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Procedia Computer Science 192 (2021) 2699–2708

Procedia Computer Science

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25th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems

Information Security Measures in Homogeneous Wireless Sensor Networks

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Abstract

The geometric models of wireless sensor networks are analyzed in this paper. To improve information security measures, the conditions for choosing the optimal network model and the way of visualizing the change in signal parameters are defined; the choice depends on the number of information nodes and their placement in space.
To develop geometric models of wireless sensor networks, three schemes are proposed. Respectively, the simplex-diamonds with one, two, and three real information nodes are used. The performance of such models is analysed in the modes of control over the real information nodes parameters and the choice of the best ways to transmit information in the wireless sensor network.

Keywords: homogeneous wireless sensor network, real information node, reference information node, geometric model, signal parameter, information transmission route, simplex-diamond, cluster;

1. Introduction

The progress of information technology requires the development of perfect tools for collecting and processing a large amount of diverse information, as well as the creation of highly effective and reliable technologies for their systematization and transmission. Technical capabilities of modern information nodes allow collecting and processing a large amount of information. Besides, such information systems assume the features of intellectual systems. Typically, these wireless sensor networks operate as homogeneous structures. Therefore, to maintain their

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10.1016/j.procs.2021.09.040

reliable and durable operation, a uniform load on each information node of the network should be applied and reliable monitoring of their signal parameters should be ensured.

2. Analysis of recent research

To solve the specified problems, the models of wireless sensor networks are used for visual monitoring of the state of charge of information nodes and their signal parameters [1].

The known mathematical and physical models of wireless sensor networks are significantly different [2, 3]. Nevertheless, they allow to solve successfully the problems of developing and improving their hardware and software components. The geometric models are significant in solving a number of complex technical problems related to the development of energy-efficient routes of information transmission [4-8] and mechanisms of control over the signal parameters of information nodes. Such models include the graphical representation of wireless sensor networks in a two-dimensional Euclidean configuration space. In geometric models, information nodes are represented by signal points. The signal parameters are called functional bonds; they are represented as a distance between signal points.

When developing geometric models, signal points are placed at the vertices of the correct geometric shapes [9]. There are square and hexagonal models of wireless sensor networks. Such models can represent networks with an unlimited number of information nodes and cover unlimited areas; they are simple, easy to use and allow information transmission planning in three directions.

According to the conducted analysis, it is difficult to track changes in signal parameters by means of these geometric models. Therefore, the geometric models in the form of planar graphs, all interiors of which are triangles [10], should be considered. In such models, the change in signal parameters of information nodes causes the change in the length of functional bonds. Therefore, the topological surface of the geometric model is increased and distorted. Analysing the nature and size of this distortion, researchers have the ability to determine the area of damage to information nodes of the network and the nature of attacks on them [11].

To identify attacked or damaged individual information nodes (or small groups of them), elementary flat geometric shapes should be used. The shapes, due to the change in size of their elements, transform into volumetric ones. Besides, the change in the volume of the geometric shape is assumed as a property of the magnitude of the change in the signal parameter. Thus, the simplex-diamonds formed by two equilateral triangles should be used [12]; there are signal points at the vertices of triangles. Four sides and a small diagonal in the simplex-diamond are functional bonds; a large diagonal is represented as a geometric bond. The change in signal parameters of information nodes causes the change in lengths of functional bonds [13]. Therefore, they determine the position of corresponding signal points in the Euclidean configuration space. Geometric bonds cannot change the form of simplex-diamonds and are determined only in the planes of simplexes. To identify attacked or damaged individual

There are two methods of visualizing the change in signal parameters of information nodes: stationary signal points and moving signal points. The methods are determined by the dependence between the length of functional bonds and the position of signal points in the configuration space. The method of stationary signal points is based on the assumption that the initial position of signal points in the simplex-diamond is fixed [14]. Thus, signal points remain stationary under the change in signal parameters of information nodes. The physical bonds changed in length transform into arcs, causing the space distortion. In case of simultaneous change in the signal parameters of a large number of information nodes, this type of visualization should be applied.

The method of moving signal points is based on the assumption the change in signal parameters of one or more information nodes causes the change in the simplex-diamond geometry. The change occurs because the functional bonds defining the performance of information nodes change their length. During this method implementation, the simplex-diamond is partially transformed providing the moving signal point is located at the end of the large diamond diagonal and possesses two physical bonds [15]. In this case, it is impossible to evaluate the magnitude of the change in the signal parameter of the information node, since the transformation of such a simplex-diamond leads to the formation of a three-dimensional geometric object, which consists of two triangles bent along a common basis – a functional bond.

This deficiency can be eliminated by developing a geometric model of a wireless sensor network, the basis of which is the correct geometric shape. In the shape, each signal point may belong simultaneously to several simplex-diamonds. In one of such simplex-diamonds, the given signal point will be placed at the end of the small diagonal of the diamond. Therefore, a simplex-cluster model of a wireless sensor network is proposed. It is developed according to the principles of forming the fractal structures such as "Koch snowflakes". The basis of this model is a cluster of the correct hexagonal form, which encompasses 18 signal points connected by 36 identical functional bonds. This cluster consists of 18 simplex-diamonds.

Based on a simplex-cluster model, methods of four-point simplexes and false signal points for tracking and analysing the signal parameters of information nodes that are part of the wireless sensor network are proposed [16]. These methods cannot be applied in networks with the number of information nodes less than 18. Therefore, the method of reference signal points is proposed.

3. Main part

To implement the method of reference signal points in the simplex-diamond, all physical bonds are determined by the same parameters of the reference information node (e). Thus, they form a simplex-diamond with five equal physical bonds of the length l and one geometric bond of the length d=3l. Parameters of the real information node (r) are transmitted to the position of the simplex-diamond, which is determined by three physical bonds. Due to the change in the controlled parameter of the real information node (r), three physical bonds are extended.

This extension causes the transformation of the flat simplex-diamond into a three-dimensional geometric object. In this case, the simplex-diamond takes the form of a triangular pyramid with a vertex in the signal point. This vertex is the real information node with the changed signal parameter (Fig. 1). The height of the pyramid h, in this case, will define the degree of change in the signal parameter.

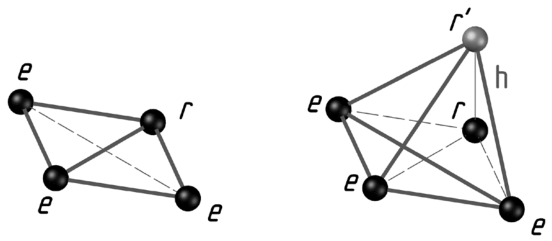


Fig. 1. Single simplex-diamond under study

The method of reference signal points allows monitoring the signal parameters both as a separate information node and as a network with an unlimited number of information nodes. In a wireless sensor network consisting of two or more information nodes, the geometric models including simplex-diamonds with one, two, and three real information nodes can be used. In Fig. 2, the variants of formation of geometric models of wireless sensor networks with three real information nodes are shown.

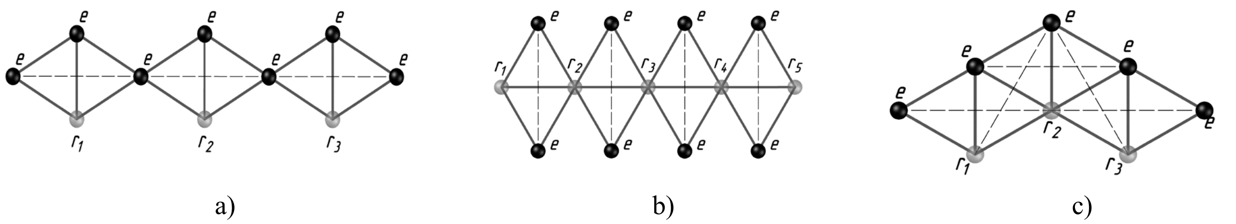


Fig. 2. Geometric models for three real information nodes: a) simplex-diamonds with one real information node; b) simplex diamonds with two real information nodes; c) simplex diamonds with two and three real information nodes.

In the studied network, signal parameters of several real information nodes change simultaneously. In case a geometric model is developed according to the scheme a, then each simplex-diamond consisting of a real information node with a changed signal parameter completely transforms into the pyramid (Fig. 1). Consequently, such information node can be easily detected, and the value of change in the signal parameter can be estimated. In case, the geometric model is developed according to the scheme b, the simplex-diamond is partially transformed due to the simultaneous change in signal parameters of two real information nodes (Fig. 3). Thus, the physical bonds are extended in the simplex-diamond; they intersect at the ends of the major axis of the diamond. Simultaneously, the simplex-diamond itself bends along a minor axis, while remaining a flat shape. Under these conditions, the change in the signal parameter cannot be detected. In case, a geometric model is developed according to the scheme в, then, applying an arbitrary combination of simultaneous changes in the signal parameters of two or more real information nodes, a simplex-diamond can be defined. The parameters of two real information nodes located respectively at the ends of the major and minor axis are changed (Fig. 4). In this case, the diamond transforms into a pyramid. Therefore, the change in the signal parameters can be fixed, but the magnitude of the change cannot be determined.

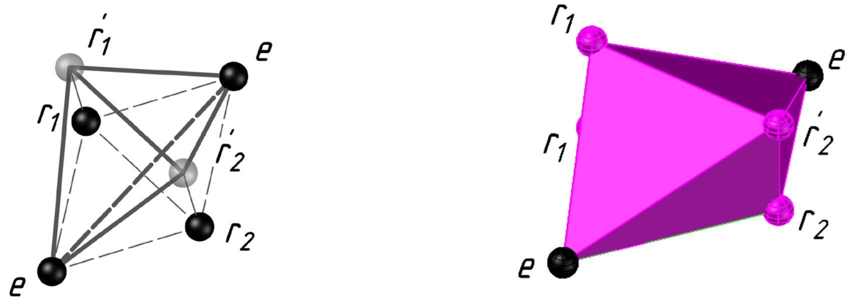


Fig. 3. Scheme of a partial transformation of the simplex-diamond due to the simultaneous change in signal parameters of two real information nodes located at the ends of minor axis.

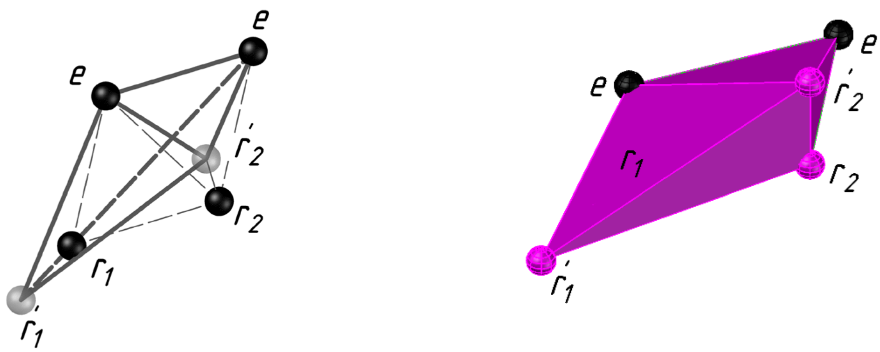
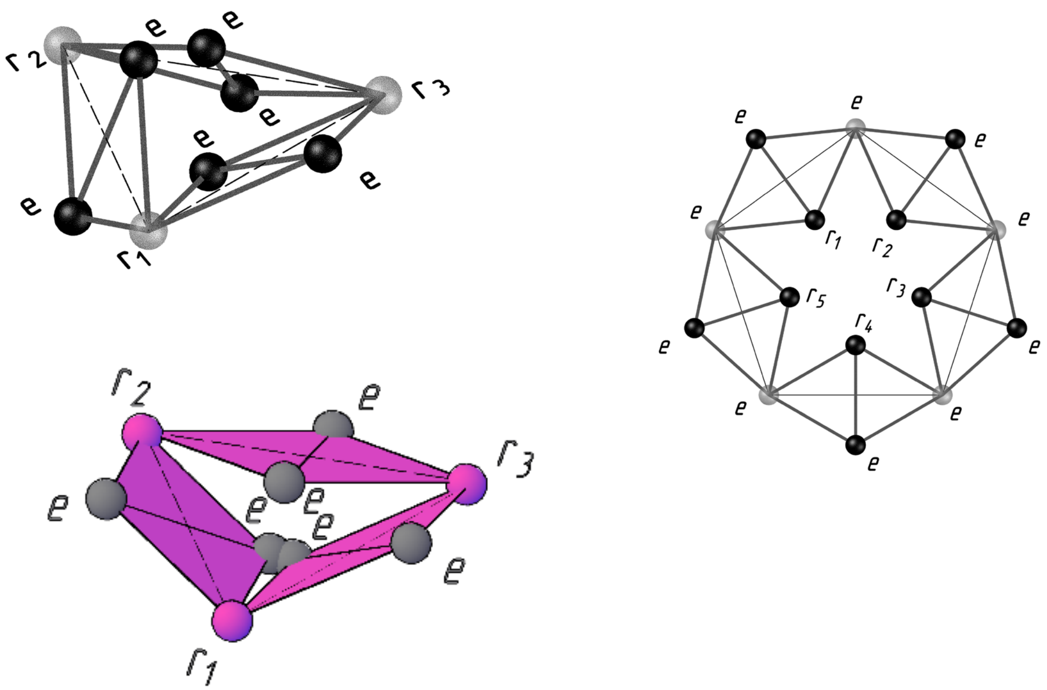


Fig. 4. Scheme of transformation of the simplex-diamond due to the simultaneous change in signal parameters of two real information nodes located at the ends of one of the sides of the diamond.

Based on the above, the following conclusion is made: when applying the method of reference signal points to analyse the parameters of real information nodes, a geometric model of the wireless sensor network should be developed according to the scheme a (Fig. 2). To realize continuous monitoring of signal parameters, a geometric model of a network with three or more real information nodes should be represented in the form of closed shapes (Fig. 5).



b)

a)

Fig. 5. Schemes of closed geometric models of wireless sensor networks: a) geometric model for three real information nodes; b) a geometric model for five real information nodes.

Such geometric model of the wireless sensor network is proved to be ideal for analysing the signal parameters of real information nodes. However, it is inapplicable for mapping the information transmission routes. Thus, there should be a physical bond between the adjacent real information nodes. Such conditions ensure the creation of geometric models developed according to the schemes b and в. The geometric models of wireless sensor networks developed according to the scheme b do not allow detecting changes in signal parameters of real information nodes. Then, to implement the method of reference signal points, the geometric model of the wireless sensor network developed according to the scheme b is used. In this case, real information nodes should be placed on one side of the schematic chain of simplex-diamonds. Disadvantages of a simplex model of wireless sensor network are as follows: the complexity of monitoring the network, which includes a large number of sensors; and the impossibility of tracing the transformation of a simplex diamond, in which the information node with the changed parameters is placed at the end of the large diagonal of a simplex diamond. To solve these problems, the cluster model of wireless sensor network is proposed. The development of such geometric model is based on the principles of designing fractal structures like "Koch snowflake". The forming part of configuration space is functional connections among signalling points. This model involves in the first phase the development of a geometric object-basis to create geometric structures that are more complex.

The basis for developing the plurality of configuration space signalling points, which carry network visualization of information nodes with the same parameters is a regular hexagon with a side. Six signalling points are placed at the tops of the hexagon . The chain of simplex-diamonds consisting of six real information nodes can be represented as a hexagonal cluster (Fig. 6).

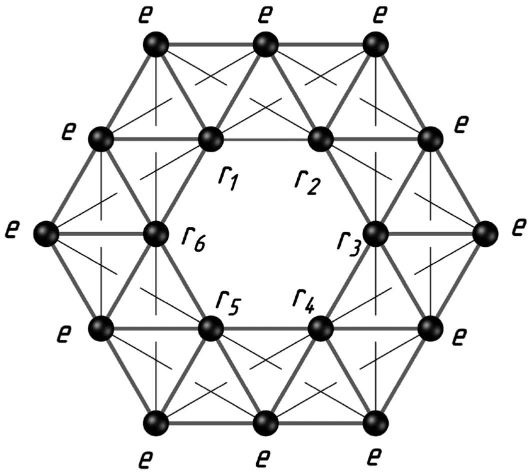


Fig. 6. Geometric model developed according to the scheme b.

To analyse the operation of such a network, well-known methods of four-point simplexes and false signal points should be applied (Fig. 7).

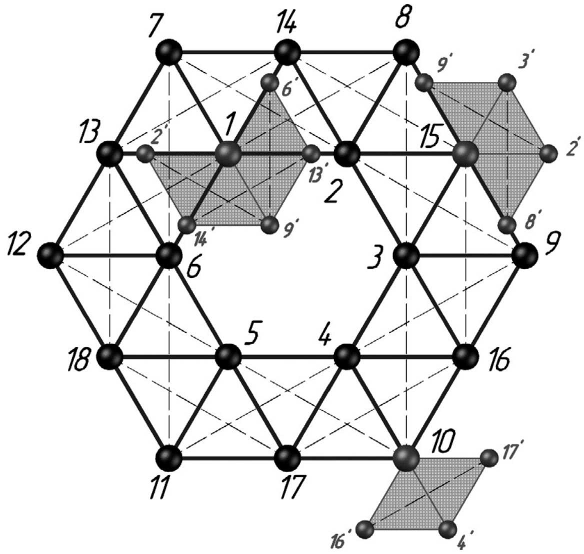


Fig. 7. Areas of complete transformation by the method of false signalling points.

Schemes of complete transformation areas with simultaneous changing of signal parameters of two information nodes are shown in Fig. 8-12. The signalling points of these nodes are the vertices of one simplex diamond in the cluster.

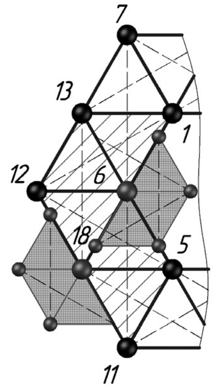


Fig. 8. Area of complete transformation with simultaneous replacement of signalling points; their positions are determined by three and five functional connections.

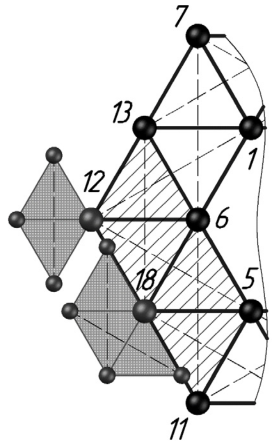


Fig. 9. Area of complete transformation with simultaneous replacement of signalling points; their positions are determined by four and four functional connections.

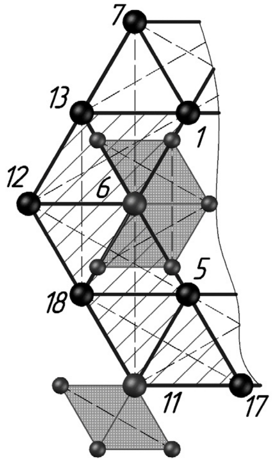


Fig. 10. Area of complete transformation with simultaneous replacement of signalling points; their positions are determined by three and five functional connections.

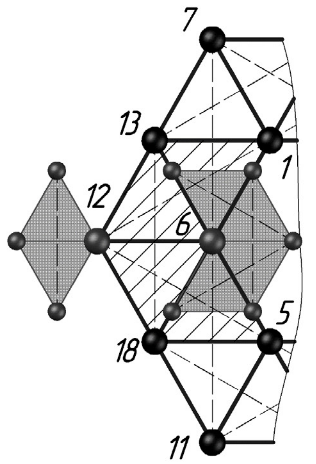


Fig. 11. Area of complete transformation with simultaneous replacement of signalling points; their positions are determined by four functional connections.

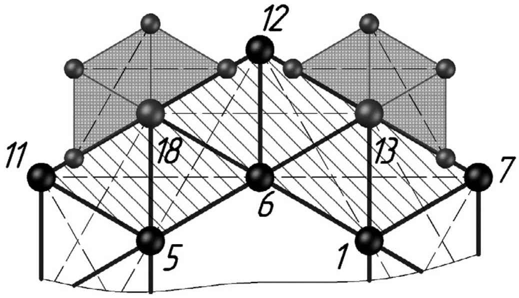


Fig. 12. Area of complete transformation with simultaneous replacement of signaling points; their positions are determined by five functional connections.

4. Conclusions

1. The method for the reference signal points allows tracking the signal parameters of information nodes in wireless sensor networks consisting of no less than 18 information nodes, or in areas of large networks, in which the hexagonal clusters cannot be created. To develop geometric models of wireless sensor networks, three schemes are proposed. Respectively, the simplex-diamonds with one, two, and three real information nodes are used. The performance of such models is analysed in the modes of control over the real information nodes parameters and the choice of the best ways to transmit information in the wireless sensor network.

2. The use of simplex-diamonds with three real information nodes in the development of geometric models of wireless sensor networks that allow implementing the method for reference signal points is motivated. The scheme of placing the real information nodes in the schematic diagram of simplex-diamonds is proposed. It allows forming hexagonal clusters under certain conditions. Besides, based on the scheme, the known methods for four-point simplexes and false signal points can be applied to analyse the network performance.

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