Sensor Network Topology as Low-interference Factor

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Abstract **– This paper presents investigation results of wireless sensor network topology connection with some main geometric structures. The aim is optimal communication organization between neighbour nodes. Sensor node range and distance between nodes as a factor for interference influence has calculated. MatLab simulation model has developed for interference investigation in sensor network design.**

Keywords **– Wireless sensor, topology control, Interference, Relative Neighbourhood Graph, Gabriel graphs.**

I. INTRODUCTION

Wireless sensor network (WSN) consists many geographically dispersed units, that communicate wirelessly with each other [1]. Missing central infrastructure supposes that networks have no particular fixed topology. This way the control of the topology [2] appears to be necessary in planning the network structure in order to maintain connectivity, effective power and optimizing network performance. Many algorithms for topology control [3] were offered in the last decades, including the most famous Delaunay Graph (DG) [4], Relative Neighborhood Graph (RNG) [5], Gabriel Graph (GG) [6]. These algorithms are principally designed for energy efficiency and connectivity between neighboring nodes, but there is another important criterion for sensor networks such as productivity.

In this paper we consider geometric structures by which to analyze the wireless sensor nodes and their geographical distribution in the environment. There shall be accordance between the network topology and a geometric structure. When algorithms for topology control are used, based on the geometric structure, it's necessary to take into account the communication range of sensor nodes. The control of topology is used in sensor networks mostly to optimize the initial topology to save energy, reduce interference and prolong the life of the network.

The main aim is to reduce the number of active nodes, according to save resources necessary for future communications. The installation of wireless sensor networks in the area appear many problems mainly related to transmitter power, conservation of energy supply of batteries and maintaining communication connectivity. In case to save the packet, it's very important to choose the right node during the organization of the communication. A wrong choice may cause blocking of the communication.

The transmitting nodes affect the ability of the other nodes to receive data. The sensor node is not able to receive data from its neighbor, if in the same time another neighbor sends data. This mutually disturbance of the communication is named interference. Reducing the interference [7] in the network leads to much fewer conflicts during the sending of packets, which actually reduces the usage of energy and extends the life of the network. Therefore, reducing the interference via using the correct graph at the disposal is an important aim for the control of the topology.

II. GEOMETRIC STRUCTURES

The geometric structures graphics are graphics where vertices are points in a plane connected by straight segments between the individual points. This kind of graphics are known as proximity graphics [8].

A. Voronoi Diagram and Delaunay triangulation

In the diagram of Voronoi (dotted lines on fig. 1) set of sensor nodes placed in a plane form discrete units, which form the convex polygons (area Voronoi). All sides inside the polygon are most closely only to one node. Through this type of structure effectively create polygons with vertices located equidistant from neighboring node.

Delaunay triangulation signed as DT (the continuous line on fig. 1) is a double graph of Voronoi diagram. This is a unique set of points, where the peaks of all triangles lie on circles. And in these circles there are no other points. The special feature of this geometric structure is that it is well balances- the triangles do not differ significantly.

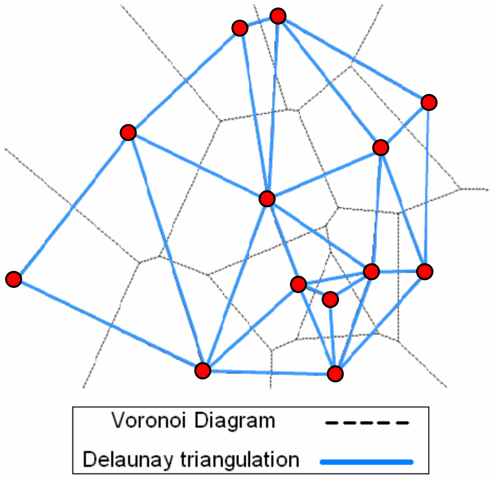

Fig. 1. Voronoi Diagram and Delaunary Triangulation

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B. Relative Neighborhood Graphs

Relative Neighborhood Graph (RNG) connects two points, *u* and *v* in the area *S*, then and only then when:

$dist(u,v) \le \max\{dist(u,q), dist(v,u)\}$, for each point $q \in S$.

With $B(x,r)$ assign the opened circle with radius *r*, and centre *x*, where $B(x,r)=\{y|dist(x,y)<r\}$.

Figure 2. shows how to set up communication links with RNG.

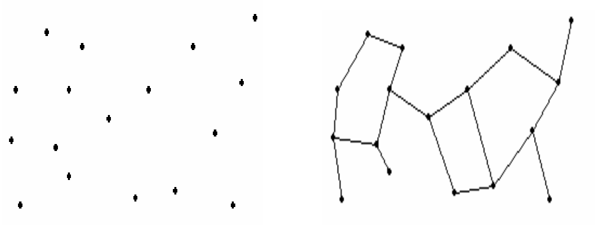


Fig. 2. Communication links in Relative Neighborhood Graph

D. Gabriel graph

Gabriel graph (GG) is under the graphic of Delaunay triangulation (DT) because of the ability called „empty circle" where in a circle with a diameter of a line joining the two nodes must be adjacent nodes (fig.3).

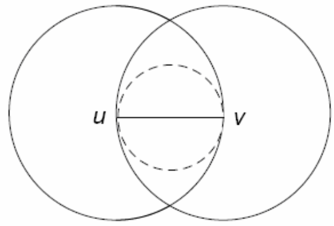


Fig. 3. Empty circle in Gabriel Graph

GG connects two points, *u* and *v* in the *S* area, then and only then when:

$$dist(u,v) \le \sqrt{dist^2(u,q)+dist^2(q,v)}\,, \qquad (1)$$

for each point $v \in S$.

Figure 4. shows how the communication connections in GG are formed.

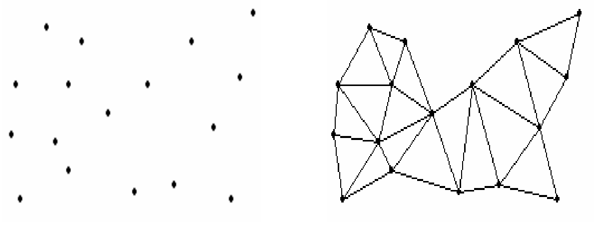


Fig. 4. Communication links in Gabriel Graph

III. FLUCTUATIONS OF ENERGY DEPENDING ON THE GEOMETRIC STRUCTURE

Saving energy is very important for the sensor networks, because the nodes are charged only vie batteries. To send the signal from one sensor node to another, the power that is used from these two nodes contains the following three parts [9]. First, the sensor node, which sends, needs some energy to prepare the signal. Second, in most cases, the power required for the realization of the communication link *uv* is $\|uv\|^{\beta}$, where $\|uv\|$ is Euclidean distance between *u* and *v* , and β is the real constant between 2 and 5 in transmission depending on the environment. Finally, when the node receives the signal needs some energy for the reception, storage and processing of this signal..

Let's take a look at each set $\pi(u,v)$ in the geometric structure from the node $u \in V$ to another node $v \in V$.

$\pi(u,v)= v_0v_1\ldots v_{h-1}v_h$, where $u=v_0$, $v=v_h$

Here the *h* appears to be the count of hops on the trail π. The general power for the emission $p(\pi)$, consumed by this path π is defined as [10] :

$$p(\pi)=\sum_{i=1}^{h}\| v_{i-1}v_i \|^{\beta} \qquad (2)$$

The trail connecting *u* and *v* with less usage of energy is known as least-energy path. Let $p(u,v)$ be the less used energy of all paths, that connect *u* and *v*, and *H* is under graph of this geometric structure. Then the usage of energy in this graph may be defined as:

$$p(H)=\max_{(u,v\in V)}\frac{pH(u,v)}{p(u,v)} \qquad (3)$$

When we change some of the parameters, that are used for sending packets in the sensor network may be reached different results for the same topology.

This topology, where the interference is with very low percent appears to be optimized for the cases when the main criterion is the energy.

IV. NETWORK MODEL

In our analysis we consider the network topology from sensor nodes randomly distributed in a plane $G=(V,E)$, where $V=\{v_1,v_2,\ldots,v_n\}$ and *E* is the aggregation of connections between neighbouring sensor nodes in the network. We accept, that all the nodes transmit at maximum power. The range of a radio R_{max} is calculated as follows [11]:

$$R_{\max}=\frac{\lambda}{4\pi}\sqrt{\frac{P_tG_tG_r(1-|G_r|^2)}{P_r}}\,, \qquad (4)$$

where:

P_t - power that the sensor sends;
G_t - gain of transmitting antenna;
G_r - gain of receiving antenna;
P_r - sensitivity of the receiver;
$|G_r|^2$- ratio of reflected power from the receiving antenna;

Algorithms for topology control , which aim is to decrease the interference are besed on different parameters based on the topology of the network itself. All the nodes are potentially disturbing for a node. Before we determine we will introduce the following definition:

- The interference area: that part of the range of the node v_1, which overlaps with the ranging area of the node v_2 and form a negative impact on the communication of these two nodes with their other neighbors.

- Potentially disturbing node: a node v_1, is potentially disturbing on node v_2, if its range could cause danger on the communication between v_2 and the rest of the nodes.

From the definition RNG [5] we suppose that the interference area has to be:

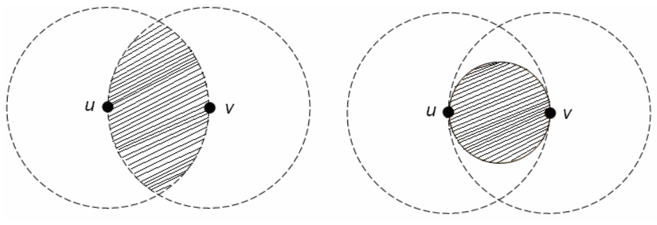
$$I_{u,v}=B(u,dist(u,v))\cap B(v,dist(u,v)), \qquad (5)$$

Which is marked with (*a*) and it is shown on fig. 3. In another words, the two points *p* and *q* form RNG then and only then when $I_{u,v}$ does not contains any other points in the *S* area.

The interference area for GG is:

$$I_{u,v}=B((u+v)/2),dist(u,v)/2, \qquad (6)$$

marked with (*b*) and shown on fig. 3. The interesting part here is the circled shape of the interference.



(a) $I_{u,v}$ for RNG (b) $I_{u,v}$ for GG

Fig. 5. Interference field in RNG and GG

V. SIMULATION STUDIES OF SENSORY UNITS IN INTERFERENCE

A. Model of interference jamming receivers of sensor nodes

The interference of node *v*, assigned as $I_{(v)}$, may be defined from the count of the other nodes, which areas of transmission are able to cover *v*.

$$I_{(v)}=|\{u\,|\,u\in V\setminus\{v\},|uv|\le r_u\}| \qquad (7)$$

The middle interference in the geometric structure G, assigned as $I_{avg}(G)$, may be defined as:

$$I_{avg}(G)=\frac{\sum_{v\in V}I_{(v)}}{V} \qquad (8)$$

For a node with radius of transmission r_v, may be defined a interference made by it on the following way:

$$I_{(v,r_v)}=|\{u\,|\,u\in V\setminus\{v\},|uv|\le r_v\}| \qquad (9)$$

So we have:

$$I_{avg}(G)=\frac{\sum_{v\in V}I_{(v)}}{V}=\frac{\sum_{v\in V}I_{(v,r_v)}}{V} \qquad (10)$$

Б. Simulation results

To estimate the effectiveness of the use of energy resources and the impact of interference in the transmission of data is necessary to analyze the relative position of sensor nodes and the relevant processes in communication between the sensor modules.

If all devices on the network do not change their position and are homogeneous in terms of hardware components, there is a fixed set of positions in which each sensor node will have the same radio range and will spend the same amount of energy for communication.

As we mentioned earlier the sensor nodes cannot receive and process several signals at the same time, and because of that for clustering of multiple nodes the probability for disturbing of the communication between them is very large.

Using the topology based on RNG we define the parameter θ (fig.6.), which is the angle, that composes from the sensor node of the two abutments of the circles, describing their own range and the range of the neighboring node.

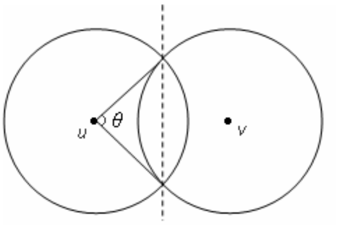


Fig.6 Graphical representation of the angle θ.

Fig. 7 shows the influence of the interference when θ changes, as to more accurately simulate real communication between neighboring nodes, we add an additional disturbing influence (Gaussian noise), which may be amended percent depending on weather, topography and more.

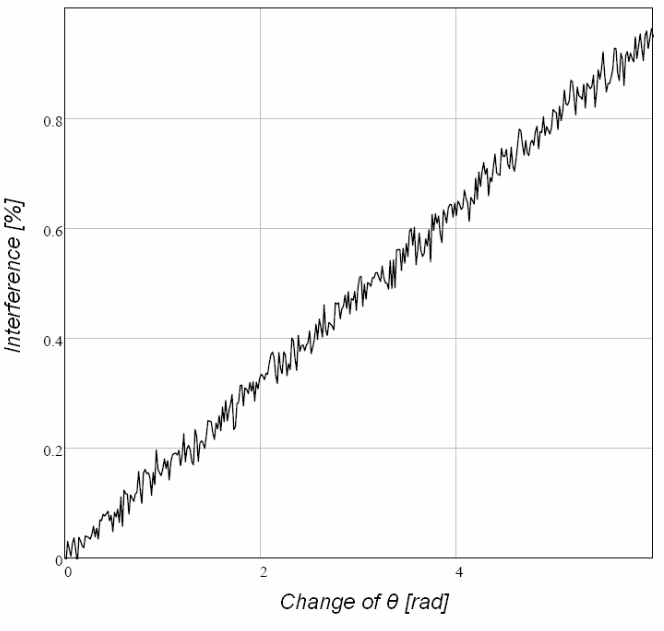


Fig. 7. The change of the interference depending on the parameter of θ

The distance between the mobile sensor nodes causes influence over the interference. When neighboring nodes are located very close, θ has large values, therefore, a high interference. It is the use of geometric structure to limit the communication links between nodes.

The subordination of θ from the distance is shown on fig. 8.

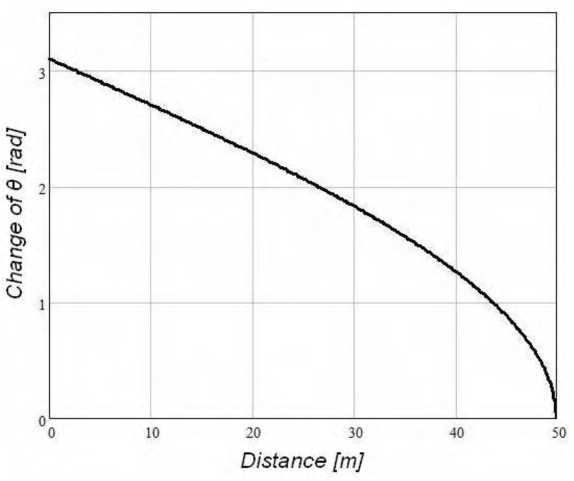


Fig.8. The change of the parameter θ when the distance changes

To define the amount of the interference at GG, shown on fig. 9., we use the recovering that the “Empty Circle” ability makes, and the distance between the neighboring nodes.

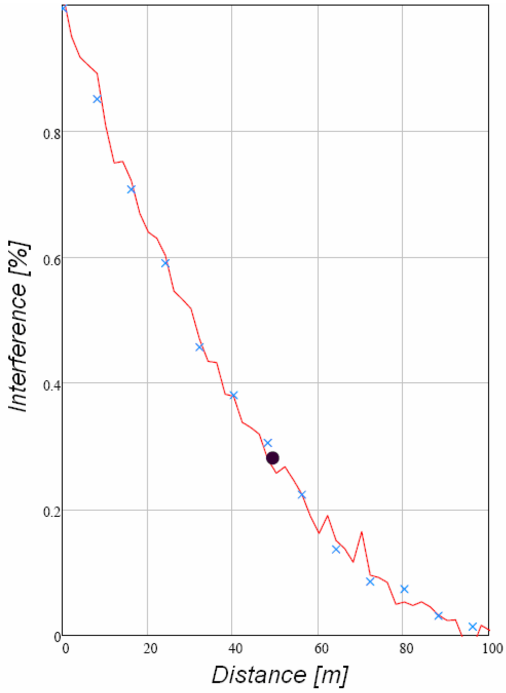


Fig. 9. Relation between the distance and interference when using topology with GG

The black point represents the certain event at a set distance between adjacent sensor nodes and the percent hedging, from which the influences of interference in this topology. It gets clear from the graphic that when the distance between the neighboring nodes is increased the interference will be significantly reduced.

VI. CONCLUSION

Although the algorithm for calculating RNG and GG is pretty easy to do, from the graphics we see either excessive accumulation of sensor nodes, or not enough count neighbors for a normal communication, which significant impacts on interference.

We study the influence of the interference at the topology, build on RNG and GG, and the results of the simulation are the following:

- The interference may be damped, if we localize the amount of communication connections;
- If we have n number nodes distributed in certain geographic area it is necessary to build particular communication structure;
- We must use a tree structure if we want to have optimal topology related with less interference;
- The interference will be less if the sensor nodes are placed in a distance that they communicate in a range close enough to r_{max}.

The results, based on the analysis provide guidelines for design optimization of interference in sensor networks.

Our studies in future are directed to improve the method that allows exchange of the sensor nodes between the different work groups. Also our simulation method of the interference between the sensors may be used for an online education. We also analyze other techniques to improve the interference effect in the future.

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