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A Method for Determining Ad-Hoc Redundant Coverage Area in a Wireless Sensor Network

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Abstract. This paper proposes an analytical method for determining ad-hoc redundant coverage area in a wireless sensor network. This method can be alternatively used in order to determine a man-in-the-middle attack.

Keywords- wireless sensor network, ad-hoc networks, redundancy, coverage area, man-in-the-middle attack

1. Introduction

Wireless networks have come to be one of the most common facilities of technological society and we live in the present days. More than this, the concept of communicating by not wired methods, has provided a large spectrum of applications and new opportunities for corporations. Military applications, search and rescue operations, disaster management, environmental monitoring, collaborative computing are just a few examples in which this technology is largely applied. The key point in all these different practical solutions is built on wireless communication and also on sensors. The sensors are the media which can harvest for data. The data is vital for the applications. Regarding the type of application, it ca be vital for the life of so many people that are depending on it. Therefore the research area of wireless sensor networks is of huge importance. More than this, the problem of security assurance is a state-of-the-art one giving the reliable nature of such a network

A wireless ad-hoc network is defined as being a wireless network without any central controlling authority [1]. Every data can be send from a certain node to any other node through zero, one or more intermediate nodes. Such networks are characterized by the fact that the data communication from a source to a destination can pass through certain intermediate nodes. This means that a node can not only to send and receive data, but also to act as a router because it can forward data to the other nodes.

Even if such a network is a fixed infrastructure [1] that has a manageable access point, a very important feature is the fact that the devices can self-organize among themselves to form an on-the-fly network.

In modeling such a network, especially an ad-hoc sensor network, a problem can be the coverage areas of the sensors. While the ideal case is a perfect homogenous area (Figure 1a), a more realistic approach is a heterogeneous coverage (like the one in Figure 1b)

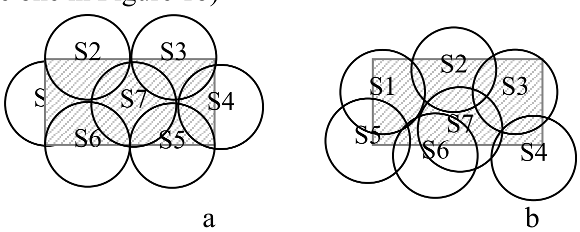

Figure 1. a – homogeneous coverage of an area, b –heterogeneous coverage of an area

In both cases presented in Figure 1, some degree of redundancy in the coverage area is present. It should be noted that in both cases presented in Figure 1, the whole concerned area (the marked rectangle) is seen by the sensor, though with different degrees of overlapping. That can lead to the definition of the coverage overlap degree between two sensor nodes – the probability that a communication between a sensor and a sensor node will be intercepted and processed by another sensor node. For example, figure 2 presents different cases of coverage overlap degree.

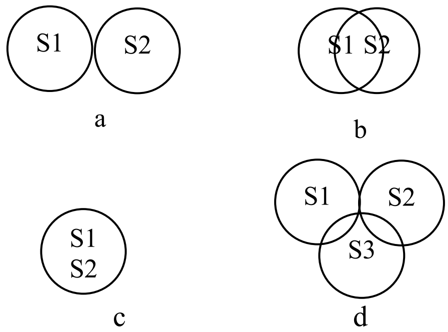

Figure 2. The coverage overlap degree – a) 0%, b) 50%, c) 100%, d) 0% between S1 and S2, 15% between S1 and S3, 15% between S2 and S3

In this paper, we extend the idea of coverage overlap to a structure containing sensor nodes. Sensor nodes can receive transmissions not only from their own sensors, but also from neighboring sensor nodes' sensors. We shall label the coverage of data to the same sensor node by different processing nodes' sensors as overlapping of sensor nodes, while by redundancy level we shall regard the probability by which the sensor belonging to different sensor node will send data to a another sensor node.

The rest of this paper is structured as follows: section II deals with the simulation of different degrees of coverage overlapping, while section III presents the discussion of the results. Further on, different ideas for future work are established.

2. Simulating the coverage overlap degree

In order to simulate, oriented on the entities and not on the particular topologies, we used AweSIM. We simulated the sensors using initiator nodes, that periodically, with an exponential distribution, create data. The sensor data is further processed by a sensor node. The processing requires time and once over, the processed data is send to a higher-level node. So as to reproduce the coverage overlap, we implemented a probability of data transmission between the sensor and sensor nodes. That probability reflects the overlap.

In implementing we had three types of sensor nodes: nodes that have no coverage overlap, nodes that have coverage overlap from only one of the near-by sensors node's sources, and nodes that have two neighboring sensor nodes whose sensors overlap the studied sensor nodes' sources.

Assuming a redundancy level of 10%, this means that 90% of the nodes sensing area is not overlapped, and for this hypothesis the results are presented in Figure 3.

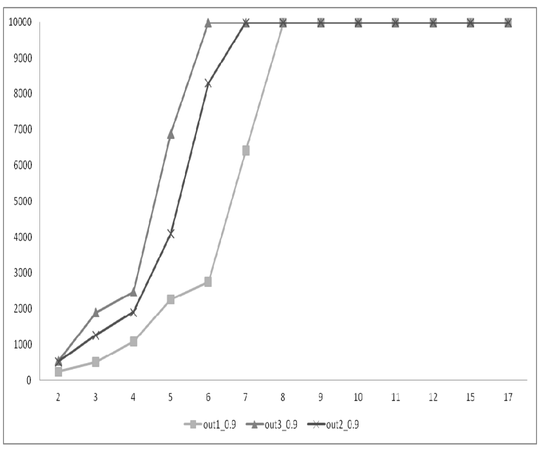

Figure 3. Redundancy level of 10%

Runtime was 10000 ms, with the lowest transmission time from sensor to sensor node of 10 ms. We are interested in the average busy time, on the line, and how that time varies by increasing processing time (horizontal axis) or by increasing the redundancy degree of sensor communication. The busy time for the output in the sensor node that presents overlapping of 3 nodes (one being its own sensors and two being the other two nodes' sensors) crests rapidly with the increase in processing time in the sensor node. Close besides is the node that overlaps 2, while the homogeneous node (out1) is clearly lower to reach congestion.

The same behavior remains for a redundancy level of 20% (Figure 4) and 30 % (Figure 5). If we compare the load on the output line for the same level of overlapping, some interesting results occur. For higher level of overlapping like two (Figure 6) or three (Figure 7) sensor nodes there is no

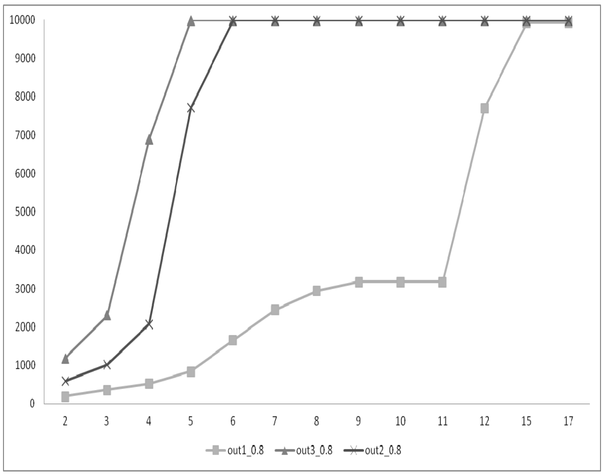

Figure 4. Redundancy level of 20%

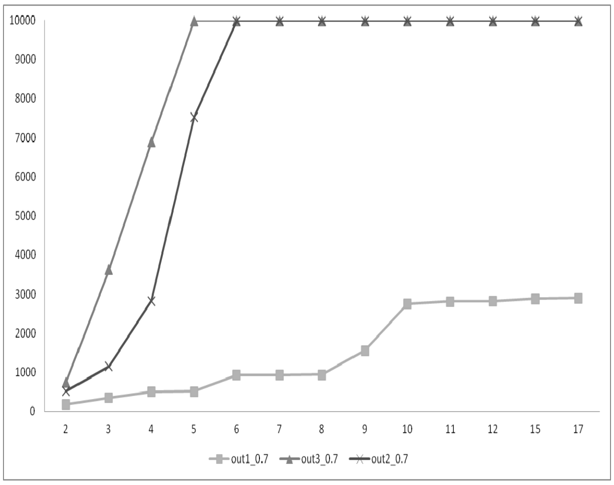

Figure 5. Redundancy level of 30%

significant difference in the behavior for a percent of redundancy larger than 20%.

An interesting phenomenon occurs in Figure 4 and Figure 5 where a limitation takes place for the sensor node that has no overlapping with the neighboring sensors. This leads us to compare the load on the output line for the same level of overlapping, where more interesting results revealed.

For higher level of overlapping like two (Figure 6) or three (Figure 7) sensor nodes there is no significant difference in the behavior for a percent of redundancy larger than 20%.

For no overlapping (Figure 8), the higher the degree of redundancy, the faster congestion is attained. For lower levels (like 30%), congestion was not yet attained until the end of simulation.

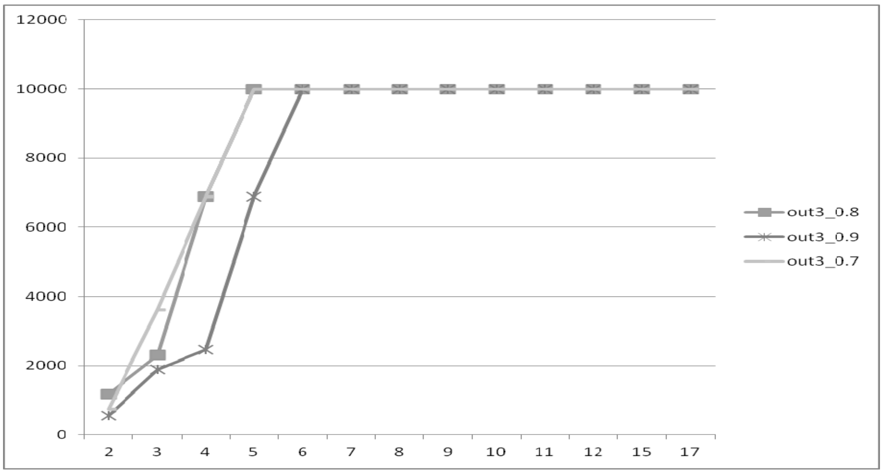

Figure 6. Higher level of overlapping 3 nodes

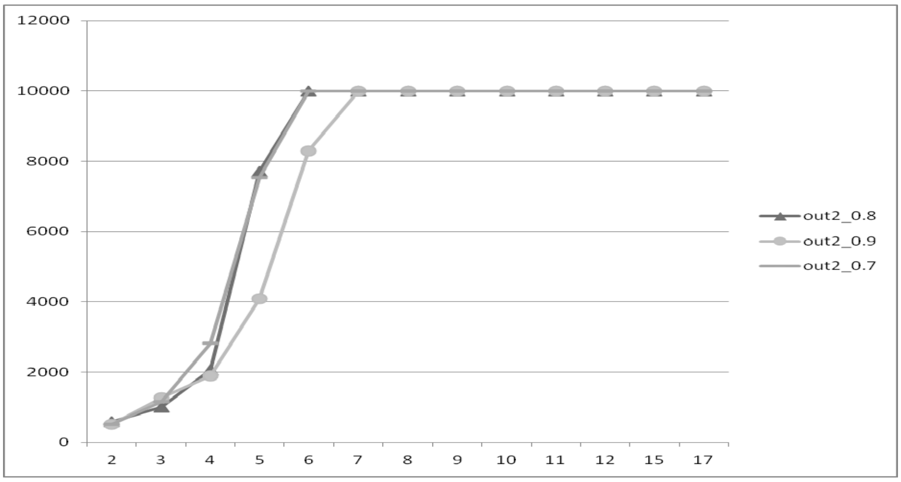

Figure 7. Higher level of overlapping 2 nodes

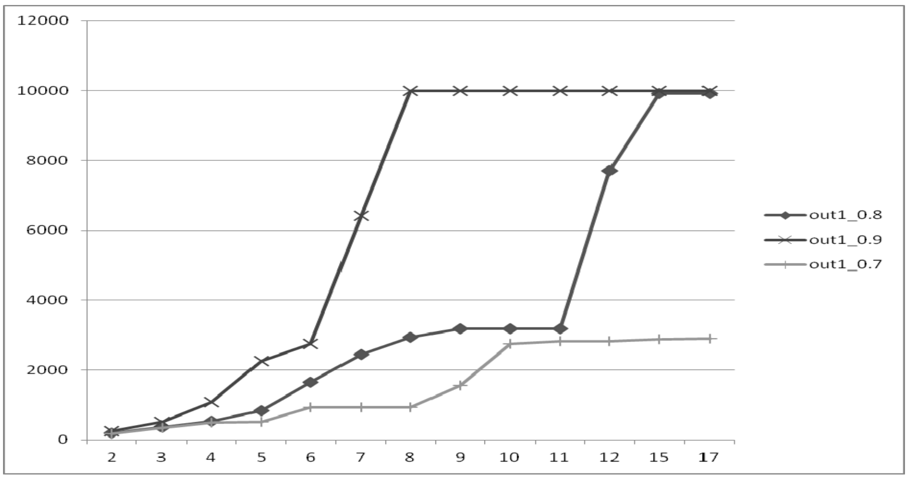

Figure 8. No overlapping

3. Conclusions and Future Work

This paper presents an analytical method by which it can be determined the ad-hoc redundant coverage area in a wireless sensor network. Different scenarios have been taken into consideration. From the experimental results, it can be noted that for higher level of overlapping, there is no significant difference in the behavior for a percent of redundancy larger than 20%. In the case of no overlapping, the congestion is faster attained once the degree of redundancy increases.

4. References

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