RETRACTING ACT

The present paper, entitled ***PERFORMANCE EVALUATION OF WSN TOPOLOGY CONTROL ALGORITHMS THAT CAN BE USED IN SMART CITY CONCEPT*** *(authors:* ***Alexandru LAVRIC, Valentin POPA****) is a redundant publication (is submitted to more than one journal simultaneously, and is accepted and published at the same time). Therefore, the editors of the* ***ACTA TECHNICA CORVINIENSIS - Bulletin of Engineering*** *retracted the paper.*

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We notice that the main purpose of retractions is to correct the literature and ensure its integrity rather than to punish authors who misbehave. Retractions are used to alert readers to cases of redundant publication (i.e. when authors present the same data in several publications).

If you still want to read the present paper, entitled ***PERFORMANCE EVALUATION OF WSN TOPOLOGY CONTROL ALGORITHMS THAT CAN BE USED IN SMART CITY CONCEPT*** *(authors:* ***Alexandru LAVRIC, Valentin POPA****), having been informed of its status (retracted, redundant publication), it is available here.*

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PERFORMANCE EVALUATION OF WSN TOPOLOGY CONTROL ALGORITHMS THAT CAN BE USED IN SMART CITY CONCEPT

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Abstract: *Smart City concept is a topical issue. The main contribution of this paper is the performance evaluation of topology control algorithms that can be integrated in the Smart City concept. Thus, the following topology algorithms A3, A3 Coverage and EECDS are considered. The parameters evaluated are: the number of active nodes after the topology reduction algorithm is applied, the number of packets sent and the energy consumed for building the topology. From the results we conclude that the topology construction algorithm A3 provides the lowest number of active nodes and is recommended for use in the Smart City concept.*
Keywords: *large-scale, Smart City, WSN*

INTRODUCTION

The Smart City concept is a topical issue. The structure of a WSN network that can be integrated within such a concept is of large-scale type and has a number of characteristics such as in comprising of a very large number of nodes distributed over a wide geographical area (large-scale). Thus, to achieve a high level of performance the optimal network topology construction is an issue that should not be neglected. In the scientific literature, there are a number of specialized algorithms that reduce the initial network topology having as main purpose to increase the lifetime of WSN nodes which are often battery powered.

The main contribution of this paper is the performance level evaluation of the topology control algorithms that can be integrated in a Smart City. In the first part of the paper summarizes the main topology control algorithms which can be integrated in the concept of Smart City, meanwhile the second part presents the results obtained in simulations.

TOPOLOGY CONTROL ALGORITHMS

In this section are presented the most used topology control algorithms that can be integrated in the concept of Smart City. The topology control algorithms presented in this section are used to reduce the initial network topology and don't ensure its maintenance. Because the vast majority of WSN nodes within the concept of Smart City are fixed, we consider only control/construction algorithms to ensure the highest possible performance level.

CDS (Connected Dominating Set) Algorithm

The main goal of the CDS (Connected Dominating Set) algorithm involves determining a backbone type structure by selecting a subset of nodes that can guarantee and provide connectivity while allowing any other nodes in the WSN network to communicate directly with a backbone node. Thus, low delays, packet loss and network capacity are considerably increased.

The determination of the dominant nodes can be achieved by solving the mathematical CDS problem. A set of dominant nodes $D \subset V$ within a graph (V), assures that any other node that do not belong to this subset (D) must have a link with at least one node from the subset. A CDS topology control algorithm is proposed in [1]. The set of dominant components of a graph consists of a set of nodes whose neighbors, together with themselves constitute all nodes in the topology graph. As can be seen from Figure 1 the dominant nodes (N4, N7) are shown in blue and provide a backbone for the entire WSN network.

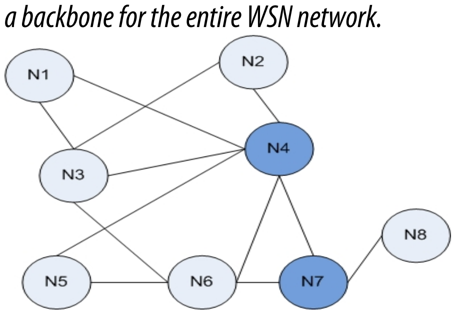

Figure 1. *The set of dominant nodes within the network topology*

The CDS graph can be constructed by determining, step by step, the tree topology which can be established by using Prim's algorithm [2]. Prim's algorithm determines the minimum tree topology for ensuring the connectivity condition within a graph. The construction process is based on a set of nodes that are part of the topology tree at time t. With time, the nodes within the set evaluate all adjacent nodes, in order to expand the tree graph. This process continues until all nodes in the graph are evaluated, some nodes are declared as active, while the other are set to sleep mode. Using this algorithm guarantees connectivity for a new node with at least one active node in the topology tree. However, each branch of the tree topology does not fulfill the condition of reliability. CDS algorithm starts from the sink node and ensures a high performance level for hierarchical based routing algorithms.

EECDS Algorithm (Energy Efficient CDS)

In an undirected graph, a set of MIS (Maximal Independent Set) nodes is also a dominating set (DS - Dominating Set). The vast majority of distributed algorithms first determine the MIS set that is then used to determine the CDS set of nodes. The papers [3], [4] propose, for the first time, a series of distributed algorithms that can be used for determining the CDS set of nodes by building UDG (UDG-Unit Disk Graphs). This algorithm consists of two steps: the first step involves the formation of the spanning tree graph that will then be used to determine the MIS set of nodes in the tree.

In [5] is presented an algorithm to ensure efficiency in terms of power consumption EECDS (Energy Efficient CDS) meanwhile determining the CDS nodes. The algorithm uses two steps to determine the CDS optimal set in terms of power consumption by using a coloring process. The algorithm starts with all the nodes colored in white. An initiator node is chosen that is part of the MIS set, it sends messages to neighboring nodes informing them that it's part of the MIS and changes his color to black. Upon receipt of these messages, each node neighbor turns gray. Gray colored nodes send notification messages to the neighboring nodes colored with white to announce their color change. Therefore, all white nodes receiving a message from a gray node are neighbors of a node that doesn't belong to the MIS set. These nodes are then colored to black. Thus, a node sends a request message to all neighboring nodes to know their status. If it doesn't receive a response from a black node becomes himself a black initiator node and the process is resumed. The second part of the EECDS algorithm, is the formation of the CDS by using the nodes that don't belong to the MIS set [6].

A3 Algorithm

In terms of routing protocol in order to achieve a high level of performance the CDS set must contain a low number of nodes, so the retransmission of packets in the network can be achieved with a minimum number of hops and hence a much lower energy consumption.

Therefore Wightman PM in [7] proposed a topology construction algorithm which determines the approximate CDS sub-optimal set of nodes. The A3 (A tree) algorithm uses four types of messages to achieve topology discovery. The CDS construction process is initiated by a pre-defined node which could even be the sink node of the WSN network, which sends hello messages to all nodes within communication range.

The WSN nodes that receive the hello message from the parent node (sink node) send back the information regarding the remaining power and the signal strength of the signal received. This information will be used to calculate a metric. The metric will have a low value in case of timeout or a value that gives priority to the nodes with higher energy which are further from the sink node. This metric is used in the construction of the reduced topology which must incorporate a minimum number of nodes. As soon as the sink node receives confirmation to be a parent node sends back a list of all child type nodes selected by using the metric. This list contains information about all child nodes belonging to a parent node. This procedure is repeated by the neighboring nodes with the purpose of forming the reduced WSN topology. The nodes that don't receive a reply to the hello message go to sleep mode.

A3 Coverage Algorithm

The Coverage A3 algorithm was also developed by Pedro M. Wightman and is presented in [11]. The protocol is a topology construction algorithm which emphasizes the development of the optimal topology aimed at increasing coverage of WSN sensors. Coverage A3 is similar to the A3 algorithm which involves the development of a backbone in the WSN network to ensure guarantee connectivity between nodes.

All the nodes that are part of the backbone will remain active while the remaining nodes can enter sleep mode to save energy. The considerable difference between the two algorithms can be seen in the mode they ensure the growth of coverage. Thus, in the algorithm A3, the coverage of WSN nodes is achieved by ensuring connectivity of the nodes in the sleep mode (passive nodes) by using the communication range of active nodes. In contrast A3 Coverage algorithm uses the sensing range of the active nodes to ensure the coverage condition [11].

TESTS RESULTS

Atarraya is a simulation tool that can be used to assess the performance evaluation of topology control algorithms that can be integrated in a wireless sensor networks (WSN). The application was developed by the University of Florida, USA [8]. Atarraya has the following characteristics:

- *Allows fast integration of topology control and topology maintenance algorithms;*
- *Positioning of the WSN nodes can be achieved by using mathematical distributions;*
- *The simulation environment allows the user to develop, test and implement new topology control algorithms;*
- *The simulator also allows the use of mathematical models to ensure node mobility [9].*

In a previously published paper [10] is presented the performance evaluation of topology control algorithms that can be integrated into a street lighting monitoring and control system which is based on a large-scale, long-thin WSN network.

Figure 2 presents the Atarraya simulator interface.

In order to determine the best topology control algorithms that can be integrated in the Smart City concept were implemented a series of test scenarios. Thus, we consider the following algorithms A3, A3 Coverage and EECDS. One of the simulation parameters evaluated is the number of active nodes after the topology construction algorithm is performed.

Other parameters considered are the number of packets sent and the energy consumed in the topology building process.

Thus, we developed a large-scale sensor network WSN distributed on a large geographical area of 2.5 x 2.5 Km. In the simulation scenarios the number of sensor nodes was varied from 500 to 1000, 1500, 2000 and 2500. Atarraya simulator offers the possibility the node position through the use of mathematical distributions such as uniform distribution, constant, normal or central distribution. In the implemented simulation scenarios the nodes were distributed in the defined geographical area, using the uniform mathematical distribution.

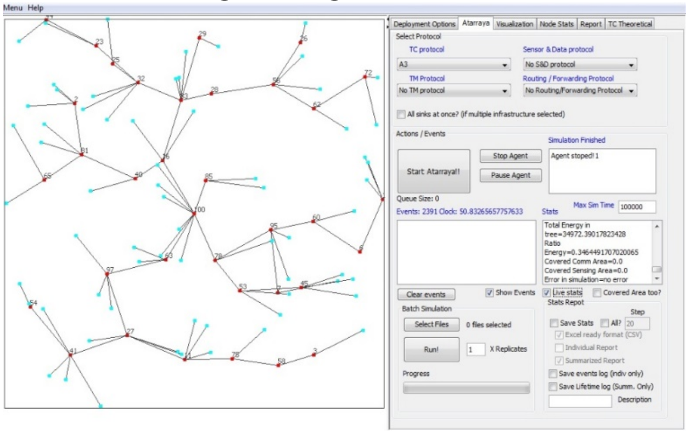

Figure 2. *Atarraya graphical user interface (GUI)*

Figure 3 presents the reduced topology for the network with 2500 nodes using the A3 algorithm.

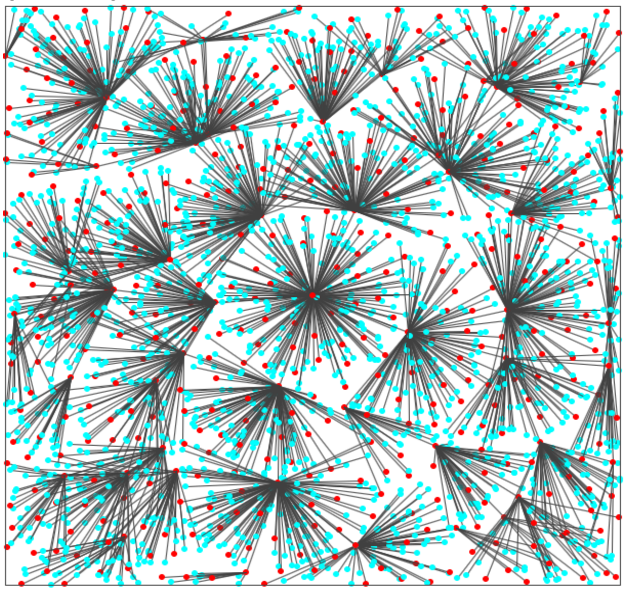

Figure 3. *The reduced network topology by using the A3 algorithm (2500 node architecture)*

In Figure 4 is presented the variation of the active nodes as compared to the total number of nodes. If the standard tree protocol (Just Tree) is used all nodes in the topology, are considered active as can be observed.

The number of active nodes represents the number of nodes that cannot go into sleep mode. Thus, these nodes cannot be supplied from a battery device as they actively participate in the routing and packet forwarding process.

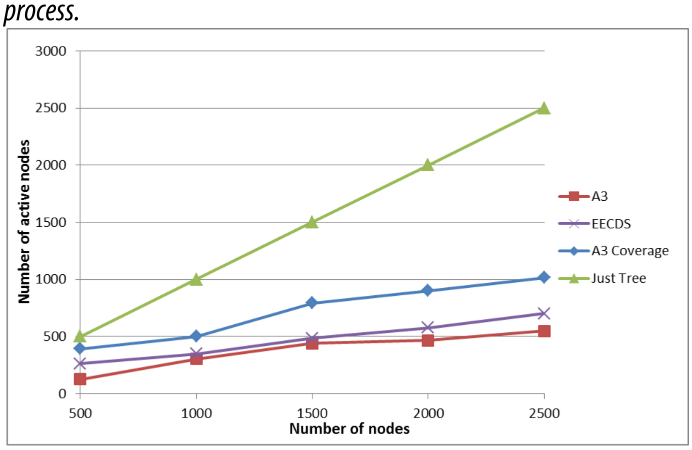

Figure 4. *Number of active nodes*

From the obtained results the topology construction algorithm A3 provides the lowest number of active nodes, i.e. 547 nodes, for the network topology with 2500 nodes and is recommended for use in the Smart City concept.

Figure 5 shows the variation of the number of packets sent inside the network in order to generate the topology when the EECDS algorithm is used.

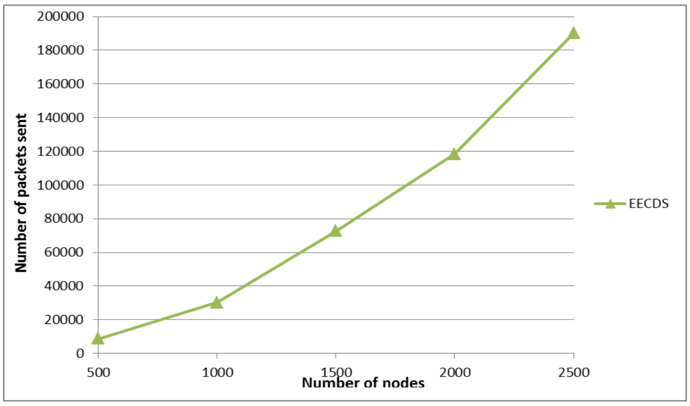

Figure 5. *Number of packets sent by the EECDS algorithm*

Figure 6 shows the variation of the number of packets sent within the network topology when the A3, A3 Covergecast and standard tree algorithms are used to reduce initial network topology.

From the results obtained the EECDS algorithm has the largest number of packets sent (190060 packets for the 2500 node topology) unlike A3 algorithm which sends a number of 7579 packets for the same topology. Thus, the concept of Smart City is recommended A3 algorithm in terms of number of packets sent. The A3 algorithm in terms of the performance of is followed by the algorithms A3 Coverage and Just Tree.

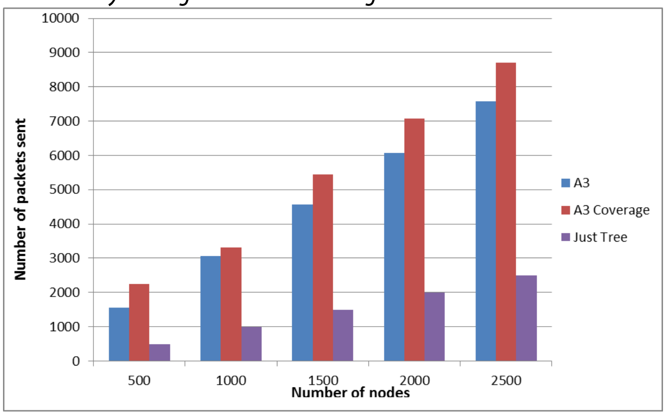

Figure 6. *Number of packets sent*

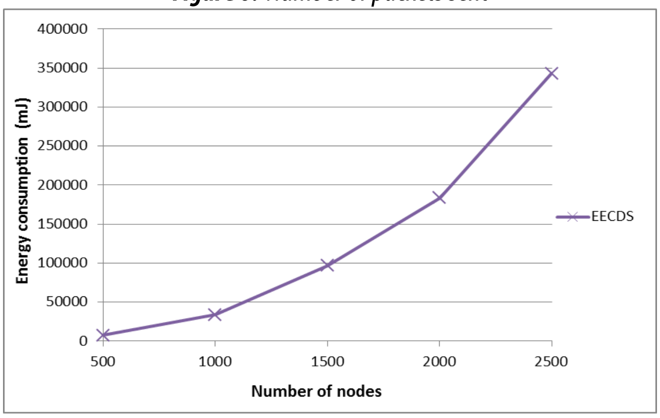

Figure 7. *Total energy consumption in EECDS topology control*

Another aspect that should not be overlooked is the total energy consumed by the network nodes to determine the network topology reduction. In Figure 7 presents the variation of the energy needed to build the network topology by using EECDS algorithm.

In Figure 8 is presented the variation of energy needed for building the network topology. The algorithms used are A3, A3 Coverage and Just Tree.

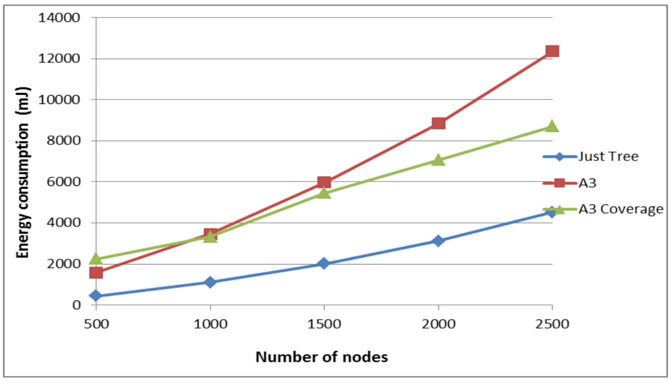

Figure 8. *Total energy consumption in topology control*

From the results obtained the standard tree algorithm provides the lowest energy consumption, which was expected because it has the lowest number of messages sent. The standard tree algorithm is followed in terms of performance by A3 Coverage and A3 respectively.

It can be observed that the most complex EECDS algorithm developed to ensure optimal energy consumption also has the highest energy consumption when the initial network topology is created.

CONCLUSION

In the scientific literature, there are many papers that approach the network topology control problem, but none of these addresses the issue of large scale WSN networks that can be integrated in the Smart City Concept [10].

Thus, the main contribution of this paper is the performance evaluation of the following algorithms A3, A3 Coverage, tree standard and EECDS respectively. From the results obtained we conclude that the topology construction algorithm A3 provides the lowest number of active nodes and is recommended for use in Smart City concept. In terms of the number of packets sent the A3 algorithm ensures the highest level of performance. From the point of view of energy consumption A3 Coverage algorithm is the most efficient algorithm and is being followed by A3, and EECDS.

ACKNOWLEDGMENT

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