Modification of routing protocols of the wireless sensor network for increasing the network life expectancy

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Abstract: - The main drawback of a wireless sensor network is the low power batteries which significantly limit the life expectancy of a network. There is irregular energy consumption in the nodes of the network; as a result the network becomes unable to perform at a certain moment when the electricity runs out in some network nodes, regardless of the biggest part of the network still working. There are several unconventional solutions where sometimes the wireless sensor network is used in an unordinary way, for instance, for transmission of multimedia data, the data processing of momentum sensors in tracing software's for detecting moving objects as well as monitoring. The article describes the modification of network routing protocols for energy balancing in nodes, using the mobility of the coordinator node which provides dynamic network reconfiguration possibilities.

Key-Words: - Sensor Network; Life circle; Data processing; Dynamic node

1 Introduction

The number of different devices for using computer networks for providing mutual reaction of information is increasing every day. Lately, the number of systems that do not require human intervention in the system process has been increasing (Machine-to-Machine communication).

Low power computing systems are regaining more and more popularity. The technology nowadays makes it possible to reduce the size of existing computing systems resulting in a low-cost low power autonomous system with the ability to use both physical and wireless networks for transmitting information. The greatest popularity this type of technology gained for receiving information from sensors and in the area of control systems. Networks that use low power computing systems and transmit data via wireless connectivity are known as wireless sensor networks and their main task is to receive information from sensors and transmitting them through the network.

Sensor networks are primarily intended for the collection of information [4]. This means that in any network there are terminal nodes for collection of information, the router nodes for transmission of information, and one or more coordinator nodes on which all the collected information across the network is sent. The nodes pertaining to information storage and processing are mainly equipped with an uninterrupted power supply, independent distribution network connectivity and high performance computing system. This means that the direction of the data is definitely known in the sensor network, the information from the data collectors (terminals) is sent to the information storage and processing nodes by using existing routers of the network. The capacity of data traffic near coordinator node is much higher than in the distant points [7].

The differentiated energy consumption in hubs [8, 9] always appears in operating sensor network; as a result, the existing elements close to processing nodes faster than others stop operating due to lack of electricity and, as a result, the network ceases its overall work.

2 Related works

The recent wireless sensor network related research can be divided into two directions:

1. Studies referring to modeling and optimizing the data flow. It needs to be emphasized here that the sensor network traffic transmission depends on the use of a network and the performance scenario. There are systems where the frequency and quantity of the conveyed information are strictly determined and there is no room for network optimization on display; therefore, irregular consumption of energy appears in the network nodes.

2. Studies related to the improvement of technical characteristics of a wireless sensor network for an increase in the life expectancy of a network. The main drawback of the wireless sensor network is the low power batteries which significantly limit the lifetime of the network. Currently, there are a number of methods that allow solving this problem. These include the choice of the capacity of an individual battery, the density of node deployment, the adjustment of transmitter power, the application of the energy-efficient data transfer protocol, the positioning of network nodes and other methods that are associated with implementing additional network costs.

Relatively recently a new method was offered meant for balancing energy through the mobility of the network coordinator node, which provides the opportunity of reconfiguring the dynamic network or, in other words, the change of network topology.

3 The planning of the movement of dynamic coordinator node

The mobility of the network coordinator is one of the factors that impact the change of network configuration. The reduction of the amount of change in network configuration will increase the amount of the remaining energy in the nodes and as a result the total network life expectancy will have increased. Suppose that whilst a network is working there is one physical coordinator which can be located in one of the N positions. For example, whilst using the "Smart House" technology the user's mobile device performs the function of the coordinator by reading the information from all the sensor nodes in the particular object. In this example, there is only one physical coordinator node. The user can read the data in places where there is a possibility to connect the system, for instance, whilst being inside. As a result WSN operates using one coordinator node which can be located in one of the N-known positions.

If the network is composed of one coordinator node, it can be assumed that the network operates on a directed graph framework. The information from all network elements is delivered to one item using a few network nodes for transmitting information.

3.1 The Mobility of a network coordinator

In a functioning coordinator system there are two types of mobility:

1. Prospective location of a coordinator – the coordinator operates cyclically, the way of the coordinator in the network is determined and the time of how much the coordinator will be located in each position is certain;
2. Random location of a coordinator – the place of the coordinator is defined by the user and if the system generates the random position of the coordinator in every network start-up cycle. The time that the coordinator will spend in one position depends on the requirements of action described in the algorithm.

It is possible to determine at which point the coordinator will be located in each stage of the system action using the estimated location of the coordinator.

Suppose that the system works via the cyclical movement of the coordinator through the defined trajectory, the location of the coordinator in the network is known as well as the time how long the coordinator stays in each position. Accordingly, the time t_{net} necessary to go through the entire trajectory is: $t_{net} = \{t_{net}^1, t_{net}^2, \dots, t_{net}^m\}$, where: t_{net}^m shows the amount of time which the coordinator stays in a set position.

Each location of the coordinator is related to the new network configuration. The system identifies the absence of the coordinator in the existing route and performs reconfiguration of the network by ensuring a new route from the nodes to the coordinator.

Let us look at the possibility of mobility management performing the reconfiguration of a network. Supposedly, the original location of the coordinator is known and the motion path of the coordinator is strictly defined. Whilst the coordinator is moving through the network, simultaneously its position in the space $V_{(x,y)}^m$ is changing. It was proven in the previous articles that an object consumes power through the transmission of data which is dependent on the distance, but is not smaller than the technically indicated consumed power in the transmission mode P_{tx} and the consumed power in the receiving mode P_{rx}.

When planning the network structure and the location of the nodes as well as knowing the movement trajectory of the coordinator there is a possibility to split the structure of the network in segments S_{net} .
As a result it can be assumed that:

$$S_{net} \subseteq \left\{V_{(x,y)}^1, V_{(x,y)}^2, \dots, V_{(x,y)}^m\right\}. \qquad (1)$$

If the coordinator is located in one of the segment S_{net} peaks the power of the transmitter in

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none of its elements will change. This is because the operating range is not changed.

The power consumed in graph G in each operating cycle t_c depends on the sector S_{net} where the coordinator node is located. It is not useful to reconfigure a network at the beginning of each operating cycle of the network if the segment of a network remains unchanged. If the management model of a node does not perform network reconfiguration due to the remaining energy E_n then the reconfiguration of the network will take place if the segment S_{net} in which the coordinator is located changes.

$$S_{net}^{n} \neq S_{net}^{n-1}. \quad (2)$$

In the case of the second scheme, the coordinator can use the randomly selected location in the network which is determined by the user.

$$V_{(x,y)}^{a} = \overline{V_{(x,y)}^{1} .. V_{(x,y)}^{n}}. \quad (3)$$

The results provide an additional condition that contributes to network reconfiguration:

Network topology is changed in the case of the condition being fulfilled (the position of the coordinator changes):

$$V_{(x,y)}^{a} \neq V_{(x,y)}^{a-1}. \quad (4)$$

3.2 The remaining amount of energy in nodes

The second group of factors that impact structural change of a network is the remaining amount of energy each of the network elements. The completion of actions in each cycle means the reduction of the remaining amount of energy of the network elements. It can be assumed that in the beginning of each cycle the remaining energy can be considered as the starting power.

$$E_0^n = E_0^n - E_a^n, \quad (5)$$

Where E_a^n is the power that is consumed in the node "n" in the active interval t_c.

It is known that in a functioning network the amount of remaining energy is different in each nodes. The closer the node to the coordinator point, the smaller the amount of remaining energy in the node. It is known that in order to reconfigurate a network, additional time and amount of energy is required in each node. Accordingly, it is not useful to reconfigure the network before each cycle of operation. A new variable p_{min} should be introduced which will indicate the point when the network reconfiguration is necessary.

$$p_{min} > \max_i P_i - \min_j P_j, \text{ where } i,j = 1,2,\dots,n. \quad (6)$$

The total amount of energy consumed in the network is calculated from the network topology and it does not change through the entire duration of the topology using the determinated network action scheme

3.3 The management method of the dynamic coordinator mobility

During the working of the system the local area network module has been introduced which controls the conditions that promote the sensor network reconfiguration in the nodes:

1. The location of the coordinator changes – $V_{(x,y)}^{a} \notin \{V_{(x,y)}^{1} .. V_{(x,y)}^{n}\}$.
2. A large difference of the remaining power in the network elements has been discovered – $p_{min} > \max_i P_i - \min_j P_j$, where *i,j = 1,2,…,n.*

The software module has two main tasks in the system:

- To ensure the collection and storage of the remaining amount of power in the nodes according to the specified step t_c^n.
- To determine the period t_c^n when it is necessary to carry out the reorganisation of the routing path.

The mathematical part of the software module is multifunctional as opposed to the network sensor elements. Some tasks can be executed simultaneously. Every executable cycle or condition of the module is carried out as an independent operation.

4 Methods for route creation for data transmission in the network

An efficiently operating system is unable to obtain all the necessary information in order to determine the life expectancy of a wireless sensor network. Some network model base values, such as the capacity of the transponder may vary depending on the time which takes the system to remain active as well as the external environment which the system works in. Let us look at some examples where it is not possible to precisely define the required parameters for the network life expectancy assessment:

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- There are technical difficulties that reduce the quality of the transmitted information in some network segments. This may be due to another network in the same region with similar or adjacent frequency. In this case the need for a repeated transmition of information is increased resulting in a significant increase in energy consumption in the sensitive area.
- The influence of the external climatic factors on the autonomous power supply can result in an increase the power consumption in the standby mode.

In another publication it was stated that wireless sensor networks can be represented with the help of a directed graph. Based on the structure of the graph, each route (v,u) can be used for transmitting information from node v node u. Each of the v nodes has a defined amount of adjacent objects $N(v) \subset V$ that may communicate with the v node. Whilst generating a route, the broadband data retransmission is used in the network [5], the information is transmitted from the $N(v)$ node to the entire network simultaneously.

The following data flow handling algorithm in the network is described in this article. After receiving the transmitted information from node S, which is designed to receive node D, node V uses the following sequence of actions:

1. The potential transponder set $R(v,d) \subset N_v$ is selected and sorted by priority from the set $N(v)$.
2. The potential transponder set of nodes belongs to the set $R(v,d) \in N_v$ and determines the operating strategy of node v.
3. Information on the functionality of the node is recorded in the service of the transmission packet and distributed to the network management agent.

To determine the retransmission priority it is important to take into account the remaining amount of energy in each individual node. The node control module selects a transponder with the greatest amount of remaining energy E_0 in the node. The route building algorithm completely concludes its operations once it has reached the recipient node d.

The paper states that each network element can operate in two modes (terminal or router). In order to split the task into the early stage of network reconfiguration of each node has to remain in listening mode. During the listening mode the remaining amount of energy E_0^n in the node is assessed.

The route of the wireless sensor network from the terminal S to the coordinator D – $S(s,d)$ takes the dendriform structure which is built using the recursive approach from terminal to the coordinator. The first stage is defined by the possible network router set $R(s,d) \in N(s)$. This will allow to describe the path $S(s,d)$ as the sorted sub-route list:

$$S(s,d) = [S(v_1,d),\dots,S(v_n,d)], v_j \in R(s,d) \quad (7)$$

The next step is to set up the local action strategy $R(v_j,d)$ for each router. As a result, each list of sub-routes can be improved:

$$S(v_j,d) = \left[S(v_{j,1},d),\dots,S(v_j,m,d)\right], v_{j,i} \in R(v_j,d). \quad (8)$$

The path from the terminal to the coordinator can be displayed as the dendriform list placed on the second level:

$$S(s,d) = \left[\left[S(v_{1,1},d),\dots,S(v_{1,m1},d)\right],\dots,\left[S(v_{n,1},d),\dots,S(v_{n,m_n},d)\right]\right].$$

When creating a route, the level is extended up until the router list contains only one coordinator D node. In this case, the segment of the sensor network is equipped with the only remaining coordinator node. Henceforth, it is to be assumed that the recipient node D (the coordinator) is fixed and will not be used in any formulas.

Let us introduce a way to combine paths. Suppose that $S(v)$ is the path from node V to the coordinator in the router list $R(v) = (v_1, v_2, \dots, v_n)$ where the node U does not exist. Also, supposedly, S(u) is a path consisting of R(v) nodes that have been excluded from the list.

Let us define the path which uses the combined list of $S(v) \in S(u)$ where U nodes are used with low levels of a factor, like this: $R(v) = (v_1, v_2, \dots, v_n, u)$.

4.1 Using metrics to determine the use of the path

It can be assumed that the amount of paths leading to the node D have been assigned with the value of metrics $l(S(s))$ which is found in the indexed amount and can be compared. Metrics in similar models are built using the recursive approach from top to bottom defining the conditions for establishing the route. [11].

$$l(S(v) = F(l(S(v_1), l(S(v_2),\dots,l(S(v_n)),\ v_j \in R(v). \quad (9)$$

For the routing algorithm of a wireless sensor network to be optimal, the management module of the node executes three validations:

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1. Defining the importance of routers.
   The node U is useful to node V, if the following condition is fulfilled:

$$\begin{pmatrix} S(v_1) \\ S(v_2) \\ \dots \\ S(v_n) \end{pmatrix}_T \xrightarrow[t,rau\check{z}]{} \begin{pmatrix} S(v_{i_1}) \\ S(v_{i_2}) \\ \dots \\ S(v_{i_n}) \end{pmatrix}_T , \qquad (10)$$

where $S\left(v_{i_j}\right) > S\left(v_{i_{j+1}}\right)$, j=1,2,…,n-1.

This condition serves a significant purpose. From the list of metrics S(v) all metrics whose indications are low will be selected. Correspondingly, the possibility to entrust the role of the router to the node will be ruled out with a small amount of power left.

2. Preserving the priorities.

The metrics stay at the same level of priority if $l(S(u)) \le l(S(v))$ is derived from $l(S(u) \le l(S(v) \oplus S(u))$ for all $\forall v \in V$ and $\forall u \in N(v)$. This means that, before adding a router to the U list S(v) it is assessed whether it will be better than anyone else from the list S(v).

3. The determination of the optimality of routers.

It determines the behavior of metrics during full reconfiguration of the router list. Let us assume that $R(v) = (v_1, v_2, \dots, v_n)$ is the quantity of routers for the node V. Let us introduce an additional list $R^*(v)$ with nodes that are sorted by metrics in an ascending order – $l(S(v_n)) \le l(S(v_{n+1}))$. The list of ordered metrics will allow the choice of optimal amount of routers for the node V:

$$l\left[S_{R*(v)}(v)\right] \le \left[S_{R*(v)(v)}\right]. \qquad (11)$$

4.2 Path selection algorithm

The procedure Breadth-Search is considered as the basis of the classic routing algorithm and it allows to analyze the graph G (V,E) in width [10]. During the procedure two variables are added to each network node dist(v) which indicate the value of the optimum distance length from node V to the coordinator and pred(v) which indicates the length of path from node V to the closest router. There is a definite starting value of the variable $dist(v) \to \infty$. This means that the node has not yet been visited. The coordinator node D has a variable value $dist(v) = 0$. The starting value of the variable is $pred(v) = 0$ which means that the node is not a router.

The procedure $BS(G, d)$ ensures that all nodes $v \in V$ are tested each variable of the node dist(v) is evaluated accordingly and the value is equal to the length of path from node V to node D. As the validation data the queue Q combined with the function First_Out(Q) (exclude the first element of the queue) and Insert_End(Q) (insert rows at the end of an element) is used.

```
Procedure BS(G,d)
for all u ∈ V {
            dist(u):=∞;
            pred(u)=0;}
dist(d)=0;
Q=[d]
while Q is not empty {
     u=Fist_Out(Q);
     for all(v,u)  ∈ E {
     if (dist(v)=∞) {
          dist(v)=dist(u)+1;
          pred(v)=u;
         Insrt_End(Q);}
     }
}
```

By completion of a cycle the variable dist(v) has the value of the minimum distance from nodes V to D; however, values of pred(v) allow to create a path from any V peak to the coordinator node D. Appropriately, the given approach can be considered as optimal in tasks which require graph path metrics.

Using the mathematical model of the network that has been defined in an article [3] written by another author it is necessary to introduce an approach that will list and take into account the remaining amount of power in each of the network nodes. It is certain that the remaining amount of energy in the node is a positive figure. In this case, it is proposed to use the Dijkstra's algorithm for the graph analysis (Image 3.11.) provided that $l(u, v) \ge 0$ where $l(u, v) = E_0 - E_n$. Subsequently, we must build the road through the paths with minimum energy difference coefficient.

```
Procedure Dijkstra(G,l,d)
for all u ∈ V {
      dist(u):=∞;
      pred(u)=0;}
dist(d)=0;
H=CreateQueue(V);
while H is not empty {
     u=Fist_Out(H);
     for all(v,u)  ∈ E {
     if (dist(v)=dist(u)+l(v,u))
        {  dist(v)=dist(u)+l(v,u);
           pred(v)=u;
```

```
            Rearrange_Queue(H,v);}
      }
}
```

The significant difference in the procedure is the use of priority queue H where all the elements are sorted by using dist(v) values. The procedure CreateQueue() forms the priority queue H placing the coordinator node dist(d)=0 at the beginning pf the queue. Procedure Rearrange_Queue(H,v) provides the reconfiguration of the queue in case of any changes in metrics V.

Every time the cycle is executed two conditions are completed:

1. There is a d>0 value where all nodes on display are $dist(v) \leq d$ and the rest of the queue nodes are $dist(v) \geq d$.
2. For each V node in the queue the value dist(v) is equal to ∞ or with the minimal length of the path from V to D. In addition, the unused nodes are removed from the queue.

The fulfillment of these conditions guarantee the optimal solution to the algorithm.

If there is a need to assess the changes in the metrics graph it is possible to use the Bellman–Ford algorithm. When the algorithm is in use with the starting value of metrics for the V node may change frequently. Every metric changes are being implemented through the following procedure :

$Update\_M(v,u) : dist(v) - min\{dist(v),\ dist(u),\ l(v,u)\}$

By completing the procedure certain properties are engaged:

- The usage of the procedure does not increase the dist(v) value;
- The optimum result corresponds to the minimal dist(v) value which means that regular usage of procedure Update_M will not be of negative effect.

```
Procedure Bellman_Ford(G,l,d)
for all u ∈ V {
dist(u):=∞;
pred(u)=0;}
dist(d)=0;
        H=CreateQueue(V);
  repeat (|V |-1) times {
    for all e∈  E Update_M(e)
}
```

For the described the algorithms to be used in wireless sensor networks a slight adaption of each algorithm is necessary. To improve the Dijkstra's algorithm it is proposed to introduce an additional function Best_Value(Q) that allows to distribute the node U from the cluster Q with the minimum path metrics to node D. The entire set of nodes V is considered as not the displayed set of nodes Q in the initialization stage and the coordinator node D is given the metrics 0.

```
Procedure Dijkstra_updated(G,d)
      Q ← V
      while Q≠0 {
       u ← Best_Value(Q)
      for (for each v ∈ N(u) ∩ Q) do {
            if l(S(v) ⊕ S(u)) ≺ l(S(v))
            S(v) ← S(v) ⊕ S(u)
        }
}
```

At the end of the algorithm each of the $v \in V$ nodes has a path S(v,d) for providing information to node D. The algorithm is repeated for as long as there are any coordinator nodes left or until all the nodes are completely loaded.

As an improvement to the Bellman-Ford algorithm let us introduce the function FindRelay() which in case of necessity withdraws the current list of V transponders and creates a new one inserting nodes in it from the N(v) list in the descending order of the metrics for as long as the next router is connected and allows to reduce the metric value of node l(S(v)).

```
Procedure Bellman_updated(G,d)
      Initialization :{
      l(S(vi )) = ∞;
       (S(d)) = 0;}
      repeat
          {
  Sorting of nodes;
      for i=2 to (|V | - 1) do {
        (S(vi )) = FindRelays(v)
        }
      }
        untill not changes defined.
```

where:

```
Function  FindRelays(v)
      Router sord DESC;
      Initialization: {
       (v) = 0;
      j = 1;}
      While    (l[S(v)   ⊕   S(uj  )]  ≺
l[S(v)])
              {
            S(v) = S(v) ⊕ S(uj );
            j = j + 1;
        }
```

```
FindRelays :=  L(S(v))
```

The algorithms that have been proposed constitute the optimal path for all the network nodes if the $(S(v))$ metrics acquire the remaining amount of power in the E0 node. If it is not possible to identify the value of E0, the network is no longer able to function.

5 The usage of the dynamic coordinator node within the network

When working with functioning systems there are some limitations that do not allow to prepare all the necessary information in order to model the life expectancy of a system:

- It is not possible to ascertain how the network coordinator will act and if it will stagnate or will it use the prospective motion path or a random location.
- The power p_k^i that is consumed by the nodes may change in time.

Accordingly it can be concluded that if a network is functioning there can be situations when the physical coordinator node cannot be reached or it is impossible to establish a communication path between the sensor node and coordinator. As a result, power consumption is increased providing ineffective communication between the terminal nodes and coordinator. To increase the life expectancy of the network, the virtual coordinator node should be introduced which would move in cycles throughout the network using a familiar motion trajectory.

There should be additional denominations for the algorithm of virtual coordinator operations:
$S(k)$ is the set of vertices for the graph G_s which includes two vertices K and K next to each other:

$$S(k) = \{k\} \cup \{j : (k, j) \in E_s\}. \quad (12)$$

$S(k)$ is the set of nodes which are physically connected to the virtual coordinator node K and is in the vicinity of it:

$$D(k) = i \in V_n : (u, i) \in E_n(k), \quad (13)$$

$$where\ u \in V_n - network\ koordinator.$$

In each of the N steps the coordinator is located in one of the p_n positions and it chooses the new optimal position from the $S(p_n)$ list for the next stepp_{n+1} based on the remaining amount of power in the nodes. If the management module of the network node facilitates any change in the network topology, then the coordinator changes its location. Being located in a new position the virtual coordinator handles the information in the node spending the amount of time t_s on it defined by the user. The key step in the algorithm is the choice of the next position p_{n+1}. Mostly this is executed by the use of any method of heuristics.

The respective literature there was a variety of heuristics methods offered [1, 2, 6]. The choice of a random position from a list of possible positions is considered as the simplest method which is $p_{n+1} = random(S(p_n)$. According to the result of modeling done by authors [2], it can be seen that in the majority of the research scenarios the life expectancy of a network is increased in comparison to the fixed coordinator location. Despite the good results of the study, the use of this method is not recommended as the repositioning of the network coordinator when detecting a random postion does not guarantee any results and in some cases it will reduce the life expectancy of a network, when the coordinator is located in the nodes which possess a low level of remaining power.

One of the authors [6] offers to ensure the relocation of the coordinator via a displayed network perimeter. This approach is based on the fact that mostly whilst the network is functioning the elements that are located in the centre contain a lower amount of the remaining power in the nodes.

Basagni [1] proposes the usage of MRE (Maximum Residual Energy) for the algorithm of coordinator movement. When the coordinator node uses the GMRE algorithm, it defines the remaining amount of energy in the adjacent nodes and chooses one of the nodes with the largest amount of energy left in it. In this case, the planning of the optimal motion of the coordinator is pegged to searching the maximum amount of the remaining energy in the nodes.

There are some definitions for the function E_k which allow to determine the location of the coordinator:

- $E_k(t) = \frac{1}{|D(k)|} \sum_{j \in D(k)} E_{rj}(t);$
- $E_k(t) = min_{j \in D(k)} E_{rj}(t);$
- $E_k(t) = max_{j \in D(k)} E_{rj}(t).$

Regardless of how the function E_k is defined, the remaining amount of energy characterizes the overall state of the network only partially and cannot be used as the sole condition. For example, a node with the smallest amount of remaining energy E_0 the lowest power consumption can work for a longer period of time than a node with the greatest

E_0 and the greatest energy consumption. The use of MRE method simply places the coordinator node in a position with the highest E_0 value; in case the network agents do not contribute to any new topology changes, this method will not increase the overall network life expectancy.

The article offers an alternative method: choosing a location p_n for the virtual coordinator in every step of the operation that allows the network to function for as long as possible on the condition that the network topology will not be changed. The name of the energy method MREML (Maximum Residual Energy Maximal Lifetime) can be defined by using an analogue:

$$E_k(t) = \arg\,(max_{k\in S(p_n)} min_{n\in D(k)} \frac{E_0^n(t)}{p_k^n(t)}), \qquad (14)$$

where: p_k^n is all the consumed energy in one cycle of operation in the node K.

If the time the coordinator spends in each of the node positions is equal to t_k and the remaining amount of energy prior to placing the coordinator in the position $E_0^n(t)$ is known as well as the amount of the energy in the node when the coordinator will leave the position is $E_0^n(t+t_k)$, then the consumed amount of energy by each node can be stated by the following formula:

$$p_k^n = \frac{E_0^n(t) - E_0^n(t+t_k)}{t_k}. \qquad (15)$$

The difference between MRE and MREML methods is that the former uses the local information of the network nodes regarding the remaining amount of energy that constantly requires additional power in order to analyzing the remaining amount of energy in the adjacent nodes. The method proposed in the article uses network agents and the static coordinator node for storing information. In case of any changes in the network topology this approach allows to obtain a global overview of the entire network configuration as well as the virtual coordinator node is able to occupy the best position in order to collect information from the nodes.

6 Conclusion

The article describes a developed network reconfiguration method which allows the increase of the life expectancy of a wireless sensor network evening out the remaining amount of energy among all the network elements.

In the network scenarios with the ability to modify the routing protocol, the use of modified Bellman-Ford and Dijkstra's algorithms is proposed for maintaining an optimal data flow route based on the increase of the criteria of a network life expectancy. The remaining amount of energy is defined as the most significant criteria for the choice of a path within a certain network node in the stage of iteration.

To avoid unnecessary network topology changes, particular conditions that determine the moment of the network structural changes are pointed out in the article. Primary conditions for topology changes have been asserted, based on technical data obtained from the sensor nodes and network structure analysis during the operations of the wireless sensor network:

- The condition which depends on the location of the;
- The condition which depends on the operating segment of the network coordinator;
- The condition which depends on the unbalanced consumed energy in the network nodes.

Using the descriptions of the calculation method for the life expectancy of the wireless sensor network nodes pointed out in other articles [3] the condition which is related to the amount of energy remaining in the nodes, was proposed to be integrated on the routing protocol level.

As a result, the article proposes the algorithm for a wireless sensor network topology change that uses the coordinator node of the network as the primary factor for the topology change in the network.

To reduce the amount of energy consumed in the nodes, the article proposes a method which anticipates the implementation of an independent software module of the network which will control the state of each network node and will promote the change of the network topology, regardless of the form of action of the node. Accordingly, a low power wireless set will be used as a means of communication which will transmit technical information to the network agent manager.

In some cases there might be situations where the physical coordinator node cannot be reached or it might be impossible to establish a communication route between the sensor node and the coordinator; the alternative would be to use the virtual coordinator which is managed by using heuristic algorithms.

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