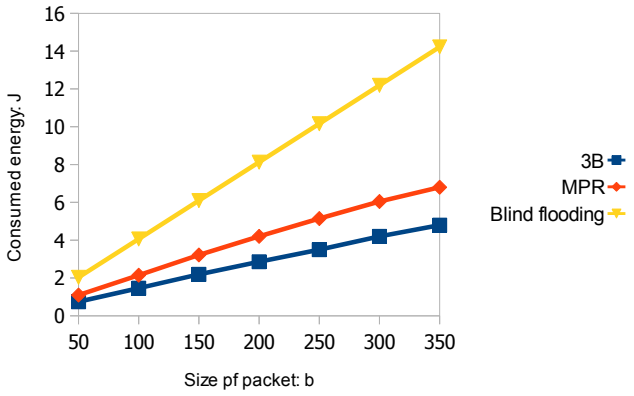

Figure 5. Comparison of consumed energy to accomplish broadcasting with 150 nodes

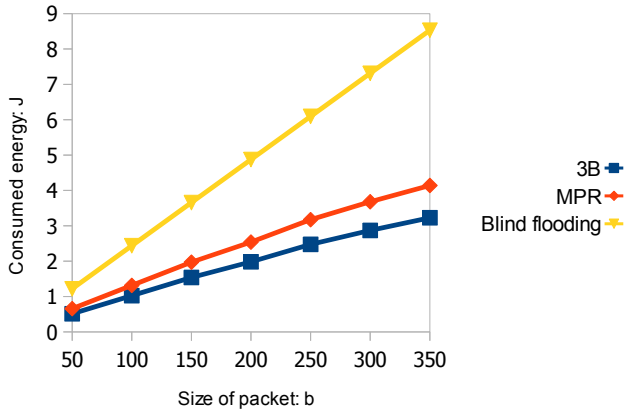

Figure 6. Comparison of consumed energy to accomplish broadcasting with 250 nodes

V. CONCLUSION

In this paper, a new broadcast heuristic is provided. This method is an improvement of MPR broadcasting in term of energy. In fact, it uses relay-based broadcast to select a backbone in the network. After, it eliminates the links between nodes able to be the source of losing energy. 3B makes an important amelioration of MPR in term of decreasing total consumed energy to accomplish broadcasting all over the network. Thus, 3B increases the network lifetime which is a critical criteria for WSNs.

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